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Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors

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Published in
Frontiers in Psychology
Frontiers in Sports and Active Living

ISSN 1664-8714
ISBN 978-2-8325-3580-6
DOI 10.3389/978-2-8325-3580-6

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Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors

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Citation

Stults-Kolehmainen, M. A., Filgueiras, A., Ash, G., Dunton, G. F., Boullosa, D., eds. (2023). *Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors*. Lausanne: Frontiers Media SA.
doi: 10.3389/978-2-8325-3580-6

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TYPE Editorial
PUBLISHED 13 September 2023
DOI 10.3389/fspor.2023.1282118

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 23 August 2023
ACCEPTED 04 September 2023
PUBLISHED 13 September 2023

CITATION
Stults-Kolehmainen MA, Dunton G, Boullosa D, Ash GI and Filgueiras A (2023) Editorial: Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors.
Front. Sports Act. Living 5:1282118.
doi: 10.3389/fspor.2023.1282118

Editorial: Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors

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KEYWORDS
motivation, affectively charged motivation states, physical activity, exercise, sedentarism, exercise psychology

Editorial on the Research Topic
Motivation states and hedonic motivation for physical activity, exercise, and sport vs. sedentary behaviors

The concept of motivation states for physical activity and sedentarism emerged from ideas emanating from addiction medicine, self-control research, and exercise psychology. To start, Robinson and Berridge's theory of *incentive salience* (1), which seeks to understand urges and cravings for addictive substances, differentiates the notions of liking versus wanting. Those addicted to exercise experience cravings for movement (2), in other words, strong desires or wants, which are perhaps independent of the pleasure they receive from it. The want or desire to move and be active, however, is not limited to athletes or exercise addicts. Indeed, most humans experience these motivation states from time to time, if not regularly (3) (Stults-Kolehmainen et al.). In pondering over this point, there is a possibility that the reader may spontaneously feel an urge to move. Such a feeling might even persist for several minutes, but could also dissipate as quickly as it arrives. Regardless, it seems obvious that humans are more motivated to move, be active, and exercise at some moments compared to others. For instance, when waking up, the desire to move may be very weak, but after some additional time awake, a cup of coffee, and a pressing appointment in the next hour, a person might be "on fire" to move. Overall, it is clear that motivation to be physically active is a transient state that is regulated by a number of factors (Stults-Kolehmainen et al.). How this has been missed in exercise psychology textbooks is a mystery.

Typically, motivation for physical activity, and exercise and sport specifically, has been considered: (1) as a stable construct, similar to a trait (4–6), and (2) from a reflective perspective (e.g., goals). Indeed, some manuscripts in this Research Topic have adhered to this conceptualization (Zhao et al., Wu et al.). Certainly, there are enduring aspects to motivation, and this has been well-described by Self-Determination Theory (7), Hedonic Theory (8) and other meta-theories of behavior (Heredia-Leon et al.). Motivation predicts physical activity and exercise behavior (Zhao et al.), perhaps by influencing self-efficacy (Zhao et al.), attitudes, intentions (Heredia-Leon et al.), and one's satisfaction with the activity (Wu et al.). Recent health behavior theories are migrating to the idea of motivation as it varies by incidental affect and affective processing, as juxtaposed against goals and reflective processing, such as the Affect and Health Behavior Framework (9), Integrative Framework (10), and the Automatic Reflective Motivation Framework (11). These models specify motivation states as being infused with an affective component, the so-called *affectively-charged motivation states* (ACMS)—first described by Kavanaugh (12). Nevertheless, these theories and others (i.e., Affective Reflective Theory of PA) (13) have assigned a relatively minor role to motivation states. Others have taken the stance that motivation states are relevant only as they pertain to avoidance or dread of activity, particularly in the case of exercise (8), or they are overpowered by the need to minimize the exercise-related (14) or general activity effort (15).

Despite these setbacks, some conceptual (16) and measurement (3) advances have been made. Nevertheless, until recently, there was no unified effort to understand the phenomena of undulating wants or desires to move and be sedentary. In 2015, we submitted our first abstract on the topic to the North American Society for the Psychology of Sport and Physical Activity (NASPSPA) (17), with details about a 13-item instrument (i.e., the CRAVE—Cravings for Rest and Volitional Energy Expenditure scale) developed to measure motivation states. At this time, we labeled spontaneous instances of wanting to exercise "CRAVE moments"—times of pressing readiness and urgency to move, that can be experienced and/or felt in both the mind and body. Seeing more complexity in the effects, we added a concise model to explain how desires to move and be sedentary might relate to each other—the Wants and Aversions for Neuromuscular Tasks (WANT) model (16). In this heuristic, there may be genuine excitement to move, or even an urge or craving, as well as active dread or diswant (i.e., aversion) for movement. Stults-Kolehmainen et al. more formally provide ten provisions of the model, which also include ideas about how motivation states can vary with certain emotions, stressful events, and various situational factors.

This Research Topic constitutes the first attempt to meld diverse literatures into a line of scholarly work on this emerging Scientific Theory. Articles published in this series reported that motivation states:

1. predict affective responses during exercise (Do et al.), and are possibly linked to leisure satisfaction (Wu et al.),
2. are predicted by previous activity behaviors (Budnick et al.), including sitting and talking during a focus group period (Stults-Kolehmainen et al.),
3. are heightened in disorders like anorexia nervosa (Casper), Restless Legs Syndrome and other disorders (Stults-Kolehmainen et al.), and weakly related to state anxiety (Filgueiras et al.),
4. are possibly modulated by endogenous factors, like caloric imbalance and leptin concentration (Casper), but also exogenous stimuli, like music (Park et al.) and a host of other factors (Stults-Kolehmainen et al.),
5. predict intentions to be active and sedentary (Budnick et al.);
6. are linked to self-reported exercise behavior (Filgueiras et al.), and
7. follow a circadian pattern (Budnick et al.).

Measurement of motivation states was conducted with a variety of instruments. Do et al. asked participants to rate how they felt about their upcoming exercise by utilizing a sliding visual analogue scale with the endpoints being "Dreading it" to "Excited to do it". Such a scale was used in a subsequent investigation (18), but another study from this laboratory queried participants with the phrase "Feel like exercising?", with a response set of "yes", "no", and "sort of" (19) regarding the desire to be active. Stults-Kolehmainen et al. used the CRAVE scale (3), which they also translated into Portuguese and whittled down to single items for the want/desire to move and rest (Filgueiras et al.). Pedersen et al. used an unvalidated scale to measure perceived readiness to train (20), which included an item for daily motivation (i.e., "Rate your motivation to train today"). A limitation to be solved in further research with this last item is that it cannot distinguish between appetitive and reflective motivation.

People typically want what they like and are reinforced to do, and movement may provide some individuals a considerable source of reward (21). Many articles in this Research Topic highlighted the key role of exercise affective responses and pleasure/displeasure. Andersen et al. found that a traditional workout was perceived as less effortful, but also less preferable, to a more time efficient workout utilizing supersets, which produced more discomfort, but also a greater sense of pleasure, as assessed 15 min post-exercise. The same group (Pedersen et al.) found that most participants (22 out of 24 people) in a trial exploring the differences between a longer training session and two shorter sessions, preferred the longer session. They also found that the longer session was perceived as more pleasurable, even though it had higher perceptions of effort and discomfort. Timme et al. found that individuals have general preferences for engaging in activity (or not), but when making choices between active and sedentary activities, decisions are likely impacted to a greater degree by the specific options presented within a situation, and these choices are regulated by highly automated processes. Motivation states are likely under a high degree of automatic, unconscious control, and future studies should explore the interplay of these ideas. Furthermore, if exercise can be made more pleasurable or enjoyable, will people want it more? Such a possibility has yet to be tested.

In this Research Topic, we also expanded the concept of motivation states to incorporate classic ideas of drive—that the motivation to move may emanate not just from experiences of pleasure and positive reinforcement, but also negative reinforcement (Stults-Kolehmainen). In other words, are some motivation states partially the result of some pressing need to move, which has been unsatisfied (e.g., with prolonged sitting) and then prompted into consciousness? Ryan and Deci (7) highlighted a discussion from Ladygina-Kohts (22) about the drive for physical activity in primates that observed, "Active play with live creatures represents an essential need for the chimpanzee… That is why movement for the sake of movement is his unalterable, unquenchable desire… He can engage in it for hours, from dawn to sunset, day in and day out" (p. 134). It seems likely that such statements could also be made for many or most human children (and some adults). Ryan and Deci (7) have termed such tendencies "inherent propensities" and intrinsic motivation—motivated behaviors which do not require external rewards or prompts but are naturally engaged in with great interest. Flack et al. detailed how the drive to move may even result in an appetite for physical activity, perhaps a craving, and this can be altered by exercise training, though perhaps to a detriment (i.e., exercise compensation). Finally, it should be considered that the desire to move may be spurred by boredom and the need for cognitive stimulation (e.g., that comes from engaging muscles and/or moving one's physical body throughout the environment). Such perspectives seem to align with Paul Bloom's ideas of an affective "sweet spot" and "motivational pluralism"—notions that a person is motivated by more than attainment of pleasure, but also by aspects of intended pain and displeasure (23).

With the conclusion of this Research Topic, the Editors conclude that the idea of affectively-charged motivation states (ACMS) for physical activity, exercise, and sedentarism can move from the proof-of-concept stage to an emerging Scientific Theory. Important knowledge gaps were filled in, including information about intraday variation in motivation states, social influences, and how individuals think about motivation states in lay terms (Stults-Kolehmainen et al.). Significant progress was made in the measurement of motivation states, including scale development, validation, and cultural and linguistic adaptations (Filgueiras et al.). We also understand more about the reinforcing properties of exercise and factors that increase the pleasure of it. The articles in the Research Topic approached the concept from qualitative and quantitative perspectives, with observational and experimental data. Despite these advances, we underscore that these studies were mostly conducted in adults, and children likely have stronger urges to move based on motor development needs. Another gap in knowledge exists for athletes completing large amounts of movement during a competitive season, putting them at risk for burnout and neutralization of motivation. Moreover, there is great need to translate research findings into actionable strategies, such as just-in-time adaptive interventions (JITAI) (24), to promote physically active lifestyles for the greater health and well-being of all people. In this pursuit, it is clear that the next chapter for physical activity motivation begins with the "right now" or "in this very moment". Meanwhile, we would like to thank all the authors and referees involved in this Research Topic for their outstanding scholarship.

Author contributions

MS-K: Conceptualization, Writing – original draft, Writing – review and editing. GD: Writing – original draft, Writing – review and editing. DB: Writing – original draft, Writing – review and editing. GA: Writing – original draft, Writing – review and editing. AF: Writing – original draft, Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

GA was supported by American Heart Association Grant #852679 (GA, 2021–2024), and the National Institute of Diabetes, Digestive, and Kidney Diseases of the National Institutes of Health under a mentored research scientist development award (K01DK129441). DB was supported by Grant RYC2021-031098-I funded by MCIN/AEI/10.13039/501100011033, by "European Union NextGenerationEU/PRTR", and by a productivity research grant (PQ1D) from CNPq (Brazil).

Acknowledgments

The authors would like to thank those who provided substantial support for the development of this project and Research Topic, including Rajita Sinha (Yale Medical School, New Haven, CT), John B. Bartholomew (The University of Texas at Austin, Austin, TX), Todd Gilson (Northern Illinois University, DeKalb, IL), Miguel Blacutt (University of Notre Dame, Notre Dame, IN), and Philip R. Stanforth (The University of Texas at Austin, Austin, TX). A podcast made by the first author explaining the conceptual basis and measurement of motivation states is available here: https://www.scipod.global/dr-matthew-stults-kolehmainen-measuring-our-motivation-for-physical-activity-and-sedentary-behaviour/.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Robinson TE, Berridge KC. The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Res Rev*. (1993) 18:247–91. doi: 10.1016/0165-0173(93)90013-p

2. Hausenblas HA, Downs DS. Exercise dependence: a systematic review. *Psychol Sport Exerc*. (2002) 3:89–123. doi: 10.1016/s1469-0292(00)00015-7

3. Stults-Kolehmainen MA, Blacutt M, Fogelman N, Gilson TA, Stanforth PR, Divin AL, et al. Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front Psychol*. (2021) 12. doi: 10.3389/fpsyg.2021.568286

4. Kilpatrick M, Hebert E, Bartholomew J. College students' motivation for physical activity: differentiating men's and women's motives for sport participation and exercise. *J Am Coll Health*. (2005) 54:87–94. doi: 10.3200/JACH.54.2.87-94

5. Stults-Kolehmainen MA, Ciccolo JT, Bartholomew JB, Seifert J, Portman RS. Age and gender-related changes in exercise motivation among highly active individuals. *Athletic Insight*. (2013) 5:45–63.

6. Stults-Kolehmainen MA, Gilson TA, Abolt CJ. Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. *J Sport Behav*. (2013) 36:306–27.

7. Ryan RM, Deci EL. Active human nature: Self Determination Theory and the promotion and maintenance of sport, exercise and health. In: Haggar MS, Chatzisarantis NLD, editors. *Intrinsic motivation and self-determination in exercise and sport*. Champaign, IL: Human Kinetics (2007). p. 1–19.

8. Williams DM, Bohlen LC. Motivation for exercise: reflective desire versus hedonic dread. In: Anshel MH, editor. *APA handbook of sport and exercise psychology, volume 2: Exercise psychology*. Washington, DC, US: American Psychological Association (2019). p. 363–85.

9. Williams DM, Evans DR. Current emotion research in health behavior science. *Emot Rev*. (2014) 6:277–87. doi: 10.1177/1754073914523052

10. Williams DM, Rhodes RE, Conner MT. Conceptualizing and intervening on affective determinants of health behaviour. *Psychol Health*. (2019) 34:1267–81. doi: 10.1080/08870446.2019.1675659

11. Williams DM. A meta-theoretical framework for organizing and integrating theory and research on motivation for health-related behavior. *Front Psychol*. (2023) 14:1130813. doi: 10.3389/fpsyg.2023.1130813

12. Kavanagh DJ, Andrade J, May J. Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol Rev*. (2005) 112:446–67. doi: 10.1037/0033-295x.112.2.446

13. Brand R, Ekkekakis P. Affective–reflective theory of physical inactivity and exercise. *Ger J Exerc Sport Res*. (2018) 48:48–58. doi: 10.1007/s12662-017-0477-9

14. Taylor IM, Whiteley S, Ferguson RA. Disturbance of desire-goal motivational dynamics during different exercise intensity domains. *Scand J Med Sci Sports*. (2022) 32:798–806. doi: 10.1111/sms.14129

15. Cheval B, Boisgontier M. The Theory of Effort Minimization in physical activity (TEMPA). *Exerc Sport Sci Rev*. (2021) 49:168–78. doi: 10.1249/JES.0000000000000252

16. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Gilson TA, Ash GI, Mckee PC, et al. Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front Psychol*. (2020) 11:568390. doi: 10.3389/fpsyg.2020.568390

17. Stults-Kolehmainen MA, Gilson TA, Brotnow L, Bartholomew JB, Ciccolo J, Sinha R. Conceptualizing and measuring the desire for energy expenditure and sedentary behavior: the CRAVE scale for movement and rest. *J Sport Exerc Psychol*. (2015) 37:S93. doi: 10.1123/jsep.37.3.S1.S1

18. Crosley-Lyons R, Do B, Hewus M, Dunton GF. An ecological momentary assessment study of affectively-charged motivational states and physical activity. *Psychol Sport Exerc*. (2023) 67:102423. doi: 10.1016/j.psychsport.2023.102423

19. Ponnada A, Wang S, Chu D, Do B, Dunton G, Intille S. Intensive longitudinal data collection using microinteraction ecological momentary assessment: pilot and preliminary results. *JMIR Form Res*. (2022) 6:e32772. doi: 10.2196/32772

20. Lombard W, Starling L, Wewege L, Lambert M. Changes in countermovement jump performance and subjective readiness-to-train scores following a simulated soccer match. *Eur J Sport Sci*. (2021) 21:647–55. doi: 10.1080/17461391.2020.1757764

21. Cheval B, Radel R, Neva JL, Boyd LA, Swinnen SP, Sander D, et al. Behavioral and neural evidence of the rewarding value of exercise behaviors: a systematic review. *Sports Med*. (2018) 48:1389–404. doi: 10.1007/s40279-018-0898-0

22. Ladygina-Kohts NN, De Waal F, Wekker BT. *Infant chimpanzee and human child: A classic 1935 comparative study of ape emotions and intelligence*. Oxford, UK: Oxford University Press (2002).

23. Bloom P. *The sweet spot: Suffering, pleasure and the key to a good life*. New York: Random House (2021).

24. Hardeman W, Houghton J, Lane K, Jones A, Naughton F. A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity. *Int J Behav Nutr Phys Act*. (2019) 16:31. doi: 10.1186/s12966-019-0792-7

frontiers in Psychology

ORIGINAL RESEARCH
published: 09 December 2021
doi: 10.3389/fpsyg.2021.758858

The Influence of Motivation, Attitudes and Obstacles for Middle School Students' Participation in Leisure Activities on Their Leisure Satisfaction in Southwest China

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OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *15 August 2021*
Accepted: *08 November 2021*
Published: *09 December 2021*

Citation:
Wu Y, Sun J, Fan F, Wang X and Peng Y (2021) The Influence of Motivation, Attitudes and Obstacles for Middle School Students' Participation in Leisure Activities on Their Leisure Satisfaction in Southwest China. Front. Psychol. 12:758858. doi: 10.3389/fpsyg.2021.758858

Purpose: To explore the relationship among leisure motivation, barriers, attitude and satisfaction of middle school students in Chengdu, Sichuan, to help students establish a positive leisure attitude and provide a reference for youth leisure counseling.
Methods: Based on consulting research literature, this paper designs a survey volume of teenagers' leisure motivation, barriers, attitude, and satisfaction; 2249 valid questionnaires of middle school students in Chengdu were obtained by stratified random sampling. The data were statistically processed by the combination of exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).

Results: (1) There are significant positive correlation effects between leisure motivation and leisure attitude, leisure attitude and leisure satisfaction, and leisure motivation and leisure satisfaction; (2) There is a low degree of positive correlation effect (r = 0.35 *) between leisure barriers and leisure motivation, which is contrary to common sense and needs to be further studied in the follow-up; (3) Leisure barriers has no significant direct impact on leisure satisfaction, but it can have a significant negative impact on leisure satisfaction with the intermediary variable of leisure attitude; (4) Leisure motivation is the most important variable in the whole leisure model structure. It not only has the greatest direct impact on leisure satisfaction but also has a great positive impact on leisure satisfaction through the intermediary of leisure attitude.

Conclusion: Adolescent leisure motivation, barriers, attitude, and satisfaction are complementary and interdependent. Among them, leisure motivation is the core variable and leisure attitude is the dual intermediary variable. Through the initiation of leisure motivation, helping adolescents establish a positive leisure attitude may be the key to ensure their leisure satisfaction.

Keywords: leisure motive, leisure barrier, leisure attitude, leisure satisfaction, structural equation mod

INTRODUCTION

Leisure life is the product of national economic growth and the change of social industrial structure. Due to the development of science and technology and socio-economic progress, the form of social life has changed significantly, which indirectly allows Chinese people to have more free time, and the demand and willingness for leisure activities have also increased. The rise of leisure activities has gradually become the focus of Chinese life, If leisure time is used to plan and improve leisure activities, it can not only bring personal health and relaxation benefits but also promote the beneficial interaction between people. Teenagers are the most energetic population in society. It is not only a critical period of personality development and life adaptation but also a stage with the greatest impact of physiological and psychological changes. The growth experience and the establishment of many ideas and behaviors in this period often have a decisive impact on their future personality development and behavior characteristics. At present, youth education is facing new opportunities and challenges. As an important educational activity, sports, leisure, and entertainment are inextricably linked with the educational theory itself. Research Report from sports, leisure, and entertainment educators: 11–16 years old is the most important stage to complete the socialization process of teenagers. If collective leisure and entertainment activities can be arranged at this stage, it is very important to train teenagers' cooperation ability and team spirit. Leisure projects such as orienteering, multi-person rowing, and sailing are the best choice for this age group (Weybright et al., 2016; Song, 2017; Florian and Jörg, 2018).

Attitude plays an important role in forming personal behavior. A correct sports attitude can improve sports behavior, and attitude and behavior affect each other. Learning theory emphasizes that past behavior experience is also one of the factors forming attitude. Many scholars believe that leisure attitude is an individual's response tendency for leisure, which represents an individual's likes and dislikes for leisure activities and an individual's readiness for leisure activities, and divides the structure of leisure attitude into three dimensions (Bailey et al., 2016; Holahan et al., 2017; Freire and Teixeira, 2018): (1) cognitive: including personal and social levels, refers to the knowledge and belief in leisure; Understand the belief of leisure and health, happiness and work relationship; The belief that leisure is beneficial to individuals' relaxation and self-development, such as personal sexuality, expertise, the source of leisure information, etc.; (2) Affective: refers to an individual's feeling of leisure, the degree of liking and disliking of leisure activities and experience, including the evaluation of leisure experience and activities, the degree of liking and dislike and direct and immediate feelings, such as personal values, expectations and interests; (3) Behavior: refers to the behavioral tendency of individuals to participate in leisure in the past, present and future, including the tendency to select leisure activities and choices; Past and present leisure activity participation status and experience.

Motivation is a force that urges people to take a certain behavior to meet a certain demand, because Motivation is the psychological or internal force that urges a person to carry out activities and it is the internal process that causes an individual activity and maintains the activity toward a certain goal (Weissinger and Bangalos, 1995). It is an internal driving force of an individual. Laroche et al. (2019) Based on previous research literature and theories (Downs et al., 2013; Ramey et al., 2016), proposed that leisure motivation is the psychological and social reasons for people to participate in leisure behavior, and divided leisure motivation into four-factor dimensions: (1) Intelligence: refers to the individual's motivation to participate in leisure activities, including psychological activities of learning, exploration, discovery, creation or imagination; (2) Social: it means that the individual's motivation to participate in leisure activities is for social reasons. It includes two basic needs: the needs of friendship and interpersonal relationship, and the needs of others' respect; (3) competence-mastery: refers to the individual's competence proficiency reason for participating in leisure activities, which is to achieve achievements, master, challenge, compete and master the characteristics of skilled activities, usually out of the instinct of the body; (4) Stimulus avoidance: the constituent elements are the motivation to escape and the living environment away from too much stimulation, and the need to pursue solitude and peaceful environment, as well as to rest and relax.

Leisure barriers are the hindrance of personal perception or experience, which is not necessarily the result of not participating in leisure activities, but may affect personal leisure preferences and change leisure participation. It can be seen that leisure barriers are related to an individual's ability to overcome and deal with obstacles to successfully engage in leisure and has an impact on leisure experience and behavior (Jackson and Rucks, 1995). Cho and Price (2018) defined leisure barriers as individual subjective perception or reasons that affect individuals' dislike or involvement in certain leisure activities, and summarized the influencing factors into three categories: (1) Individual barriers: refers to the psychological factors and states within an individual that affect his leisure preferences or participation, such as stress, anxiety, belief, etc.; (2) Interpersonal barriers: refers to the factors that affect an individual's leisure preferences or participation due to lack of appropriate or sufficient leisure partners; (3) Structural barriers: refers to external factors that affect individual leisure preferences, such as resources, money, equipment, etc.

Leisure satisfaction is a subjective feeling that individuals affect their leisure experience. It is the concrete realization of motivation, preference, demand, or expectation (Rusbult et al., 1998). Rosa et al. (2019) pointed out that leisure satisfaction refers to the positive and good feelings obtained by individuals when participating in leisure activities, and the satisfaction of individuals with leisure experience and situation, and classified leisure satisfaction into six categories: (1) Psychological: Based on intrinsic motivation, individuals participate in freely selected activities and self-realization needs, so that individuals can show their individuality from leisure activities and seek self-expression; (2) Education: individuals pursue intellectual stimulation in participating in leisure activities, need new experiences to meet the curiosity of participants, and expand their personal life experience by learning new things and increasing knowledge; (3) Social aspect: individuals volunteer to participate in service groups or organizations to maintain the free choice of social relations. At the same time, the naturally formed interpersonal network is conducive to individual social interaction and communication, and obtaining social respect and respect from others; (4) Relaxation: Games and sports can restore vitality. Individual participation in leisure activities can enable individuals to have a full rest, relax and relieve the pressure and tension from work and life; (5) Physiologic: when individuals participate in leisure activities, some are physiologically challenging or maintain health, strengthen muscle and cardiopulmonary function, control weight and maintain good posture; (6) Aesthetic: the places where individuals participate in leisure activities are more satisfactory if the environment is beautiful, and make the leisure experience more interesting and pleasant.

The relationship between leisure satisfaction and leisure attitude, leisure motivation, leisure barriers, and other variables has long attracted the attention of scholars at home and abroad. Choi et al. (2017) found that leisure motivation and leisure attitude have a direct impact on leisure satisfaction respectively, and pointed out that there is a typical correlation between leisure attitude and leisure motivation; Soos et al. (2019) found that leisure attitude and leisure motivation are important factors affecting teenagers' leisure behavior, and leisure attitude is its internal psychological factor, which is exposed externally through the stimulation of leisure motivation. Sukys et al. (2019) investigated college students and found that the correlation between leisure attitude and leisure barriers reached a significant level and was negatively correlated, while it was significantly positively correlated with leisure satisfaction. The higher the leisure identity, the higher the satisfaction from leisure experience. Hainey et al. (2013) found that leisure attitude and leisure motivation are important factors affecting teenagers' leisure behavior. Leisure attitude is its internal psychological factor, which is exposed through the stimulation of leisure motivation. Zheng (2008) found that there was a significant negative correlation between leisure attitude and leisure barriers; Pu and Xu (2015) found that there is a significant positive correlation between leisure attitude and leisure satisfaction. Those who hold a higher leisure attitude can get higher leisure satisfaction from leisure experience; Wen (2019) found that leisure attitude has a direct and positive impact on leisure satisfaction, and believes that leisure satisfaction is the psychological satisfaction of leisure experience obtained by individuals engaged in leisure activities based on their attitude toward leisure. Chen (2019) found that leisure barriers are negatively correlated with leisure satisfaction. When leisure barriers increase, the satisfaction obtained from leisure decreases. Zhang et al. (2012) research proposed that the intensity of an individual's motivation to engage in leisure is easily affected by barriers. If he thinks that engaging in leisure may be disturbed, his leisure intention and behavior will also be affected.

To sum up, it is not difficult to find that attitude plays an important role in the formation of personal behavior. It is very necessary to enable middle school students to adjust their study and life through leisure activities and improve their cognition of leisure activities. By establishing a correct leisure attitude, we can achieve substantial results in the formation of leisure experience; Leisure motivation is the internal driving force to promote and maintain people's activities. Understanding the reasons and motivation of individuals engaged in leisure activities can obtain the psychological motivation and tendency of individuals engaged in leisure activities. The stronger the leisure motivation, the higher the frequency of leisure participation; Leisure barriers is a factor affecting individuals to engage in leisure activities. The frequency of leisure participation and leisure barriers are negatively related, and leisure satisfaction is a positive psychological result after engaging in leisure activities, providing fascinating and unforgettable leisure experience. At present, although many scholars at home and abroad have discussed teenagers' leisure attitude, leisure motivation, and leisure barriers, few scholars have a comprehensive and in depth understanding of the relationship between leisure satisfaction and leisure attitude, leisure motivation and leisure barriers. Understanding the relevant factors and relationships affecting teenagers' leisure behavior, properly planning their leisure life, and appropriately engaging in leisure activities will have a positive impact on Teenagers' school life and personality growth. Based on this, this study puts forward the following four hypotheses based on previous studies: (1) there are multiple groups of typical correlation structures among leisure motivation, leisure barriers, leisure attitude, and leisure satisfaction; (2) Leisure motivation has a positive impact on leisure attitude and leisure satisfaction, while leisure attitude also has a positive impact on leisure satisfaction; (3) The influence of leisure barriers on leisure attitude is negative, and the influence of leisure motivation on leisure attitude should be higher than that of leisure motivation on leisure satisfaction; (4) Leisure attitude plays an intermediary role in leisure barriers and leisure satisfaction. At the same time, leisure attitude also plays an intermediary mechanism between leisure motivation and leisure satisfaction (see **Figure 1**).

SUBJECTS AND RESEARCH DESIGN

First, junior high schools and senior high schools in Chengdu are stratified according to different districts, and then 5 schools are selected by random sampling. Each school is divided into grade 1 and grade 2 of junior middle school and grade 1 and grade 2 of senior high school (Note: considering the graduation class, grade three of junior middle school and senior high school are not the objects of the questionnaire). Students at each level are randomly selected for the questionnaire survey. A total of 2550 questionnaires are sent out, 2351 are recovered, and 102 invalid questionnaires are excluded, with an effective recovery rate of 88%. See **Table 1** for sample distribution.

Research Methods

Questionnaire Survey Method

The whole questionnaire consists of basic data of subjects and four scales: The basic data of the subjects include gender, age, grade of study, accommodation, monthly discretionary funds for leisure activities, average academic achievement, and

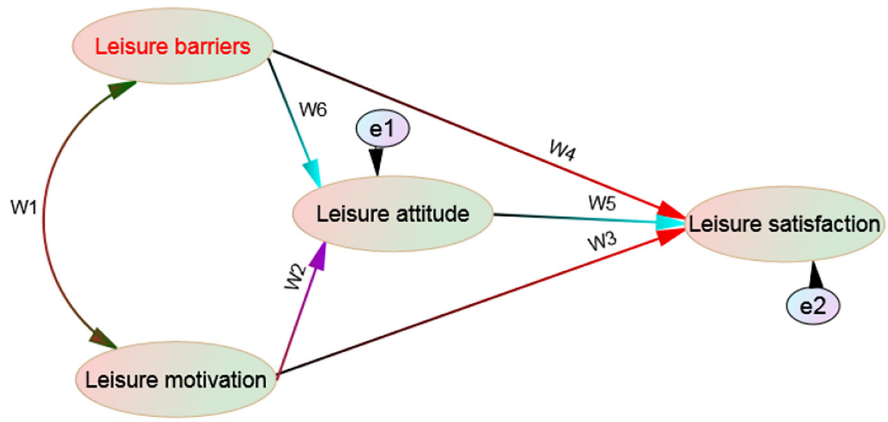

FIGURE 1 | Hypothetical diagram of the relationship among leisure motivation, barriers, attitude and satisfaction.

TABLE 1 | Statistical table of sample distribution in different regions.

Academic name	Questionnaire (*N* = 2351)			Valid sample (*N* = 2249)		Junior middle school		Senior high school	
	Distribute	Regain	Delete	Male	Female	Grade 1	Grade 2	Grade 1	Grade 2
Sichuan normal affiliated middle school	510	469	16	51.3%	48.7%	26.5%	25.6%	22.7%	25.2%
Chengdu No.17 middle school	510	475	31	49.6%	50.4%	24.8%	25.9%	26.1%	23.2%
Shishi United middle school	510	457	25	50.9%	49.1%	25.6%	26.7%	25.9%	21.8%
Chengdu Lianxin middle school	510	471	30	53.7%	46.3%	27.1%	25.6%	24.9%	22.4%
Chengdu Yandaojie middle school	510	479	0	52.5%	47.5%	25.9%	27.1%	25.4%	21.6%
Total	2550	2351	102	1160	1089	581	589	563	516

family residence. Among the four scales, The measurement of leisure attitude is compiled by Wei and Liu (2013), which is divided into three dimensions with a total of 16 items, namely leisure cognition (e.g., leisure activities are beneficial to personal health), leisure behavior (e.g., I often engage in leisure activities) and leisure emotion (e.g., my leisure activities are novel and interesting); The leisure motivation scale is compiled by Wang (2007), which contains 4 dimensions and 21 items in total, namely, develop intelligence (e.g., I participate in leisure to stimulate imagination or cultivate creativity), social skills (e.g., I participate in leisure to establish and maintain good friendship), competent and skilled (e.g., I want to gain a sense of achievement by participating in leisure activities) And stimulus escape (e.g., I participate in leisure activities to escape crowded and noisy daily life); The leisure barriers scale was compiled by Zhao (2003), which contains three dimensions and 17 items in total, namely internal obstacles (for example, I am too shy and introverted to engage in leisure activities), internal barriers (for example, people I know usually don't have good skills, so they can't engage in leisure activities with me), and junction observation (for example, if I have transportation, I am more likely to engage in leisure activities); The leisure satisfaction scale was compiled by Chen (2008), which contains 6 dimensions and 25 items in total, namely mental health (for example, participating in leisure activities makes me very interested), education happy (for example, participating in leisure activities can increase my knowledge), social satisfaction (for example, participating in leisure activities can give me opportunities to interact socially with others), pressure relief (for example, participating in leisure activities can help me relax my body and mind) Physical health (for example, participating in leisure activities can help me recover my strength) and field aesthetic feeling (for example, participating in leisure activities can let me enjoy the beauty of nature). The five-point Likert-scaled items are adopted for the above scales, which are divided into very disagree, disagree, uncertain, agree, and very agree, with 1 to 5 points respectively.

Questionnaire Validity and Reliability

On March 15, 2019, this study selected two classes in Chengdu Shishi middle school and Jinniu middle school respectively, distributed 300 questionnaires, recovered 278 questionnaires, deducted 12 invalid questionnaires and 266 valid questionnaires. The validity and reliability of the questionnaire were tested and corrected based on the pre-test. The formal investigation was completed from September 15 to 30, 2019.

Table 2 shows:

Exploratory factor analysis (EFA) showed that the sports leisure attitude scale with 16 items was suitable for factor analysis (KMO = 0.87, Bartlett's test for sphericity $p < 0.001$), and three common factors could be extracted, and the corresponding Cronbach' α coefficients were 0.84, 0.81, and 0.83 respectively. In addition, the overall scale α coefficient = 0.85; Confirmatory factor analysis (CFA) showed that the fitness indexes AGFI, CFI, NFI, and IFI were 0.92, 0.95, 0.93, and 0.91, which were all greater

TABLE 2 | Validity and reliability test of attitude, motivation, hindrance, and satisfaction scale of leisure activities.

Scale name	KMO and bartlett ball test	Number of items included	Dimension name	Composite reliability	Cronbach α coefficient
Leisure attitude scale	KMO = 0.87	6	Leisure cognition	0.80	0.84
	P = 0.000	5	leisure behavior	0.85	0.81
		5	leisure emotion	0.81	0.83
Verification results of scale 1: AGFI = 0.92, CFI = 0.95, NFI = 0.93, IFI = 0.91, RMSEA = 0.03; The overall cronbach's α coefficient is 0.85.					
	KMO = 0.78	6	Develop intelligence	0.82	0.79
Leisure Motivation Scale	*P* = 0.000	5	Social skills	0.81	0.78
		5	Competent and skilled	0.87	0.85
		5	Stimulus escape	0.84	0.80
Verification results of scale 2: AGFI = 0.91, CFI = 0.92, NFI = 0.92, IFI = 0.93, RMSEA = 0.04; The overall cronbach's α coefficient is 0.88.					
	KMO = 0.85	6	Internal Obstacles	0.88	0.86
Leisure barriers scale	*P* = 0.000	5	Interpersonal barriers	0.80	0.82
		6	Junction obstruction	0.79	0.83
Verification results of scale 3: AGFI = 0.94, CFI = 0.90, NFI = 0.91, IFI = 0.93, RMSEA = 0.02; Overall Cronbach's α coefficient 0.85.					
	KMO = 0.82	5	mental health	0.86	0.84
Leisure satisfaction scale	*P* = 0.000	4	Education happy	0.83	0.81
		4	Social satisfaction	0.81	0.89
		4	Pressure relief	0.87	0.86
		4	Physical health	0.82	0.85
		4	Field Aesthetic feeling	0.86	0.81
Verification results of scale 4: AGFI = 0.91, CFI = 0.93, NFI = 0.95, IFI = 0.92, RMSEA = 0.03; The overall cronbach's α coefficient is 0.84..					

than the standard of 0.90, RMSEA = 0.03 (less than 0.05, with good adaptation); In addition, the combined reliability of the three common factors (potential variables) is more than 0.79, which shows that the scale has good reliability and validity.

Exploratory factor analysis showed that the leisure motivation scale with 21 items was suitable for factor analysis (KMO = 0.78, Bartlett's test for sphericity $p < 0.001$). The scale could extract 4 common factors, corresponding to Cronbach' α coefficient is between 0.79–0.85, and the overall scale α Coefficient = 0.88; Confirmatory factor analysis showed that the fitness indexes AGFI, CFI, NFI, and IFI were 0.91, 0.92, 0.92, and 0.93, which were all greater than the standard of 0.90, RMSEA = 0.04 (less than 0.05, good adaptation); In addition, the combined reliability of the four dimensions (potential variables) is more than 0.81, which shows that the reliability and validity of this scale are good.

Exploratory factor analysis showed that the leisure barriers scale with 17 items was suitable for factor analysis (KMO = 0.85, Bartlett ball test $p < 0.001$). The scale could extract three common factors, corresponding to Cronbach ' α coefficient is between 0.82–0.86, and the overall scale α Coefficient = 0.85; Confirmatory factor analysis showed that the fitness indexes AGFI, CFI, NFI, and IFI were 0.94, 0.90, 0.91, and 0.93, which were all greater than the standard of 0.90, RMSEA = 0.02 (less than 0.05, good adaptation); In addition, the combined reliability of the three dimensions (potential variables) is more than 0.79, which shows that the reliability and validity of this scale are good.

Exploratory factor analysis showed that the leisure satisfaction scale with 25 items was suitable for factor analysis (KMO = 0.82, Bartlett's test for sphericity $p < 0.001$). The scale could extract 6 common factors, corresponding to Cronbach ' α coefficient is between 0.81–0.86, and the overall scale α Coefficient = 0.84; Confirmatory factor analysis showed that the fitness indexes AGFI, CFI, NFI, and IFI were 0.91, 0.93, 0.95, and 0.92 in order, which was all greater than the standard of 0.90, RMSEA = 0.03 (less than 0.05, good adaptation); In addition, the combined reliability of the six dimensions (potential variables) is more than 0.81, which shows that the reliability and validity of this scale are good.

Mathematical Statistics

Canonical correlation analysis is a statistical method used to test the correlation degree between one group of control variables and another group of criterion variables. It aims to find the maximum correlation between the linear combination of control variables and the linear combination of criterion variables. Therefore, canonical correlation analysis tests the canonical correlation combination of multiple criterion variables and multiple control variables, Canonical correlation analysis can produce a combination of significant and insignificant canonical correlation. Generally, it can provide the following basic information: one is the typical correlation coefficient can reflect the correlation degree between the linear combination of control variables and the linear combination of standard variables. The typical correlation coefficient must reach a significant level to represent the significant correlation between the two groups of linear combinations. The second is the judgment coefficient (i.e., the square value of typical correlation coefficient R). It means that the typical factors of the standard variable can be explained by the typical factors of the control variable (not less than 10%). The third is the structural coefficient (typical load). It is intended to control the correlation between the variable and the criterion variable to their respective typical linear combinations. The absolute value of the coefficient must be more than 0.30 to explain that their respective typical linear combinations have explanatory power.

SPSS17.0 and Amos version 17.0 statistical analysis software were used to statistically process the survey data by using the methods of canonical correlation analysis, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Explore and calculate the mediating effect of physical activity according to the bootstrap method (Liu et al., 2017). In this study, non-parametric percentile bootstrap was used to test the significance of mediating effect. The original data were sampled 2000 times and 95% confidence interval (CI) was estimated. Firstly, it is judged that the indirect effect does not contain 0 within the 95% confidence interval and reaches a significant level, indicating that there is an intermediary effect. At this time, if the direct effect contains 0 within the 95% confidence interval, it means that the direct effect is not significant and is a complete intermediary effect; If the indirect effect and direct effect do not include 0 in the 95% confidence interval, both reach a significant level, and the total effect does not include 0 in the 95% confidence interval, reaching a significant level, it is a partial intermediary effect. The significance level of all indicators was set as $\alpha = 0.05$.

RESULTS

Analysis of the Typical Relationship Among Teenagers' Leisure Barriers, Attitudes, Motivation, and Satisfaction

Figure 2 shows that there are six groups of typical correlations among leisure barriers, leisure attitude, leisure motivation, and leisure satisfaction:

The first canonical correlation reflects the relationship between leisure attitude (control variable) and leisure barriers (criterion variable). The canonical correlation coefficient $r = 0.44^{**}$ and reached a significant level, and the determination coefficient $R^2 = 0.194$, indicating that the canonical factors in the control variable group can explain 19.4% of the total variation of canonical factors in the standard variable group (exceeding the minimum standard of 10%). In the control variable group, leisure cognition, leisure behavior, and leisure emotion were highly correlated with leisure attitude, and the typical factor loads were 0.90, 0.88, and 0.75 respectively. Therefore, it can be considered that leisure attitude affects leisure barriers through leisure cognition, behavior, and emotion in its variable group, while the variables highly related to leisure barriers are internal barriers and structural barriers, and the corresponding loads are −0.68 and −0.87 in turn; From the positive and negative signs of factor load, the relationship between the two is reversed.

The second group of canonical correlation reflects the relationship between leisure barriers (control variable) and leisure motivation (criterion variable). Its canonical correlation coefficient $r = 0.49^{**}$ and reaches a significant level, and its determination coefficient $R^2 = 0.24$, indicating that the canonical factors in the control variable group can explain 24% of the total variation of canonical factors in the criterion variable (exceeding the minimum standard of 10%). In the control variable group, intrinsic and structural barriers have a high correlation with leisure barriers, and their typical factor loads are −0.68 and −0.87 respectively. Therefore, it can be considered that leisure barriers mainly affect leisure motivation by the intrinsic and structural barriers in the variable group, while the variables highly correlated with leisure motivation are the development of intelligence, social skills, proficiency, and stimulus avoidance, The corresponding loads are −0.74, −0.63, −0.79, and −0.89; From the positive and negative signs of factor load, the relationship between the two is in the same direction.

The third group of canonical correlations reflects the relationship between leisure motivation (control variable) and leisure attitude (criterion variable). The canonical correlation coefficient $r = 0.67^{**}$, reaching a significant level, and the determination coefficient $R^2 = 0.45$, indicating that the canonical factors in the control variable group can explain 45% of the total variation of canonical factors in the standard variable (exceeding the minimum standard of 10%). Among the control variables, the development of intelligence, social skills, competence, proficiency, and stimulus avoidance is highly correlated with leisure motivation, and the typical factor loads are 0.65, 0.72, 0.85, and 0.66 respectively. Therefore, it can be considered that leisure motivation affects leisure attitude through the development of intelligence, social skills, competence, proficiency, and stimulus avoidance, while the variables highly correlated with leisure attitude are leisure cognition The corresponding loads of behavior and emotion were 0.90, 0.88, and 0.75 respectively; From the positive and negative signs of factor load, the relationship between the two is in the same direction.

The fourth group of canonical correlation reflects the relationship between leisure barriers (control variable) and leisure satisfaction (criterion variable). Its canonical correlation coefficient r is 0.29^{**}, reaching a significant level, but the determination coefficient R^2 is only 0.08, indicating that the canonical factors in the control variable group can only explain 8% of the total variation of canonical factors in the criterion variable and fail to reach the minimum standard of 10%. Therefore, it can be considered that the correlation between leisure barriers and leisure satisfaction is weak, and the impact on each other is limited.

The fifth group of canonical correlation reflects the canonical correlation between leisure motivation (control variable) and leisure satisfaction (criterion variable). Its canonical correlation coefficient $r = 0.77^{**}$ and reaches a significant level, and the determination coefficient $R^2 = 0.59$, indicating that the canonical factors in the control variable group can explain 59% of the total variation of the canonical factors of the criterion variable (exceeding the minimum standard of 10%). In the control variable group, the development of intelligence, social skills, competency proficiency, and stimulus avoidance is highly correlated with leisure motivation, and the typical factor loads are −0.79, −0.71, −0.89, and −0.73 respectively. Therefore, it can be considered that leisure motivation affects leisure satisfaction through the four dimensions of development intelligence, social skills, competency proficiency, and stimulus avoidance in the variable group, The variables highly correlated

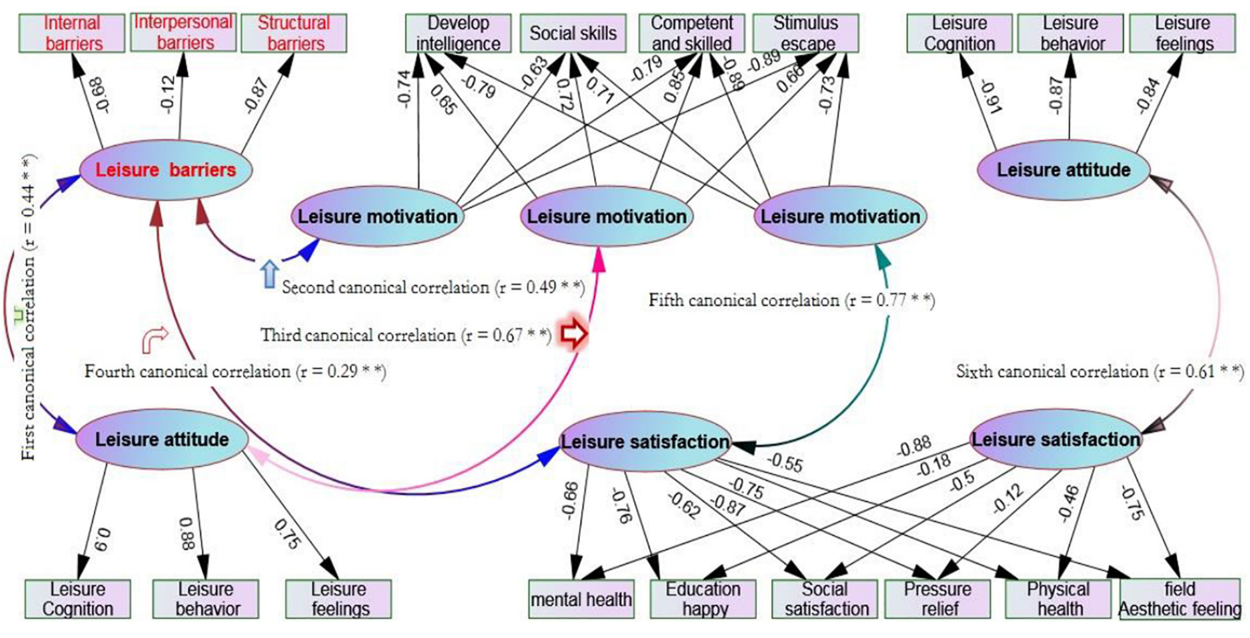

FIGURE 2 | Typical correlation among leisure motivation, attitude, barriers, and satisfaction.

with leisure satisfaction were mental health, educational pleasure, social satisfaction, stress relief, physical health, and site aesthetics, and the corresponding loads were −0.66, −0.76, −0.62, −0.87, −0.75, and −0.55 respectively; From the positive and negative signs of factor load, the relationship between the two is in the same direction.

The sixth group of canonical correlation reflects the relationship between leisure attitude (control variable) and leisure satisfaction (criterion variable). The canonical correlation coefficient $r = 0.61^{**}$, reaching a very significant level, and the determination coefficient $R^2 = 0.37$, indicating that the canonical factors in the control variable group can explain 37% of the total variation of canonical factors in the standard variable group (exceeding the minimum standard of 10%). In the control variable group, leisure cognition, behavior, and emotion are highly correlated with leisure attitude, and their typical factor loads are −0.91, −0.87, and −0.84, respectively. Therefore, it can be considered that leisure attitude affects leisure satisfaction through cognition, behavior, and emotion in the variable group, while the variables highly correlated with leisure satisfaction are mental health, social satisfaction, physical health, and site aesthetics, The corresponding loads are −0.88, −0.50, −0.46, and −0.75; From the positive and negative signs of factor load, the relationship between the two is in the same direction.

Structural Equation Model Analysis of Leisure Barriers, Motivation, Attitude and Satisfaction Structural Model Verification

Table 3 shows:

From the results of absolute fit test: the initial mode absolute fit index $x2 = 81.01$, $X2/DF = 9.17$, $P = 0.000 < 0.05$, indicating that the covariance matrix of the hypothetical model is not well matched with the observed data (generally, the value of $x2/DF$ should be between 1 and 3); GFI = 0.817 (> 0.90 is the adaptation), AGFI = 0.808 (> 0.90 is the adaptation), RMSEA = 0.341 (generally, RMSEA < 0.05 is excellent, and 0.05 ∼ 0.08 is good). From the value-added adaptation test results, NFI = 0.787 (adaptation > 0.90), IFI = 0.801 (adaptation > 0.90), CFI = 0.830 (adaptation > 0.90), RFI = 0.785 (adaptation > 0.90). In short, whether absolute fit or Increment fit test, the initial correlation model of this study is not well matched with the actual data, so the correlation model must be corrected.

According to the path suggested by the correction index in the initial model, this study modifies the initial model with the original theoretical framework and adds the covariance relationship between the measurement index error terms (e2-e5, e1-e8, e2-e4, e11-e6, e1-e6, e2-e9) one by one. The results show that the absolute adaptation index of the modified model is $X^2 = 5.88$, $X^2/DF = 1.89$, $P = 0.081 > 0.05$, indicating that the covariance matrix of the model is adapted to the observed data ($X^2/DF = 1.78$ is adapted between 1 and 3); GFI = 0.925 (> 0.90 for adaptation), AGFI = 0.930 (> 0.90 for adaptation), RMSEA = 0.054 (good at 0.05∼0.08). From the increment fit test results, NFI = 0.932 (adaptation > 0.90), IFI = 0.941 (adaptation > 0.90), CFI = 0.934 (adaptation > 0.90), RFI = 0.945 (adaptation > 0.90). It can be seen that the initial correlation model of this study is well adapted to the actual data after correction (see **Figure 3**).

Analysis of the Dual Mediating Role of Leisure Attitude

Figure 3 shows in combination with **Table 4**:

The indirect effect of leisure motivation on middle school students' leisure satisfaction is 0.22^{**}, which is very significant.

TABLE 3 | Statistical table of fitness test for model evaluation (*$P < 0.05$, indicating that the model is not suitable; $P > 0.05$, indicating adaptation).

	Absolute fit test						**Increment fit test**			
	X^2	X^2/df	*P*	**RMSEA**	**GFI**	**AGFI**	**NFI**	**IFI**	**CFI**	**RFI**
Initial model	81.01	9.17*	0.000	0.341	0.817	0.808	0.787	0.801	0.830	0.785
Modified model	5.88	1.89	0.081	0.054	0.925	0.930	0.932	0.941	0.934	0.945

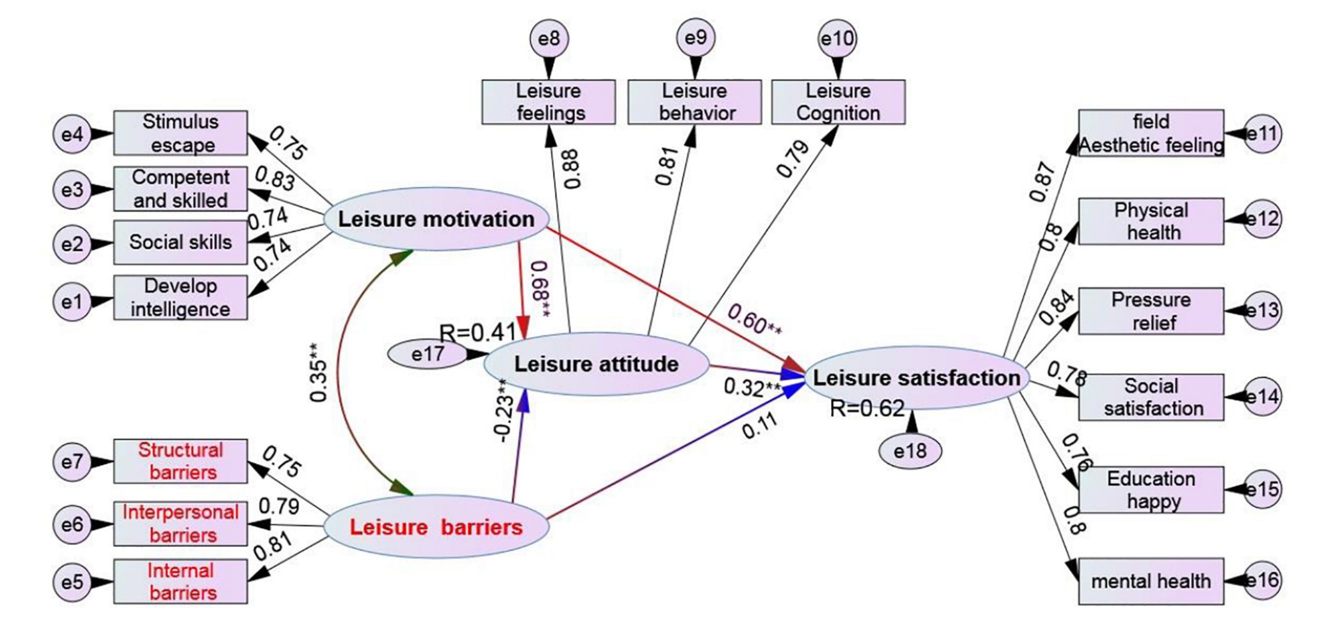

FIGURE 3 | Overall structural equation model of leisure barriers, motivation, attitude, and satisfaction.

TABLE 4 | Analysis of leisure attitude as a dual intermediary effect.

Intermediary model I: leisure motivation → leisure attitude → leisure satisfaction			**Intermediary model II: leisure barriers → leisure attitude → leisure satisfaction**		
	Standardization coefficient	**95% confidence interval**		**Standardization coefficient**	**95% confidence interval**
Indirect effect: leisure motivation → leisure attitude → leisure satisfaction	0.22**	0.102~0.411	Indirect effect: leisure barriers → leisure attitude → leisure satisfaction	−0.07**	−0.158~−0.008
Direct effect: leisure motivation → leisure satisfaction	0.60**	0.326~0.781	Direct effect: leisure barriers → leisure satisfaction	0.01	−0.109~0.159
Total effect: leisure motivation → leisure satisfaction	0.82**	0.501~0.902	Total effect: leisure barriers → leisure satisfaction	−0.06**	−0.216~−0.008

*Attachment: direct effect, indirect effect and total effect are directly derived from Amos. *, **, and *** represents significant levels of 0.05, 0.01 and 0.001 respectively.*

The confidence interval of 0.102~0.411 does not contain zero, while the direct effect of leisure motivation on leisure satisfaction = 0.60**, which is very significant. The confidence interval of 0.326~0.781 does not contain zero. At the same time, the total effect of leisure motivation on leisure satisfaction = 0.82** and the confidence interval of 0.501~0.902 also does not contain zero, This fully affirms that leisure attitude plays a partial intermediary role between leisure motivation and leisure satisfaction. The other path is the impact of leisure barriers on leisure satisfaction, in which the indirect effect of leisure barriers on leisure satisfaction is −0.07**, reaching a significant level, with a confidence interval of −0.158 ~ −0.008, obviously excluding zero, while the direct effect of leisure barriers on middle school students' leisure satisfaction = 0.01, not significant, with a confidence interval of −0.109~0.159, obviously including zero. Therefore, we can judge that leisure attitude plays a complete intermediary role between leisure barriers and leisure satisfaction.

It can be further found from **Figure 3** that the value of the judgment coefficient of the impact of leisure motivation and leisure barriers on middle school students' leisure attitude is R^2 = 0.41, which shows that 41% of the variation of middle school students' leisure attitude can be explained by leisure motivation and leisure barriers. Among them, the impact of leisure motivation on leisure attitude is positive, and the explanation strength is about 46% (from the standardized path coefficient $r = 0.68^{**}$, $0.68 \times 0.68 = 0.46$), while the impact of leisure barriers on leisure attitude is negative, and the explanation is about 5% (from the standardized path coefficient $r = -0.23^{**}$, $0.23 \times 0.23 = 0.05$), the influence of leisure motivation on leisure attitude is significantly higher than that of leisure barriers. In the influence of leisure motivation, leisure barriers, and leisure attitude on middle school students' leisure satisfaction, the judgment coefficient R^2 = 0.62, which shows that 62% of the variation of middle school students' leisure satisfaction can be explained by the direct or indirect influence of leisure motivation, leisure barriers, and leisure attitude. The direct influence of leisure motivation, leisure barriers and leisure attitude on leisure satisfaction was 36% ($0.60 \times 0.60 = 0.36$), 10% ($0.32 \times 0.32 = 0.10$), 1% ($0.11 \times 0.11 = 0.01$) respectively, intermediary I influence 22% ($0.68 \times 0.32 = 0.22$), the influence of complete mediation II is negative, and the size is 7% ($-0.23 \times 0.32 = -0.07$). The overall influence is positive (direct influence + indirect influence), and the size is 62%.

DISCUSSION

In the first group of canonical correlations, the absolute values of the structural coefficients of the control variables' leisure attitude are more than 0.70, indicating that each control variable has a high degree of correlation with leisure attitude; In the criterion variable leisure barriers, except interpersonal barriers, the absolute values of the structural coefficients of personal internal barriers and structural barriers are greater than 0.6. It can be seen that leisure cognition, behavior, and emotion are the main factors affecting personal internal barriers and structural barriers. That is, the subjects' cognition, feeling, and preference for leisure activities and experience, as well as all their leisure behavior patterns, It will affect their personality traits and mental state, leisure preferences, and leisure participation. In addition, from the perspective of leisure attitude, the structural coefficient symbols of each control variable and each leisure barriers criterion variable are reversed, indicating that the better the subjects' leisure attitude, the lower the barriers they encounter in leisure. This conclusion is the same as Kyunghyun et al. (2017) and Tan (2017). **Figure 2** of the structural model clearly shows that leisure barriers have a certain negative impact on leisure attitudes, and the standardized path coefficient is -0.23^{**}, which also supports the research results of Sylvester et al. (2018). However, the results of this study do not support the findings of Hofer et al. (2011) that leisure barriers may not completely limit individuals' leisure attitude (behavior) but do affect individuals' choices and experience in participation. If individuals have high intrinsic motivation for leisure, they can try to overcome difficulties and achieve leisure needs even in the face of leisure barriers. Therefore, this result needs further research in the future. 28–29.

The second group of canonical correlation showed that among the control variables, individual internal barriers and structural barriers were closely related to typical factors leisure barriers, among which structural barriers had the best correlation ($r = -0.87$); In terms of the criterion variable leisure motivation, the absolute value of the structure coefficient of each dimension is greater than 0.6, and the correlation between stimulus avoidance and leisure motivation is the highest ($r = -0.89$). This typical relationship reveals that personal internal obstacles and structural obstacles significantly affect leisure motives such as developing intelligence, social skills, competence, proficiency, and stimulus avoidance. Since the structural coefficients of each dimension of leisure barriers and leisure motivation are negative, the correlation coefficients of the two are shown in **Figure 3** of the structural equation ($r = 0.35^{**}$), so it is certain that the lower the degree of leisure barriers suffered by teenagers, the lower their motivation to engage in leisure. This result also does not support the view of scholar Tan (2017). Perhaps leisure barriers does not only interfere with leisure behavior, but may have a positive interaction with the feeling of happiness and satisfaction brought by leisure. Arie and Tal (2013) pointed out that leisure barriers can not only promote and form leisure experience, but also become the driving force to stimulate leisure and promote the positive feeling of leisure. If individuals simply remove leisure barriers in the process of leisure, it will have a negative impact on the formation of leisure experience.

The third canonical correlation shows that the development of intelligence, social skills, competence, proficiency and stimulus avoidance in the variable group of leisure motivation are highly correlated with them (r exceeds 0.65), while the factor load of structural factors cognition, behavior and emotion of leisure attitude in the variable group exceeds 0.74, and the symbol of factor load of leisure motivation and leisure attitude is the same direction. **Figure 3** of the structural model shows that leisure motivation has a very high direct impact on leisure attitude ($\beta = 0.68^{**}$). This fully affirms that the higher the individual's leisure motivation, the stronger their leisure attitude. This result is consistent with the research findings of McDavid et al. (2014) and Seghers et al. (2014). In addition, Axel (2013) took teenagers as the research object and found that leisure attitude and leisure motivation are important factors affecting their leisure behavior. Leisure attitude is an internal psychological factor, which is revealed in appearance through the stimulation of leisure motivation; Namho et al. (2014) put forward the hierarchical model of internal and external motivation according to self-determination theory and relevant research, which also indicates that different motivation forms will affect individual cognition, emotion, and behavior. Therefore, the significant positive relationship between leisure motivation and leisure attitude should be confirmed.

The fourth canonical correlation means that the canonical correlation between leisure barriers and leisure satisfaction is not strong ($r = 0.287^{**}$) and the structural model **Figure 3** also shows that the causal relationship is weak ($\beta = 0.11$), but it can harm leisure satisfaction through leisure attitude, which is consistent with the research results of Zhang and Yi (2013). However, previous studies on leisure barriers focused on the results of individuals' non-participation in leisure activities caused by their cognition of leisure barriers. That is, leisure barriers is the reason why personal perception or experience is hindered or affected to engage in leisure activities. Leisure barriers does not necessarily lead to the result of not participating in leisure activities but may affect personal leisure preferences and change leisure participation. Therefore, leisure barriers is related to an individual's ability to deal with barriers when successfully engaging in leisure and has an impact on leisure attitude (Zhang et al., 2017). It seems that in the process of leisure, facing the leisure barriers and paying for it, leisure satisfaction is not completely negative. It is necessary to conduct follow-up research to explore the linear relationship between the two variables.

The fifth group of canonical correlation shows that among the control variables of leisure motivation, the absolute values of the structural coefficients of developing intelligence, social skills, competence and skill, and stimulus avoidance are greater than 0.75, indicating that each dimension of the control variable is highly correlated with leisure motivation, and the absolute values of each dimension and its structural coefficient of leisure satisfaction are also greater than 0.65, so it is considered that intellectual development Leisure motivation structures such as social skills, competence and proficiency, and stimulus avoidance can significantly affect the six dimensions of leisure satisfaction. **Figure 3** of the structural model further confirms the direct influence of leisure motivation on leisure satisfaction, and the standardized path coefficient is $\beta = 0.60^{**}$. That is, to improve intelligence, establish interpersonal relationships and gain respect from others, and challenge the limits to achieve various skills, individuals often need to escape or stay away from the overstimulated life state, and leisure sports are the most suitable. Through leisure participation, we can benefit from personal psychology, obtain good social interaction with others, help understand others and surrounding things, relieve excessive life and academic pressure, develop physical fitness and obtain the best health methods.

The sixth canonical correlation shows that in the leisure attitude variable group, leisure cognition, behavior, and emotion are highly correlated with leisure attitude (r more than 0.80), while leisure satisfaction is only highly correlated with mental health, aesthetic feeling, physiological and social satisfaction. The sign of the load of the two factors shows the same direction, which shows the subjects' cognition of leisure activities and experience Feelings and preferences and all leisure behavior patterns will affect their leisure preferences and interest tendencies in open space and natural beauty, building interpersonal interaction and leisure activities. This is consistent with the research results of Badia et al. (2011) and Kono et al. (2020), that is, teenagers who hold a highly recognized leisure attitude toward leisure can get higher leisure satisfaction from their leisure experience. **Figure 3** shows that the direct influence of leisure attitude on leisure satisfaction is low ($\beta = 0.32^{**}$). According to Hamm and Yun (2018), among the three dimensions of leisure cognition, behavior, and emotion, leisure behavior has the lowest score, and perceived benefits cannot effectively predict physical activity behavior. It is further pointed out that sports benefits do not necessarily lead to physical activity behavior. It can be seen that high attitude may only lead to high cognition and emotion, which may not lead to leisure activity "behavior", That is, subjects cannot experience leisure fun without taking action, and satisfaction is naturally limited, which may be part of the reason why leisure attitude has a little direct effect on leisure satisfaction.

The overall structure model of leisure motivation, barriers, attitude, and satisfaction (**Figure 3**) shows that leisure motivation is the most important pre-variable. Through leisure attitude, leisure motivation has a significant impact on leisure satisfaction. Leisure attitude plays an important intermediary role. However, the joint explanation variation of leisure motivation and leisure barriers on leisure attitude is 41%, but the impact of leisure barriers on leisure attitude is negative. It can be seen that leisure motivation plays a dominant and dominant role in the impact of leisure attitude. For example, Mackenzie et al. (2018) pointed out that the internal motivation of leisure is the tendency of individuals to seek internal reward from leisure behavior, and it is the internal force that triggers individuals to engage in leisure activities. Zhang (2008) pointed out that leisure provides many benefits, which can adjust stress, provide positive mood, reduce negative emotion and physiological mechanisms. When individuals perceive the benefits of leisure, the internal motivation of leisure is born, because the benefits of leisure will promote individuals to participate in leisure activities, It leads to a positive relationship between leisure interests and leisure intrinsic motivation. In other words, if leisure participants can have a good experience in the process of activities, they can not only enhance their interest and love of leisure activities but also be more willing to continue to participate. When individuals have stronger leisure motivation, their leisure experience will be better, and leisure satisfaction will naturally increase with their personal experience. The results of this study echo these views.

From the perspective of the joint effect of the three variables of leisure attitude, leisure motivation and leisure barriers on leisure satisfaction, the joint explanation variation is 62%, but leisure motivation and leisure attitude are positively correlated with leisure satisfaction, while leisure barriers has a little direct impact on leisure satisfaction, while the direct impact of leisure attitude on leisure satisfaction is limited (about 10%), Therefore, it can be inferred that the main influence on leisure satisfaction is leisure motivation, which has a direct influence of 36%, and it also has an indirect influence of 22% through the intermediary of leisure attitude. As Ryan and Glendon (1998) said, leisure motivation emphasizes that individuals seek the most ideal reasons to engage in leisure to meet the needs of their internal value, such as relaxation or escape, to stimulate their motivation to participate in leisure activities. The essence of leisure satisfaction lies in the pursuit of personal choice, through the realization of personal internal leisure motivation and demand, to form the degree of satisfaction obtained by individuals engaged in leisure. Based on the important role of leisure motivation, this study suggests that at present, the decision-makers of all kinds of senior middle schools in China should pay more attention to students' leisure education, establish a correct concept of leisure and assist in appropriate leisure planning. When students encounter barriers in leisure, they should assist students to face the barriers and strive to overcome them, to stimulate their motivation to engage in leisure, Enhance the intensity of their leisure motivation, to enhance the satisfaction of leisure.

PROBLEMS AND PROSPECTS

In order to improve and increase middle school students' leisure satisfaction, we should make good use of the factors affecting leisure activities. The results of this study infer that as long as it can actively stimulate middle school students' leisure motivation and help them establish a positive leisure attitude, it should improve students' leisure satisfaction and improve their quality of life. Therefore, it is necessary to strengthen middle school students' leisure education, establish correct leisure concepts and attitudes, emphasize leisure benefits and induce their leisure motivation.

In terms of leisure motivation, schools should add leisure facilities, beautify the leisure environment and strengthen the safety of leisure venues, which will be of positive help to students' participation in after-school leisure; In terms of leisure barriers, we should provide leisure consulting and leisure counseling services, increase students' leisure sports knowledge and skills through appropriate leisure sports courses and leisure sports related activities, and regularly handle leisure sports lectures, so as to reduce the increase of students' leisure barriers, which will create a virtuous circle for the overall leisure model of teenagers (Madariag and Romero, 2016; Villar et al., 2017).

There are many factors and levels involved in the causal model affecting middle school students' leisure. This study only discusses the causal model from the variables such as leisure attitude, leisure motivation, leisure barriers, and leisure satisfaction. However, in order to fully understand the overall picture of complex leisure model, more influencing variables should be added appropriately, When verifying similar hypothetical models in the future, we should consider adding different variables to the impact model in order to obtain more complete leisure model information.

The survey participants of this study are mainly middle school students in Chengdu in the western region. Therefore, the follow-up researchers should cover the subjects in the northern, central, southern and eastern regions of China, and expand the scope of subjects to primary school students, college students and middle-aged and elderly people, so as to make the research results more representative. In addition, this study does not measure teenagers' real leisure time and specific leisure behavior, but indirectly involves this problem in the form of questionnaire, which needs to be discussed in depth in the future.

CONCLUSION

There are six typical correlation structures among leisure motivation, barriers, attitude, and satisfaction. Among them, leisure motivation has a significant positive correlation with leisure attitude and leisure satisfaction, and leisure attitude has a significant positive correlation with leisure satisfaction; Leisure barriers has a significant negative impact on leisure attitude, and the direct impact of leisure motivation on leisure attitude is significantly higher than that of leisure motivation on leisure satisfaction.

Leisure attitude is not only the intermediary between leisure motivation and leisure satisfaction, but also the intermediary between leisure barriers and leisure satisfaction. The variables of leisure motivation and leisure barriers can jointly explain 44% of the variation of leisure attitude, while the variables of leisure attitude, leisure motivation and leisure barriers can jointly explain 59% of the total variation of leisure satisfaction. After removing the negative effects of leisure barriers, it shows that, Leisure motivation is the determinant of leisure attitude and leisure satisfaction.

In terms of the impact of leisure motivation, barriers and attitude on leisure satisfaction, leisure motivation is the core variable, but leisure attitude plays a dual intermediary role. Therefore, it is possible that educating teenagers may establish a productive leisure attitude and improve leisure satisfaction.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

This study was reviewed and approved by the Ethics Review Committee of Chengdu Institute of Physical Education. However, this study does not involve human and animal experimentation, and written informed consent was not required.

AUTHOR CONTRIBUTIONS

YW was mainly responsible for the design of the manuscript and the preparation of the questionnaire and participates in the writing of the manuscript. JS, FF, and XW were mainly engaged in the distribution of the questionnaire and data processing and analysis. YP was mainly responsible for the coordination among the members of the research group, financial support, and revision of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by Youth Fund Project of Sichuan Provincial Department of Education (Grant No: 16SB0119).

ACKNOWLEDGMENTS

The authors thank the leaders of Chengdu Institute of Physical Education and Leisure College for their strong support and help.

REFERENCES

Arie, S., and Tal, S. (2013). The immaterial sustenance of work and leisure: a new look at the work–leisure model. *J. Socio Econ.* 46, 10–16. doi: 10.1016/j.socec.2013.06.003

Axel, G. (2013). Motivational profiles in study-leisure conflicts: quality and quantity of motivation matter. *Learn. Individ. Differ.* 26, 201–211. doi: 10.1016/j.lindif.2013.01.009

Badia, M., Orgaz, B. M., Verdugo, M. A., Ullan, A. M., and Martinez, M. M. (2011). Personal factors and perceived barriers to participation in leisure activities for young and adults with developmental disabilities. *Res. Dev. Disabil.* 32, 2055–2063. doi: 10.1016/j.ridd.2011.08.007

Bailey, A. W., Kang, H. K., and Schmidt, C. (2016). Leisure routine and positive attitudes age-graded comparisons of the path to happiness. *J. Leis. Res.* 48, 189–209. doi: 10.18666/jlr-2016-v48-i3-6336

Chen, C. C. (2019). A cross-country study of leisure constraints and option framing effect in Chinese and Taiwanese package tour market. *Asia Pac. Manag. Rev.* 24, 223–231. doi: 10.1016/j.apmrv.2018.06.001

Chen, Y. H. (2008). *Relationship Between Leisure Motivation, Leisure Satisfaction and Subjective Well-Being of College Students*. Ph.D. dissertation. Chengdu: Sichuan Normal University, 43–57.

Cho, D., and Price, T. (2018). Leisure constraints to participation in competitive activities and intramural sports: comparing international and domestic students. *J. Int. Stud.* 8, 884–900. doi: 10.5281/zenodo.1250389

Choi, H. Y., Tai-hyung, K., and Ji-Hwan, L. (2017). Relational analysis of smartphone sports application usage motivation, sports attitude, leisure satisfaction, exercise flow, sport continuance. *Korean Soc. Sports Sci.* 26, 551–564. doi: 10.35159/kjss.2017.06.26.3.551

Downs, D. S., Savage, J. S., and DiNallo, J. M. (2013). Self-determined to exercise? Leisure-time exercise behavior, exercise motivation, and exercise dependence in youth. *J. Phys. Act. Health.* 10, 176–184. doi: 10.1123/jpah.10.2.176

Florian, S., and Jörg, P. (2018). Leisurely encounters: exploring the links between neighborhood context, leisure time activity and adolescent development. *Child. Youth Serv. Rev.* 91, 137–148. doi: 10.1016/j.childyouth.2018.06.001

Freire, T., and Teixeira, A. (2018). The influence of leisure attitudes and leisure satisfaction on adolescents' positive functioning: the role of emotion regulation. *Front. Psychol.* 9:1349. doi: 10.3389/fpsyg.2018.01349

Hainey, T., Westera, W., Connolly, T. M., Boyle, L., Baxter, G., Beeby, R. B., et al. (2013). Students' attitudes toward playing games and using games in education: comparing Scotland and the Netherlands. *Comput. Educ.* 69, 474–484. doi: 10.1016/j.compedu.2013.07.023

Hamm, J., and Yun, J. (2018). The motivational process for physical activity in young adults with autism spectrum disorder. *Disabil. Health J.* 11, 644–649. doi: 10.1016/j.dhjo.2018.05.004

Hofer, M., Kuhnle, C., Kilian, B., Marta, E., and Fries, S. (2011). Motivational interference in school-leisure conflict and learning outcomes: the differential effects of two value conceptions. *Learn. Instruct.* 21, 301–316. doi: 10.1016/j.learninstruc.2010.02.009

Holahan, C. K., Holahan, C. J., Li, X. Y., and Chen, Y. T. (2017). Association of health-related behaviors, attitudes, and appraisals to leisure-time physical activity in middle-aged and older women. *Women Health* 57, 121–136. doi: 10.1080/03630242.2016.1157127

Jackson, E. L., and Rucks, V. C. (1995). Negotiation of leisure constraints by junior-high and high-school-students-an exploratory-study. *J. Leis. Res.* 27, 85–105. doi: 10.1080/00222216.1995.11969978

Kono, S., Ito, E., and Loucks-Atkinson, A. (2020). The measurement model of leisure constraint negotiation in leisure-time physical activity context: reflective or formative? *J. Leis. Res.* 52, 120–127. doi: 10.1080/00222216.2020.1745720

Kyunghyun, P., Myungjoo, K., and Yong, H. S. (2017). An optimal consumption, leisure, and investment problem with an option to retire and negative wealth constraints. *Chaos Solitons Fractals* 103, 374–381. doi: 10.1016/j.chaos.2017.06.017

Laroche, J. A., Girard, S., and Lemoyne, J. (2019). Tracing adolescent girls' motivation longitudinally: from fitclub participation to leisure-time physical activity. *Percept. Mot. Skills* 126, 986–1005. doi: 10.1177/0031512519864194

Liu, Q., Kang, X., Guo, Y., Su, Y., Shi, L. P., and Yang, F. X. (2017). Influence mechanism of external social capital of university teachers on evolution of generative digital learning resources of educational technology of university teachers -empirical analysis of differential evolution algorithm and structural equation model of bootstrap self-extraction technique. *Eurasia J. Math. Sci. Technol. Educ.* 13, 5327–5341. doi: 10.12973/eurasia.2017.00985a

Mackenzie, S. H., Son, J. S., and Eitel, K. (2018). Using outdoor adventure to enhance intrinsic motivation and engagement in science and physical activity: an exploratory study. *J. Outdoor Recreat. Tour.* 21, 76–86. doi: 10.1016/j.jort.2018.01.008

Madariag, A., and Romero, S. (2016). Barriers to participation in leisure activities as perceived by young people. *Rev. Psicol. Deport.* 25, 21–26.

McDavid, L., Cox, A. E., and McDonough, M. H. (2014). Need fulfillment and motivation in physical education predict trajectories of change in leisure-time physical activity in early adolescence. *Psychol. Sport Exerc.* 15, 471–480. doi: 10.1016/j.psychsport.2014.04.006

Namho, C., Chulmo, K., and Jae, K. K. (2014). Extrinsic and intrinsic motivation for using a booth recommender system service on exhibition attendees' unplanned visit behavior. *Comput. Hum. Behav.* 30, 59–68. doi: 10.1016/j.chb.2013.07.035

Pu, Z. H., and Xu, J. Y. (2015). The relationship between college students' leisure participation, leisure restriction and leisure satisfaction. *Contemp. Sports Sci. Technol.* 26, 152–154. doi: 10.16655/j.cnki.2095-2813.2015.26.152

Ramey, H. L., Lawford, H. L., and Rose-Krasnor, L. (2016). Motivations for activity participation as predictors of emerging adults' psychological engagement in leisure activities. *Leisure Sci.* 38, 338–356. doi: 10.1080/01490400.2015.1095661

Rosa, C. D., Collado, S., Profice, C. C., and Larson, L. R. (2019). Nature-based recreation associated with connectedness to nature and leisure satisfaction among students in Brazil. *Leisure Stud.* 38, 682–691. doi: 10.1080/02614367.2019.1620842

Rusbult, C. E., Martz, J. M., and Agnew, C. R. (1998). The investment model scale: measuring commitment level, satisfaction level, quality of alternatives, and investment size. *Pers. Relatsh.* 5, 357–391. doi: 10.1111/j.1475-6811.1998.tb00177.x

Ryan, C., and Glendon, I. (1998). Application of leisure motivation scale to tourism. *Ann. Tour. Res.* 25, 169–184. doi: 10.1016/S0160-7383(97)00066-2

Seghers, J., Vissers, N., Rutten, C., Decroos, S., and Boen, F. (2014). Intrinsic goals for leisure-time physical activity predict children's daily step counts through autonomous motivation. *Psychol. Sport Exerc.* 15, 247–254. doi: 10.1016/j.psychsport.2014.01.003

Song, F. M. (2017). Study on the relaxing effect of sports and leisure adjustment on the schoolwork pressure of contemporary college students. *J. Southwest Normal Univ.* 42, 140–147. doi: 10.13718/j.cnki.xsxb.2017.12.023

Soos, I., Dizmatsek, I., Ling, J., Ojelabi, A., Simonek, J., Boros-Balint, I., et al. (2019). Perceived autonomy support and motivation in young people: a comparative investigation of physical education and leisure-time in four countries. *Eur. J. Psychol.* 15, 509–530. doi: 10.5964/ejop.v15i3.1735

Sukys, S., Cesnaitiene, V. J., Emeljanovas, A., Mieziene, B., Valantine, I., Ossowski, Z. M., et al. (2019). Reasons and barriers for university students' leisure-time physical activity: moderating effect of health education. *Percept. Mot. Skills* 126, 1084–1100. doi: 10.1177/0031512519869089

Sylvester, B. D., Curran, T., Standage, M., Sabiston, C. M., and Beauchamp, M. R. (2018). Predicting exercise motivation and exercise behavior: a moderated mediation model testing the interaction between perceived exercise variety and basic psychological needs satisfaction. *Psychol. Sport Exerc.* 36, 50–56. doi: 10.1016/j.psychsport.2018.01.004

Tan, W. K. (2017). Repeat visitation: a study from the perspective of leisure constraint, tourist experience, destination images, and experiential familiarity. *J. Destination Mark. Manag.* 6, 233–242. doi: 10.1016/j.jdmm.2016.04.003

Villar, M. B. C., Crespo, L. V., and Martinez, E. M. N. (2017). Leisure activies of young people in spain. an approach to their practices and barriers. *Obets Rev. Ciencias Soc.* 12, 43–64. doi: 10.14198/OBETS2017.12.1.11

Wang, W. (2007). *The Study on Leisure Motivation and Leisure Constraints of the Elderly in Nanjing*. MA Thesis. Nanjing: Nanjing Normal University, 62–67.

Wei, T. P., and Liu, Z. M. (2013). Reliability and validity analysis of leisure attitude scale in migrant workers. *J. Shanghai Inst. Phys. Educ.* 37, 47–51. doi: 10.16099/j.cnki.jsus.2013.05.016

Weissinger, E., and Bangalos, D. L. (1995). Development, reliability and validity of a scale to measure intrinsic motivation in leisure. *J. Leisure Res.* 27, 379–400. doi: 10.1080/00222216.1995.11949756

Wen, X. Y. (2019). Study on the relationship between leisure activity preferences, types and obstacles of urban female residents– taking chengdu as an example. *J. Southwest Normal Univ.* 44, 100–109. doi: 10.13718/j.cnki.xsxb.2019.08.017

Weybright, E. H., Caldwell, L. L., Ram, N., Smith, E. A., and Wegner, L. (2016). Trajectories of adolescent substance use development and the influence of healthy leisure: a growth mixture modeling approach. *J. Adolesc.* 49, 158–169. doi: 10.1016/j.adolescence.2016.03.012

Zhang, H. L., Zhang, J., Cheng, S. W., Lu, S. J., and Shi, C. Y. (2012). Role of constraints in Chinese calligraphic landscape experience: an extension of a leisure constraints model. *Tour. Manag.* 33, 1398–1407. doi: 10.1016/j.tourman.2012.01.001

Zhang, L. H. (2008). Constructing the relationship between leisure interests and leisure satisfaction of mountain climbers: the role of leisure intrinsic motivation and leisure experience. *J. Coll. Phys. Educ.* 10, 27–40. doi: 10.5297/ser.200809_10(3).0002

Zhang, W., Feng, Q. S., Lacanienta, J., and Zhen, Z. H. (2017). Leisure participation and subjective well-being: exploring gender differences among elderly in Shanghai. *China. Arch. Gerontol. Geriat.* 69, 45–54. doi: 10.1016/j.archger.2016.11.010

Zhang, X. Q., and Yi, F. (2013). Relationship between leisure participation, leisure obstacles and leisure satisfaction of senior primary school students. *J. Shenyang Inst. Phys. Educ.* 32, 69–74. doi: 10.3969/j.issn.1004-0560.2013.04.019

Zhao, L. (2003). *Analysis of Obstacles to Youth Sports and Leisure*. Chengdu: Sichuan University, 57–69.

Zheng, N. (2008). Study on the relationship between college students' leisure attitude and leisure obstacles. *Youth Res.* 4, 74–77. doi: 10.13583/j.cnki.issn1004-3780.2008.04.015

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
published: 16 June 2022
doi: 10.3389/fpsyg.2022.912368

A Comparison of Affective Responses Between Time Efficient and Traditional Resistance Training

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Specialty section:
This article was submitted to Movement Science and Sport Psychology,
a section of the journal Frontiers in Psychology

Received: 05 April 2022
Accepted: 31 May 2022
Published: 16 June 2022

Citation:
Andersen V, Fimland MS, Iversen VM, Pedersen H, Balberg K, Gåsvær M, Rise K, Solstad TEJ, Stien N and Saeterbakken AH (2022) A Comparison of Affective Responses Between Time Efficient and Traditional Resistance Training. Front. Psychol. 13:912368. doi: 10.3389/fpsyg.2022.912368

The aim of the study was to compare the acute effects of traditional resistance training and superset training on training duration, training volume and different perceptive measures. Twenty-nine resistance-trained participants (27 ± 7 years, 173 ± 9 cm, and 70 ± 14 kg) performed a whole-body workout (i) traditionally and (ii) as supersets of exercises targeting different muscle groups, in a randomized-crossover design. Each session was separated by 4–7 days, and consisted of eight exercises and three sets to failure. Training duration and number of repetitions lifted were recorded during the sessions. Rate of perceived exertion for effort (RPE), rate of perceived exertion for discomfort (RPD), session displeasure/pleasure (sPDF), and exercise enjoyment (EES) were measured 15 min after each session. Forty-eight hours after the final session participants reported which session they preferred. The superset session led to significantly higher values for RPE (1.3 points, $p < 0.001$, ES = 0.96) and RPD (1.0 points, $p = 0.008$, ES = 0.47) and tended to be higher for sPDF, i.e., more pleasurable, ($p = 0.059$, ES = 0.25) compared to the traditional session. There was no difference in EES ($p = 0.661$, ES = 0.05). The traditional session led to significantly increased training volume (4.2%, $p = 0.011$, ES = 0.34) and lasted 23 min (66%, $p < 0.001$, ES = 7.78) longer than the superset session. Eighteen of the participants preferred the superset session, while 11 preferred the traditional session. In conclusion, performing a whole-body workout as a superset session was more time-efficient, but reduced the training volume and was perceived with greater exertion for effort and discomfort than a traditional workout.

Keywords: RPE, RPD, sPDF, EES, feeling

INTRODUCTION

Improving muscular strength is associated with several health benefits and reduced risk of mortality (Jurca et al., 2004; Gale et al., 2007; Williams et al., 2007). Consequently, it is recommended to conduct resistance training 2–3 days per week for the major muscle groups (Garber et al., 2011). Still, most individuals do not follow these recommendations and lack of time is one of the most reported barriers (Hoare et al., 2017; Hurley et al., 2018). Therefore, finding time-efficient ways to perform resistance training is of great interest from both an individual and societal perspective.

A recently published review pinpointed several ways to reduce training duration when performing resistance training (Iversen et al., 2021). Iversen et al. recommended superset training as a method to substantially reduce training time. In contrast to traditional-set resistance training, where all sets of an exercise is completed before the next exercise, superset training could be defined as performing two or more exercises in succession with no, or limited, rest between them (Haff and Triplett, 2015). The exercises could target the same muscle groups, but this would primarily be relevant in a bodybuilding program with a training goal of producing high metabolic stress in a specific muscle group. However, if time efficiency is of an essence it is recommended to perform supersets that target different muscle groups. This allows for stimulating several muscle groups in shorter time, while not reducing the trained muscle groups recovery time, severely impairing performance in the next set, which would be the case if rest periods in traditional-set training were simply shortened (Iversen et al., 2021).

Performing the same work in a shorter period of time, have shown to increase the muscle fatigue (Paz et al., 2017) and blood lactate (Weakley et al., 2017) which could potentially limit the work performed in a session. Still, cross sectional studies comparing traditional resistance training to superset training where antagonists are paired, show no difference in training volume (Antunes et al., 2018) or even a higher volume for the superset training (Maia et al., 2014; Paz et al., 2017). This could be of importance since there seems to be a relationship between training volume and effects on muscle strength and hypertrophy (Schoenfeld et al., 2017; Grgic et al., 2018). Importantly, these studies (Maia et al., 2014; Paz et al., 2017; Antunes et al., 2018) are limited by only examining two exercises. When performing supersets over a whole training session, the accumulated fatigue could become more evident and result in reduced training volume.

How an activity is perceived, may be of importance for an individual regarding the choice to continue with the activity or not (Ekkekakis et al., 2005; Williams et al., 2008). As long as the rest interval are of similar length, Superset training sessions have less rest compared to traditional training sessions, due to fewer rest intervals, which in turn imposes more fatigue compared to traditional resistance training (Paz et al., 2017; Weakley et al., 2017). Consequently, it may be speculated that superset training is perceived as more exertive, discomforting and not as enjoyable as traditional training. Two cross-sectional studies have compared exertion between superset and traditional resistance training (Weakley et al., 2017, 2020). Both studies reported higher perceived exertion when conducting superset training than traditional training. However, both studies only included rating of perceived exertion (RPE). It has been recommended that RPE is accompanied by other measures, such as discomfort (Halperin and Emanuel, 2020).

We hypothesized that when performing a full body training program, superset training would lead to a reduced training volume in addition to greater levels of perceived discomfort, effort and displeasure compared to traditional resistance training among resistance trained individuals, and that superset training would be less enjoyable. Based on the hypothesis that the superset session led to higher levels of exertion and discomfort, and being less enjoyable, we expected that most participants would prefer traditional-set resistance training.

MATERIALS AND METHODS

Study Design

In this study, we used a within-subject, crossover design to compare the volume lifted and perceptive responses from a whole-body superset vs. a traditional-set resistance training session in resistance-trained individuals. The exercise program consisted of eight exercises (see **Figure 1**) with three sets each using ~9-RM loadings. The order of the sessions was randomized and counterbalanced, and all participants were required to partake in a familiarization session prior to two experimental sessions. Fifteen minutes after each session the participants were asked to report their session perception of effort, discomfort, pleasure/displeasure and enjoyment. In addition, training volume (number of repetitions lifted) and training duration were measured.

Participants

Twenty-nine adults (15 females and 14 males) volunteered to participate in the study. They were recruited through posters, personal information, meetings, and social media. For anthropometrics see **Table 1**. The sample size was justified by performing *a priori* power analysis based on previous studies expecting a difference of 1.5 in RPE between the two sessions (Weakley et al., 2017, 2020), alpha level of 0.05 and power of 0.8. The inclusion criteria for participation were being over 18 years old, having more than 1 year experience with resistance training, being familiar with and able to perform the exercises with good technique, and not having any injuries which prohibited maximal exertion. All participants had experience with supersets, but not necessarily on a regular basis. The participants agreed to refrain from alcohol and resistance training 48 h in advance of each session. They were informed orally and in writing about the procedures, and provided a written consent before being enrolled in the study. The procedures were approved by the Norwegian Centre of Research Data (ref nr 424,466) and was conducted according to the University College's ethical guidelines.

Procedures

In the familiarization session anthropometrics were measured, the individual standardizations and load for the different exercises were determined (~9-RM) in addition to familiarizing the participants with the different scales. The intensity (9-RM) was chosen because it is in the middle of the range

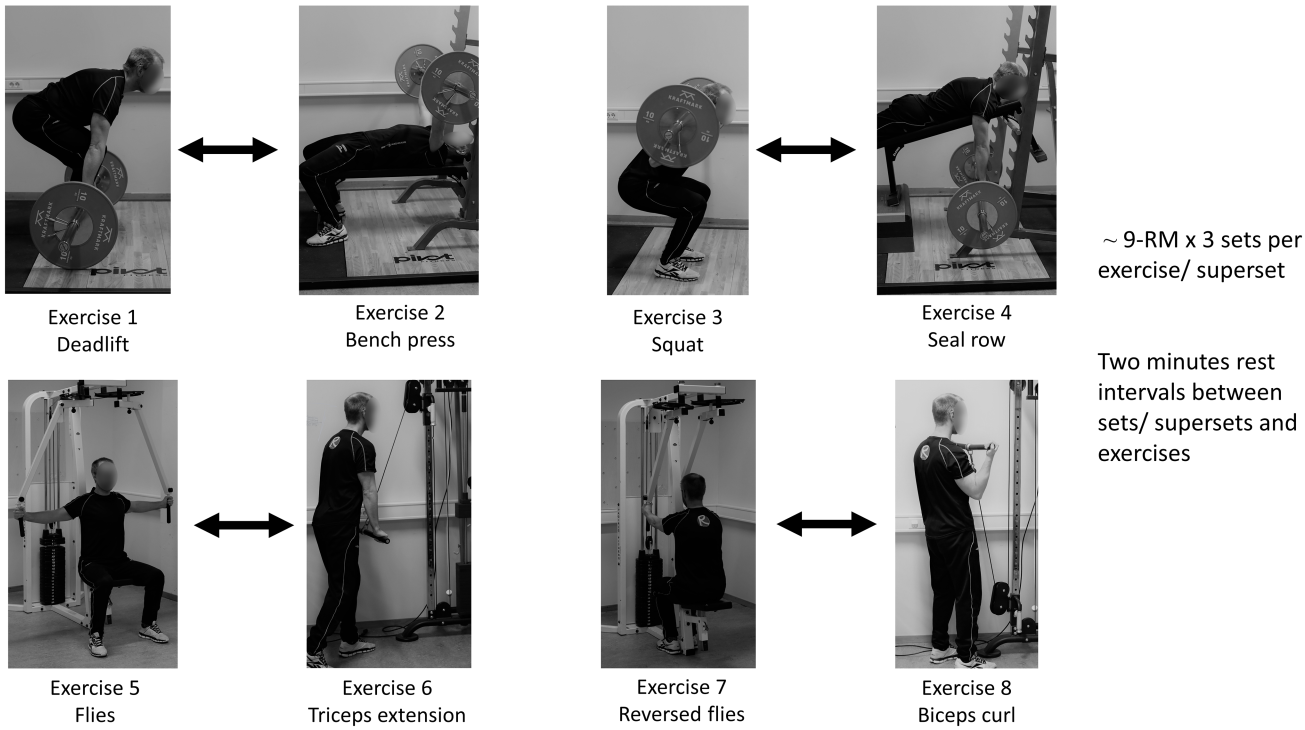

FIGURE 1 | An overview of the traditional and the superset session. Bidirectional arrows indicate exercises performed in the same superset.

TABLE 1 | Anthropometric data and self-reported 1-RM.

	All (*n* = 29)		**Females (*n* = 15)**		**Males (*n* = 14)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	27.2	7.2	26.1	7.2	28.3	7.4
Body height (cm)	173.4	9.2	168.9	7.7	178.4	9.6
Body weight (kg)	70.2	14.0	62.1	7.0	79.9	13.9
Resistance training experience (years)	8.4	6.6	7.5	7.2	9.4	5.9
Self-reported 1-RM						
–Bench press (kg)	70.7	28.6	47.9	11.8	95.1	19.3
–Squat (kg)	91.5	32.0	68.9	12.5	115.7	28.5
–Deadlift (kg)	111.6	39.1	83.0	16.7	142.1	32.3

RM, repetition maximum, SD, standard deviation.

(6–12-RM) recommended for resistance-trained individuals (Garber et al., 2011). Since the participants were resistance trained and familiar with most of the exercises, they estimated their 9-RM in each exercise. If they were unsure, they performed sets with progressive loading in the specific exercise until they could report a specific load. Importantly, the same loads were used in both sessions. The scales were presented to the participants as a measure of the participants' subjective experience of the sessions in turn of effort, discomfort, pleasure/displeasure, and enjoyment. Further, each scale was presented as in the experimental session (see below under measurements) and the participants were told that they should answer with the value representing their subjective assessment for that specific affection.

The two experimental sessions were conducted in a randomized order with 2–5 days between the sessions. In the beginning of each session, participants conducted a standardized warm-up consisting of two sets of deadlift, bench press, squat, and seal row. The first set consisted of six reps at 50% of the self-reported 9-RM and the last set consisted of six reps at 80% of self-reported 9-RM. The rest interval between each set was 90 s. After the final warm-up set the participants had 2 min rest before the session started. Three sets were conducted for each exercise using the same self-reported 9-RM load. In the traditional session, each set in one exercise was completed before a rest interval (2 min) while in the superset session two consecutive exercises (one set from each) were conducted immediately after each other before a similar rest interval (2 min). Otherwise, the sessions were equal. The resistance training program was a full-body program, consisting of eight exercises (see **Figure 1** for an order of exercises and overview of the sessions). Training duration and training volume, defined as number of repetitions, were recorded during both sessions. Fifteen minutes after each session, participants were asked how they perceived the session related to effort, discomfort, pleasure/displeasure, and enjoyment. Forty-eight hours after the last session, participants were asked which of the two sessions they would use as their regular training routine, and the main reason for that choice.

The participants were instructed to complete as many repetitions as they could (i.e., until failure) in each set. The repetitions had to be performed continuously throughout the set, with a self-selected but controlled tempo (e.g., no bouncing allowed). The same test leader was present in all sessions for each individual to control that the standardizations noted in the familiarization-session were used, and to ensure that the execution of repetitions was as identical as possible within the set and between the sessions. Furthermore, the test leader kept track of time used in each session, counted the repetitions in each set, observed that the sets were at or close to failure and presented the scales to the participants. If the test leader perceived that the sets were not performed at or close to failure, he was instructed to remind the participants to complete as many repetitions as they could in each set. Of note, this was not needed during the data collection. To avoid distractions and keep the settings as similar as possible between sessions, all sessions were conducted in a lab with only one participant and the test leader present at the time. Of note, the participants had a minimum of 1 year of resistance training experience (average 8.4 years) and most of them were familiar with the exercises.

Measurements

How the participants perceived the two sessions was assessed through four different scales. None of the participants had any previous experience with the scales. The scales were shown to the participants in the same order as listed below, 15 min after completing the last set. The participants were instructed to consider the whole session when giving their answers. All scales were shown to the participants while the test leader read the question to them (also listed on top of the scales). The scales were translated from the original forms to Norwegian. Prior to the study, three of the authors (AHS, HP, and VA) translated the scales independently before comparing, discussing, and agreeing on the final versions. These versions were then translated back to English by a professional. The new English versions were then compared with the originals. In general, there were only minor differences between the versions, which were adjusted after mutual agreement.

The perception of exertion was differentiated into effort and discomfort (Steele et al., 2016). Effort was measured using The rating of perceived exertion for effort scale (RPE), while discomfort was measured using the rating of perceived exertion for discomfort scale (RPD) (Fisher and Steele, 2017). Both scales consist of 11-items and ranges from no effort/discomfort to maximal effort/discomfort. Based on recent recommendations (Halperin and Emanuel, 2020), the RPE scale was presented to the participants with the following phrase: "*How much of your perceived physical capacity out of your perceived maximum (10 being your maximum) did you invest to complete this workout?*." The upper and lower limit were anchored by the following sentence "*0 can be described as sitting still during the whole session while 10 would be maximal effort using your maximal physical capacity throughout the whole session*." The RPD scale was presented with the following phrase: "*Based on the completed session, how much discomfort did you feel? The scale ends at 10 which could be described as you could not imagine the sensations relating to physical activity being any more intense?"* (Steele et al., 2016). The upper and lower limit were anchored by the following sentence *"0 can be described as feeling no noticeable sensation relating to the training while 10 would be the most intense training related sensation you could imagine*."

The perceived pleasure/displeasure with the session was measured using the session pleasure/displeasure feelings scale (sPDF). The scale is a bipolar 11-point scale stretching from −5 (very bad) to 5 (very good), where 0 is considered neutral. The sPDF scale was presented with the following phrase: "*How was your workout?*" (Ribeiro et al., 2019). *The upper and lower limit were anchored by the following sentence "-5 can be described as perceiving the session as one of the worst/least pleasurable training sessions you have ever conducted while 5 would be one of the best/most pleasurable training sessions you have ever conducted*." How much the participants enjoyed the sessions was measured using the exercise enjoyment scale (EES). The scale range is 1 (not at all)–7 (extraordinary). The scale was presented with the following question "*How much did you enjoy the exercise session?*" (Schwartz et al., 2021). The upper and lower limit were anchored by the following sentence "1 can be described as perceiving the session as one of the least enjoyable training sessions you have ever conducted while seven would be one of the most enjoyable training sessions you have ever conducted."

Forty-eight hours after the last experimental session, the participants were contacted by e-mail and asked the following questions "*If you had to choose one of the two training sessions as your regular training session, which would you prefer, and what is the main reason for this choice?*." The participants answered by replying to the mail. The answers were aggregated and grouped based on the underlying theme of the explanation.

Statistical Analysis

The statistical analyses were performed using SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). For the ordinal variables (RPE, RPD, sPDF and EES) the Wilcoxon signed rank test was used to compare the data between the sessions. The data regarding training duration and training volume (number of reps) was checked and confirmed for normality by visual inspection. Paired t-tests were used to assess differences between the two sessions. All results are presented as means ± standard deviations and Cohen's d effect size (ES). ES was calculated using the following equation: mean pre-mean post divided by the pooled standard deviations of the two. Effect size was interpreted as

TABLE 2 | Accumulated number of repetitions for three sets using ~9RM loading for each exercise.

	Deadlift		Bench press		Squat		Seal row		Flies		Triceps extension		Reversed flies		Biceps curl	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Traditional	30	6	27	4	26	5	30	7	26	5	33	6	31	6	29	5
Superset	30	6	25	3	26	5	26	6	26	4	28	5	29	4	27	5

SD, standard deviation.

$0.2 < d < 0.5$ small; $0.5 < d < 0.8$ medium, $d \leq 0.8$ large (Cohen, 1988). Statistical significance was accepted at $p \leq 0.05$.

RESULTS

The total number of repetitions conducted in the traditional session was 4.2% greater than the superset session (227 ± 29 vs. 218 ± 26 repetitions, $p = 0.011$, ES = 0.34, **Table 2**) while the training duration was 66% longer (58 ± 3 vs. 35 ± 3 min, $p < 0.001$, ES = 7.78).

The RPE was in average rated 1.3 points higher ($Z = -3.845$, $p < 0.001$, ES = 0.96, **Table 3**) and the RPD 1.0 point higher ($Z = -2.671$, $p = 0.008$, ES = 0.47) in the superset compared to the traditional session. Although not significantly different, there was a statistical trend for perceiving the superset session more pleasurable than the traditional session ($Z = -1.891$, $p = 0.059$, ES = 0.25). There was no significant difference in EES between the different sessions ($Z = -0.440$, $p = 0.661$, ES = 0.05).

When asked which session they would prefer as their regular training session, 18 preferred the superset session while 11 preferred the traditional session.

DISCUSSION

The aim of this study was to compare the acute effects of supersets versus traditional-set resistance training on training volume and different perceptive measures. In accordance with our hypothesis the results showed that among resistance trained individuals, a whole-body superset training session that was considerably shorter than a traditional-set training session (35 vs. 58 min), led to 4% lower training volume and resulted in greater perceptions of discomfort and effort when compared to traditional resistance training. The superset session tended to be more pleasurable, but there were no differences in enjoyment. When asked what they would prefer in regular training, 18 participants answered supersets and 11 traditional sets.

There have been some previous studies comparing training volume and perceptive responses between traditional and superset resistance training (Maia et al., 2014; Paz et al., 2017; Weakley et al., 2017, 2020; Antunes et al., 2018). Interestingly, previous studies reported that training volume was similar (Antunes et al., 2018) or even increased (Maia et al., 2014; Paz et al., 2017) when conducting two exercises in a superset compared to separately. Importantly, these studies only used two exercises (1–3 sets per exercise) focusing on less muscle mass i.e., upper body (Paz et al., 2017) and single joint exercises (Maia et al., 2014; Antunes et al., 2018). Therefore, it appears that the decrease in performance during superset training first becomes apparent when the session includes multiple exercises and/or sets. This speculation is strengthened when comparing the training volume for the first two exercises in our study. Here, we did not find any difference in number of repetitions lifted between the two sessions (difference; 1.4 repetitions, $p = 0.249$). To the best of our knowledge, no previous study has compared perceived discomfort between traditional resistance training and superset training, but two studies have reported effort

TABLE 3 | Perceptive measures for the traditional and superset session.

	Traditional		Superset			
	Mean	**SD**	**Mean**	**SD**	***p*-value**	**Effect size**
RPE (0–10)	6.6	1.5	7.9	1.2*	<0.001	0.96
RPD (0–10)	5.4	2.2	6.4	2.0*	0.008	0.47
sPDF (−5–5)	2.8	1.9	3.3	2.0	0.059	0.25
EES (1–7)	4.5	1.3	4.6	1.3	0.661	0.05

**, significantly different from traditional $p < 0.05$.*
RPE, rate of perceived exertion effort, RPD, rate of perceived exertion discomfort, sPDF, session pleasure/displeasure, EES, exercise enjoyment.

(Weakley et al., 2017, 2020). In agreement with our findings both studies reported greater RPE after completing two (Weakley et al., 2020) or six exercises (Weakley et al., 2017) in a superset session compared to a traditional session.

The reduction in training volume could be explained by increased fatigue in the superset session. Previous studies have shown that performing two exercises in a superset increases neuromuscular fatigue (Paz et al., 2017) and metabolic (e.g., increased lactate) and endocrine (e.g., cortisol) stress responses (Weakley et al., 2017). This increased stress may also explain the difference in effort and discomfort. It has been argued that performing sets until fatigue should yield a similar response in RPE (Fisher and Steele, 2017), however, in our study the participants were asked to consider the session as a whole and not after task failure in one set. Consequently, the difference in rating between the sessions may be explained by other factors than task-failure in each set. Of note, although effort and discomfort are different perceptions, they are reported to be related (Steele et al., 2016). Therefore, the increased perception of effort and discomfort could, at least partly, explain each other. Finally, the lack of difference in enjoyment could also be explained by our population. The fact that the participants were resistance trained with an average of 8 years of training experience indicate that they in general find enjoyment in performing resistance training.

The present study has some limitations that must be addressed. First, the participants in the study were resistance trained and the findings cannot necessarily be generalized to other populations, such as elite athletes or untrained individuals. Further, although all participants were familiar with supersets in their training routine, they did not necessarily use it on a regular basis. Therefore, it may be possible that their rating on the different perception scales would have been different if they had been using supersets more often. Although the different scales were presented to the participants in the familiarization session, they were not familiar with them prior to the study. The scoring might have been different if they had had more experience with the scales. Importantly, the order of the sessions was randomized so a potential familiarization effect should be similar for both sessions. Also, the measures were only assessed after the sessions. It has been shown that people are more positive toward training after the exercise (affective rebound effect; Ekkekakis et al., 2011). Therefore, the perception of the sessions may have changed throughout the sessions.

The intensity used in the sessions (9-RM) was subjectively reported by the participants. Therefore, it may be that the intensity was not the actual 9-RM. However, the reported intensity was close to the number of repetitions they were able to perform in the 9-RM testing, and it is unlikely that the deviation between reported and actual loading effected the results. Importantly the same load was used in both sessions to allow for comparisons between the two sessions. Also, we did not measure any physiological parameters such as heart rate, lactate etc. Such information could have provided additional insights.

From a practical point of view, performing superset training seems like a viable training form for resistance-trained individuals. As long as the length of the rest intervals are the same, superset training is more time efficient and is perceived more strenuous than traditional resistance training. Importantly time-efficiency and the feeling of working hard were the two major reasons why most of the participants (62%) preferred the superset session over the traditional session. Although, the superset session reduced the training volume compared to the traditional session by 4.2% (ES = 0.34), supersets can still be considered time efficient as the duration of the session was considerably shorter. These findings may be of individual and societal interest, if they can encourage individuals who struggle to find time for resistance training.

In conclusion, among resistance trained individuals, a whole-body superset training session that was considerably shorter than a traditional-set training session (35 vs. 58 min), led to 4% lower training volume, but greater perceptions of effort and discomfort when compared to traditional resistance training. Still, the superset session tended to be more pleasurable, and was preferred by most individuals. These findings suggest that those who are concerned about time efficiency and motivated for higher levels of exertion should favor superset training.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VA came up with the idea and wrote the first draft. All authors helped in developing the methodology. KB, MG, and KR collected the data. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors would like to thank the participants for their positivity and participation in the study.

REFERENCES

Antunes, L., Bezerra, E. S., Sakugawa, R. L., and Dal Pupo, J. (2018). Effect of cadence on volume and myoelectric activity during agonist-antagonist paired sets (supersets) in the lower body. *Sports Biomech.* 17:502. doi: 10.1080/14763141.2017.1413130

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (*2nd Edn.*), Hillsdale, NJ: L. Erlbaum Associates.

Ekkekakis, P., Hall, E. E., and Petruzzello, S. J. (2005). Variation and homogeneity in affective responses to physical activity of varying intensities: an alternative perspective on dose-response based on evolutionary considerations. *J. Sports Sci.* 23, 477–500. doi: 10.1080/02640410400021492

Ekkekakis, P., Parfitt, G., and Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Med.* 41, 641–671. doi: 10.2165/11590680-000000000-00000

Fisher, J. P., and Steele, J. (2017). Heavier and lighter load resistance training to momentary failure produce similar increases in strength with differing degrees of discomfort. *Muscle Nerve* 56, 797–803. doi: 10.1002/mus.25537

Gale, C. R., Martyn, C. N., Cooper, C., and Sayer, A. A. (2007). Grip strength, body composition, and mortality. *Int. J. Epidemiol.* 36, 228–235. doi: 10.1093/ije/dyl224

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., et al. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med. Sci. Sports Exerc.* 43, 1334–1359. doi: 10.1249/MSS.0b013e318213fefb

Grgic, J., Schoenfeld, B. J., Davies, T. B., Lazinica, B., Krieger, J. W., and Pedisic, Z. (2018). Effect of resistance training frequency on gains in muscular strength: A systematic review and Meta-analysis. *Sports Med.* 48, 1207–1220. doi: 10.1007/s40279-018-0872-x

Haff, G. G., and Triplett, N. T. (2015). "Essentials of strength training and conditioning 4th edition," in *Human Kinetics*. Champaign, Illinois.

Halperin, I., and Emanuel, A. (2020). Rating of perceived effort: methodological concerns and future directions. *Sports Med.* 50, 679–687. doi: 10.1007/s40279-019-01229-z

Hoare, E., Stavreski, B., Jennings, G., and Kingwell, B. (2017). Exploring motivation and barriers to physical activity among active and inactive Australian adults. *Sports (Basel)* 5. doi: 10.3390/sports5030047

Hurley, K. S., Flippin, K. J., Blom, L. C., Bolin, J. E., Hoover, D. L., and Judge, L. W. (2018). Practices, perceived benefits, and barriers to resistance training Among women enrolled in college. *Int. J. Exerc. Sci.* 11, 226–238.

Iversen, V. M., Norum, M., Schoenfeld, B. J., and Fimland, M. S. (2021). No time to lift? Designing time-efficient training programs for strength and hypertrophy: a narrative review. *Sports Med.* 51, 2079–2095. doi: 10.1007/s40279-021-01490-1

Jurca, R., et al. (2004). Associations of muscle strength and fitness with metabolic syndrome in men. *Med. Sci. Sports Exerc.* 36, 1301–1307. doi: 10.1249/01.MSS.0000135780.88930.A9

Maia, M. F., Willardson, J. M., Paz, G. A., and Miranda, H. (2014). Effects of different rest intervals between antagonist paired sets on repetition performance and muscle activation. *J. Strength Cond. Res.* 28, 2529–2535. doi: 10.1519/JSC.0000000000000451

Paz, G. A., Robbins, D. W., de Oliveira, C. G., Bottaro, M., and Miranda, H. (2017). Volume load and neuromuscular fatigue during an acute bout of agonist-antagonist paired-set vs traditional-set training. *J. Strength Cond. Res.* 31, 2777–2784. doi: 10.1519/JSC.0000000000001059

Ribeiro, A. S., Dos Santos, E. D., Nunes, J. P., and Schoenfeld, B. J. (2019). Acute effects of different training loads on affective responses in resistance-trained men. *Int. J. Sports Med.* 40, 850–855. doi: 10.1055/a-0997-6680

Schoenfeld, B. J., Ogborn, D., and Krieger, J. W. (2017). Dose-response relationship between weekly resistance training volume and increases in muscle mass: a systematic review and meta-analysis. *J. Sports Sci.* 35, 1073–1082. doi: 10.1080/02640414.2016.1210197

Schwartz, H., Emanuel, A., Rozen Samukas, I. I., and Halperin, I. (2021). Exploring the acute affective responses to resistance training: a comparison of the predetermined and the estimated repetitions to failure approaches. *PLoS One* 16:e0256231. doi: 10.1371/journal.pone.0256231

Steele, J., Fisher, J., McKinnon, S., and McKinnon, P. (2016). Differentiation between perceived effort and discomfort during resistance training in older adults: reliability of trainee ratings of effort and discomfort, and reliability and validity of trainer ratings of trainee effort. *J. Trainol.* 6, 1–8. doi: 10.17338/trainology.6.1_1

Weakley, J. J. S., Till, K., Read, D. B., Phibbs, P. J., Roe, G., Darrall-Jones, J., et al. (2020). The effects of superset configuration on kinetic, kinematic, and perceived exertion in the barbell bench press. *J. Strength Cond. Res.* 34, 65–72. doi: 10.1519/JSC.0000000000002179

Weakley, J. J. S., Till, K., Read, D. B., Roe, G. A. B., Darrall-Jones, J., Phibbs, P. J., et al. (2017). The effects of traditional, superset, and tri-set resistance training structures on perceived intensity and physiological responses. *Eur. J. Appl. Physiol.* 117, 1877–1889. doi: 10.1007/s00421-017-3680-3

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., and Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol. Sport Exerc.* 9, 231–245. doi: 10.1016/j.psychsport.2007.04.002

Williams, M. A., Haskell, W. L., Ades, P. A., Amsterdam, E. A., Bittner, V., Franklin, B. A., et al. (2007). Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation* 116, 572–584. doi: 10.1161/CIRCULATIONAHA.107.185214

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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MINI REVIEW
published: 11 July 2022
doi: 10.3389/fpsyg.2022.901272

Urges to Move and Other Motivation States for Physical Activity in Clinical and Healthy Populations: A Scoping Review Protocol

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 21 March 2022
Accepted: 13 May 2022
Published: 11 July 2022

Citation:
Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Boullosa D, Janata P, Koo BB, McKee PC, Casper R, Budnick CJ, Gilson TA, Blakemore RL, Filgueiras A, Williamson SL, SantaBarbara N, Barker JL, Bueno FA, Heldring J and Ash GI (2022) Urges to Move and Other Motivation States for Physical Activity in Clinical and Healthy Populations: A Scoping Review Protocol. Front. Psychol. 13:901272. doi: 10.3389/fpsyg.2022.901272

Motivation for bodily movement, physical activity and exercise varies from moment to moment. These motivation states may be “affectively-charged,” ranging from instances of lower tension (e.g., desires, wants) to higher tension (e.g., cravings and urges). Currently, it is not known how often these states have been investigated in clinical populations (e.g., eating disorders, exercise dependence/addiction, Restless Legs Syndrome, diabetes, obesity) vs. healthy populations (e.g., in studies of motor control; groove in music psychology). The objective of this scoping review protocol is to quantify the literature on motivation states, to determine what topical areas are represented in investigations of clinical and healthy populations, and to discover pertinent details, such as instrumentation, terminology, theories, and conceptual models, correlates and mechanisms of action. Iterative searches of scholarly databases will take place to determine which combination of search terms (e.g., “motivation states” and “physical activity”; “desire to be physically active,” etc.) captures the greatest number of relevant results. Studies will be included if motivation states for movement (e.g., desires, urges) are specifically measured or addressed. Studies will be excluded if referring to motivation as a trait. A charting data form was developed to scan all relevant documents for later data extraction. The primary outcome is simply the extent of the literature on the topic. Results will be stratified by population/condition. This scoping review will unify a diverse literature, which may result in the creation of unique models or paradigms that can be utilized to better understand motivation for bodily movement and exercise.

Keywords: physical activity, motivation, motivation states, affectively charged motivation states, urge for movement, Restless Legs Syndrome, movement disorder, groove

BACKGROUND

Physical activity, exercise and bodily movement in general, is the product of multi-factorial processes involving cognitive, emotional and motivational factors (Rhodes et al., 2019), the latter of which has become of central interest. Importantly, one's motivation for movement likely varies in the moment (Gernigon et al., 2004), just as one's actual movement behavior varies moment-by-moment (Sartini et al., 2015). Therefore, there has been a call to understand how motivation for physical activity works *in the moment* or *right now* (Stults-Kolehmainen et al., 2020, 2021). Transient desires to move or rest are driven by at least 3 main factors: (1) the preceding set of behaviors; the desire to move increases (i.e., craving rises) with prolonged sitting and decreases with excessive activity, as recently demonstrated by Stults-Kolehmainen and colleagues (Stults-Kolehmainen et al., 2021) and others (Taylor et al., 2022), (2) anticipations of pleasure and displeasure (hedonic motivation) (Williams and Evans, 2014; Rhodes et al., 2019; Williams et al., 2019) and (3) the innate drive to move (and rest) (Feige, 1976; Rowland, 1998; Garland et al., 2011), similar to thirst or hunger, that is reinforcing in and of itself. In other words, movement relieves the tension that builds with inactivity, just as drinking relieves the tension that builds with thirst. This conceptual understanding of motivation states stands in contrast to the more conventional understanding of motivation as relating to traits (e.g., "I am not a motivated person") or enduring characteristics of a person (e.g., "Recently, I have felt ready to exercise"), goals (e.g., "I want to gain 5 pounds of muscle this Spring"), motives (e.g., "fitness"), affective and emotional antecedents (e.g., "When I feel stressed I am not physically active"), or anticipated outcomes (e.g., "Exercise makes me feel good") (Roberts and Treasure, 2012; Stults-Kolehmainen et al., 2013; Williams and Evans, 2014; Naves-Bittencourt et al., 2015; Hoare et al., 2017; Williams et al., 2019).

Kavanagh et al. (2005) first described the concept of *affectively-charged motivation states* (ACMS) – desires, wants, cravings and urges – as applied to health behaviors (e.g., smoking, drinking, eating snacks, etc.). Ostensibly, desires and wants are weaker motivation states while urges and cravings feel stronger, may last longer and likely have a greater impact on behavior (Desmurget and Sirigu, 2012). Importantly, ACMS involve a physiological component - physical tension felt as discomfort, which relates directly to the craving and drives behavior to relieve these states. This is clearly relevant for movement and sedentary behaviors as both excessive sitting (i.e., deprivation of activity) and excessive physical activity (i.e., deprivation of rest), whether at work or during leisure time, prompt physical discomfort and fatigue, instigating action (Stults-Kolehmainen et al., 2020, 2021). However, concerning the notion of groove (i.e., the ability of music to motivate muscular movement), the driver is typically a positive tension, such as the motivation to go dance to a funk band on a Friday night as a form of relaxation and for enjoyment (Janata et al., 2012, 2018). In both cases, the tension is internal or endogenous to the person. However, there are also exogenous drivers of desire, such as environmental conditions (e.g., lighting, images, temperature, and nature). Another example is music that is high in groove, which induces an urge to move, irrespective of a person's initial states. In other words, absent hearing the music, the motivation or urge to move might be low (no endogenous driver), but upon experiencing a sensory signal with particular qualities, the urge to move and possible movement increases substantially. Overall, one may think of motivation states as actionable feelings - perceptual lodestones that attract attention to a behavior to move or be sedentary. Recent models of behavior demonstrate how these processes may influence cognition (Hofmann and Van Dillen, 2012) or be highly automatic, incorporating affective valuations that vary by the endogenous or exogenous nature of the stimulus (Brand and Ekkekakis, 2018).

Our group recently described how motivation states apply to movement and sedentary behaviors as proposed in the WANT model (Wants and Aversions for Neuromuscular Tasks) (Stults-Kolehmainen et al., 2020). This framework describes how desires and urges to move and rest reflect a range of motivational inputs that can result in ACMS being complementary or act in opposition. In other words, they are loosely coupled and operate asymmetrically in response to various situations and a range of stimuli, from stressful circumstances to meditation. For instance, if studying late at night, one might have a strong urge to rest or sleep, and to remain seated while studying, but one also may feel antsy, and have a strong desire to get up and move. The model also specifies aversions, dread or "diswants" for movement and rest, as in the case of abstaining from movement to avoid pain (Barke et al., 2012; Glaviano et al., 2019). While the model has yet to be rigorously tested, a significant leap forward was made when an instrument was created to facilitate measurement of motivation states for movement and sedentarism – the CRAVE scale (Cravings for Rest and Volitional Energy Expenditure) (Stults-Kolehmainen et al., 2021). The CRAVE is a 13-item survey gauging ACMS with two versions: "right now" and "over the past week".

The WANT model and subsequent work (Stults-Kolehmainen et al., 2020, 2021) ties together a previously unconnected literature describing urges to move and other affectively-charged motivation states (ACMS). Most of the literature is predominately clinical, describing ACMS when such states are (a) highly problematic and (b) central to the disorder, such as in exercise dependence/addiction (Hausenblas and Downs, 2002), Restless Legs Syndrome (Khan et al., 2017), bipolar disorders/mania (Cheniaux et al., 2014), akathisia (i.e., intense urges to move related to drug use) (Iqbal et al., 2007), tic disorder (Sanger et al., 2010) anorexia nervosa/starvation (Keys et al., 1950; Casper, 2020; Casper et al., 2020), and terminal restlessness and agitation (Brajtman, 2003). Over 50% of individuals with eating disorders report excessive movement behaviors (Fietz et al., 2014). However, ACMS have also been extensively described in motor control, in music psychology (i.e., "groove") (Janata et al., 2012, 2018; Madison and Sioros, 2014) and, more recently, exercise psychology (Ponnada et al., 2022; Taylor et al., 2022). Examining this diverse literature, it appears that the desire or urge to move is influenced by a number of stable characteristics (e.g., age) (Stults-Kolehmainen et al., 2021), food, drugs (e.g., caffeine, amphetamines) (Kaplan et al., 1997; Ferreira et al., 2006), and medicine (e.g., haloperidol, lurasidone and vilazodone) (Tripathi et al., 2019), and situational and environmental factors (Levitin et al., 2018).

Unfortunately, there are no systematic reviews spanning the topic apart from one conceptual development paper and narrative review that did not aim to comprehensively address the topic (Stults-Kolehmainen et al., 2020). Consequently, unknowns include: (a) the scope of the literature describing ACMS, (b) the relevance of apparently-related concepts (e.g., restlessness; appetence; psychomotor retardation), and (c) the frequency of ACMS in pertinent literatures, such as diabetes (Warren et al., 2003) and depressive disorders (Buyukdura et al., 2011). One major hindrance is a lack of an appropriate search strategy to find relevant studies in scientific databases. For instance, using "motivation", "state*" and "physical activity" returns ∼2,750 results in Web of Science. Using "movement" instead of PA results in 1,603. This investigation aims at rectifying these issues with a scoping review.

REVIEW OBJECTIVES

A scoping review is employed to determine the research landscape for a topic, particularly when no previous reviews have been conducted, the literature is highly heterogeneous and quantitative methods are difficult to utilize (Munn et al., 2018). This review aims to systematically and comprehensively investigate motivation states for human bodily movement, physical activity and exercise - examining all types of relevant research from all accessible sources. This will follow the PCC model for scoping reviews (population, concepts, and context) (Tricco et al., 2018; Peters et al., 2020).

The objectives of the review are to answer the following research questions:

1) What is the extent of the evidence for motivation states for movement (e.g., desires or urges to move) in both clinical and healthy populations - *in any context*?
2) What topical areas are represented in studies incorporating clinical and/or healthy populations?
3) What nomenclature is ascribed to motivation states in these content areas (e.g., "urges," "wants" or "desires" to move; restlessness; appetence; "drive for activity") (Casper, 2018)?
4) What descriptors are used within the current scientific literature to describe such states (e.g., the valence and/or magnitude of the feelings)?
5) What is the theoretical basis of such states, and do conceptual models exist to explain related phenomena?
6) Is a systematic review or meta-analysis feasible at this juncture (Stults-Kolehmainen and Sinha, 2014)?

This scoping review also aims to discover other pertinent details, such as how frequently these states are measured with validated instruments, correlates and mechanisms of action that may be common to or differentiate motivation states in various populations. The data analysis will be mostly descriptive, per the guidelines from Peters (Peters et al., 2020). The current approach will include quantitative and qualitative research on various motivation states (i.e., wants, desires, urges, and cravings) for physical activity.

INCLUSION CRITERIA

Types of Participants Included

Following the PCC model (Tricco et al., 2018; Peters et al., 2020), the inclusion criteria will involve all human populations in any context, as motivation states are theoretically relevant and observable across the spectrum of human experience. Included will be healthy individuals (of all ages), as well as clinical populations, such as individuals with movement disorders (e.g. Parkinson's disease, tic disorder, etc.), exercise-related disorders (i.e., dependence/addiction), etc. We may also consider animal models (Ferreira et al., 2006), such as in primates and rodents, but will not incorporate inquiries on robotics/AI.

Types of Research Included

As this is a scoping review, all types of research will be considered, including "gray literature." There is no specific intervention of interest. It is anticipated that the database search will find a wide variety of different investigations, including retrospective and prospective observational, case-control, cohort, cross-sectional, pilot and case studies. We expect a limited number of randomized controlled trials, cross-over trials and non-randomized intervention studies. Review articles will be considered. Only full-text, English and Portuguese-language articles will be included.

METHODS

Outcomes

The scoping review seeks to answer six main questions (see above). The primary outcome is simply the extent of the literature on the topic of motivation states. **Supplementary Material 1** provides information for how each question will be addressed. Wherever possible, information will be presented quantitatively (e.g., frequency, percentages). Note that we will not specifically search for ACMS for sedentary behavior in this review but will note any findings when doing the search for movement ACMS.

Procedures

A three-stage process will be utilized to identify published research articles relevant to the research question. First, an initial, limited search of databases will take place in PubMED, Scopus, Web of Science, and APA PsycInfo. This will look solely within titles and index terms in order to determine feasibility of anticipated search terms, whether new ones may be needed, and which combination of search terms (e.g., "motivation states" and "physical activity"; "urge to move"; "desire to be physically active") captures the greatest number of relevant results. Then, a full search will be conducted searching within titles, abstracts, keywords and index terms using optimal search terms from step one. Third, if new relevant key terms are identified during the previous stages, the authors will conduct new searches. Two investigators will independently scan the literature. Studies will be included if motivation states for movement (i.e., desires, wants, cravings, and urges) are specifically addressed. Studies will be excluded based on criteria below. A charting data extraction form (see **Supplementary Material 2**) was developed for data extraction of all relevant documents, according to guidelines set forth by Peters (Peters et al., 2020). Guidelines for reporting evidence will be followed as outlined by the PRISMA-ScR Checklist (Tricco et al., 2018).

Search Strategy

A unique database search strategy will be employed because conducting searches with simple terms, such as ("wants" AND "physical activity") results in returns >10,000 articles. Instead, we will use a novel combination of the following search terms in four steps.

Step 1 (basic search): ("Motiv* state*") AND (Exercise OR "Physical activity").

Step 2 (advanced search) will use *infinitive phrases* (e.g., urge to exercise), such as: (Urge* OR Desire* OR Crav* OR Want* OR Drive*) AND (To OR For OR "To be") AND (Move* OR Exercise OR "Physical* activ*").

Step 3 (using *nominalization of verb*): The last combinations of search words will be: (Move* OR Exercise OR "Physical* activ*") AND (Urge OR Desire OR Craving). "Want" will not be used in this third step (e.g., "movement want" is highly unlikely to be relevant). Note that in PubMed the strategy will be modified because the use of the * symbol is not possible.

Step 4 (known pertinent terms): Five terms known to overlap with the phenomenon of motivation states will be searched: restlessness (mental/physical), hyperkinesia, psychomotor retardation, appetence and "drive for activity" (Keys et al., 1950).

The authors decided not to use the key term "feel like" (e.g., feel like moving or exercising) in the current searches as used elsewhere (Ponnada et al., 2022).

An initial search utilizing this novel search strategy narrows down the returns in Web of Science to 921 (from 2,750). Furthermore, a quick inspection reveals that the returns are more relevant. Abstracts will be expelled from results if they fall into one of 11 exclusion criteria categories, such as motivation being described as a trait, not in the English or Portuguese languages, if describing secondary desires for movement (i.e., whereas movement is motivated by other wants), etc. See **Supplementary Material 3**. In the event of a disagreement between two reviewers, a third independent and impartial reviewer will resolve the discordance. The databases will be searched from inception to June, 2022.

Data Extraction

Articles that meet the inclusion criteria for the scoping review will have data extracted using a charting data extraction form (**Supplementary Material 2**) based on JBI's System for the Unified Management, Assessment and Review of Information (SUMARI) (Aromataris and Munn, 2020). We anticipate a high number of relevant returns (i.e., >500 articles), mostly due to the inclusion of studies on the topic of Restless Legs Syndrome (RLS). Consequently, studies relating to RLS will be limited to the last 5 years. An author who is an expert on the topic of RLS (BK) will guide selection of studies from before that period.

Some data will be extracted by just a single independent reviewer who will search for information, such as (1) field of study, (2) clinical or non-clinical, (3) condition or pathology, (4) study design, etc. See **Supplementary Material 4** for a full list. Two reviewers will search deeper in each article to search for constructs relevant to the study of motivation states and the WANT model (Stults-Kolehmainen et al., 2020), such as (5) "physical activity," "exercise" or bodily movement, (6) theoretical orientation, (7) description of motivation states, etc. See **Supplementary Material 4** for all 19 variables of interest. A third independent and impartial reviewer will resolve any disagreement between the two reviewers. If required, corresponding authors of articles will be contacted for additional information. The charting data extraction form will be piloted with 10–20 studies in the early stages to ensure extraction can proceed smoothly.

Data Synthesis

In scoping reviews, no formal data analysis is undertaken (Tricco et al., 2018; Peters et al., 2020); therefore, this review does not aim at statistically pooling quantitative components (as in a meta-analysis). Consequently, data synthesis will follow the procedures utilized in Peters (Peters et al., 2020). This largely involves a basic descriptive analysis (e.g., frequency of topic of interest, expressed as percentages), which will be mapped in tables and graphics. We will also stratify findings by clinical vs. non-clinical populations as aggregating across conditions is problematic, and there may be biases inherent to specific pathologies. Specific literatures that feature prominently, such as Restless Legs Syndrome, will receive further stratification (Khan et al., 2017). At this time, it is not clear if a critical appraisal (i.e., assessment of methodological quality) of individually selected studies will occur, as outlined in the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (Tricco et al., 2018), as such an analysis is not required for scoping reviews, but may be helpful. In scoping reviews, critical appraisal often takes the place of evaluation of risk of bias, and such a decision will be made once the data is extracted. Findings will be presented in narrative form, and will include tables and figures to aid in data presentation.

DISCUSSION

This scoping review is the first of its kind to both unify and quantify the literature on motivation states for bodily movement, physical activity and exercise to determine the state of knowledge in this area for both healthy and clinical populations. A previous narrative review and conceptual analysis from Stults-Kolehmainen et al. (2020) had the aim of developing the concept of motivation states for movement as a relevant and valid construct. However, it did not attempt to quantify the material or make systematic comparisons between relevant topical areas. This scoping review protocol has been designed to fill that gap - to understand the research landscape surrounding this concept as opposed to a specific question regarding it.

The proposed search protocol has strengths, but also some delimiters (i.e., designed limits) and limitations. To capture the greatest extent of relevant literature, we selected novel search terms crafted from infinitive phrases (e.g., "urge to move," "desire to be physically active"). These were not exhaustive, however. For instance, we did not include phrases, such as "have to move" or "need for exercise" and related terms. We chose this approach to keep the search manageable. On a different note, some topical areas are likely to dominate returns. For instance, Restless Legs Syndrome is defined by the urge to move (Khan et al., 2017), and we anticipate that this single condition will account for >50% of studies we will find. Limited resources will prevent extracting data from this entire topical area. However, one author on this team who is an expert in this area (BK) will examine the studies from 2014 and before to select ones that may be most pertinent. Also, we have topical experts in the areas of music psychology/groove (PJ), motor control and movement disorders (RB), psychiatric disorders (AF), exercise training studies (DB), exercise and sports psychology (TG, JBB), eating disorders (RC) and muscle dysmorphia (NS). It is our hope that this expertise will allow us to safeguard against any serious omissions while highlighting the most pertinent research.

There are potential downstream implications for this proposed review; both healthy and clinical populations may ultimately receive some benefit from a better understanding of the literature on motivation states for movement. First, apart from RLS, many conditions related to diminished or excessive motivation states for movement have received relatively little recognition (e.g., akathisia) or have recently emerged in the literature (e.g., muscle dysmorphia); therefore, these disorders are poorly understood (Iqbal et al., 2007; SantaBarbara et al., 2020). This scoping review may mitigate this shortcoming by helping to describe the time course, subjective experience, pathology and important mechanisms of action (e.g., neurotransmitters, hormones, psychological antecedents). For instance, there is substantial amount of MRI data that exists on the topic of groove (Janata et al., 2012, 2018), which may be applicable in other literatures, such as sport and exercise psychology. It is also reasonable to expect that this review will result in progress in evaluation, including measurement tools and scoring, interpretation, and clinical cut-offs – as well as protocols for longitudinal assessment so patterns of ACMS may be delineated. Following these advances, the role of motivation states in conditions like burnout and depression may become clearer – helping us to understand if ACMS are useful for identifying these disorders (Sandmeir et al., 2021). These hypokinetic conditions, together with the hyperkinetic disorders previously mentioned, may fall along a common motor or movement urge dysfunction spectrum (MUDS) that includes normal sensations. The collection of these might even typify a new classification of conditions - the movement urge dysfunction disorders (MUDD), which has some verisimilitude but is still speculative.

A more pressing need is to better understand the relationship between motivation states and movement behaviors, including physical activity, exercise and displacement behaviors (Mohiyeddini et al., 2015). Part of the problem is the lack of explicit explanatory models and theories that attempt to describe this association and how it operates across a variety of conditions and contexts. However, some research paradigms exist in related topical areas (Berridge, 2012) and by examining these it may be possible to develop testable and practical models which facilitate better understanding of the current topic. Behavioral models may then be expanded to incorporate important linkages to other health behaviors (e.g., sleep), emotions and cognitions, as well as describe triggers (e.g., images, music) and other antecedents, barriers (e.g., fatigue, boredom), and additional factors (Williams et al., 2019). Down the road, there may be development of algorithms to predict when ACMS result in conscious and unconscious movement choices - as well as predictive models that could be used to identify the best targets for behavioral modification efforts. These may be employed as either treatments to diminish bothersome urges and cravings or interventions and technologies to enhance tepid wants and desires. It is imaginable that all of these advances would be more feasible with the results from this scoping review.

Proximal outcomes of this review would likely vary by the research focus or perspective (e.g., clinical, public health or athletic performance), condition and/or population and the primary objectives related with each. For instance, in the case of muscle dysmorphia, exercise addiction or eating disorders, potential deliverables could be educational modules for those affected and for psychiatric professionals to raise awareness of risks. Taking this a step further, this review may lead to the creation of interventions to reduce engagement in problematic behavior and mitigate harm caused by unhealthy movement patterns. Interventions might incorporate aspects of mindfulness, such as meditation or exercises that are inherently mindful, such as martial arts (Naves-Bittencourt et al., 2015; Stults-Kolehmainen et al., 2015). For those at risk of disease and not physically active, this review may help to map out just-in-time adaptive interventions, perhaps mobile-based, to identify ideal time points for action, which we call "CRAVE moments", and to modify the environment or lead people to environments that both: (a) produce desire-promoting stimuli for movement and (b) reveal opportunities to act on these desires (Hardeman et al., 2019; Ash et al., 2021; Liu et al., 2021). Additionally, understanding the factors that drive a person to engage in exercise, their natural experience of movement desires, and their activity preferences, could lead to flexible and personalized exercise prescriptions, leading to better exercise initiation, engagement, further adherence and less drop out. Given that exercise is considered a "polypill" for health enhancement (Fiuza-Luces et al., 2013), such initiatives should be a priority. Please, refer to Stults-Kolehmainen et al. (2020) for a more extensive discussion of implications and applications of motivation states research. By being able to understand underlying motivation for movement, particularly as it occurs within the moment, this review can collectively enable both individuals and practitioners to exercise greater volitional control over when and how movement occurs.

AUTHOR'S NOTE

This review was registered on August 11, 2020 with PROSPERO (National Institute for Health Research) here: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020191459.

AUTHOR CONTRIBUTIONS

The main conceptual ideas were developed by MS-K, MB, DB, JBB, PJ, GA, and PM, in that order. The manuscript was primarily written by MS-K, MB, and DB, in that order. Testing of the protocol search strategies was carried out by MS-K and PM. The study protocol and manuscript text were further evaluated and refined by authors JBB, GA, BK, RC, CB, TG, RB, AF, SW, NS, JLB, FB, and JH, in that order. All authors provided critical feedback, reviewed, and approved the final manuscript.

FUNDING

GA was supported by a fellowship from the Office of Academic Affiliations at the United States Veterans Health Administration, a Robert E. Leet and Clara Guthrie Patterson Trust Mentored Research Award, Bank of America, N.A., Trustee, and American Heart Association Grant #852679 (GA, 2021–2024).

ACKNOWLEDGMENTS

We would like to thank Melissa Eden, Ph.D. (Hanover College, IN) for her valuable assistance in refining aspects of the search strategy. Khristdman Cavalcanti helped with technical aspects of the study. Sunao Akashi Slayton, PharmD BCOP (Smilow Cancer Hospital, Yale – New Haven Hospital, CT) evaluated clinical information and provided nomenclature.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.901272/full#supplementary-material

REFERENCES

Aromataris, E., and Munn, Z. (2020). *JBI Manual for Evidence Synthesis.* Available online at: https://synthesismanual.jbi.global (accessed December 1, 2021).

Ash, G. I., Nally, L. M., Stults-Kolehmainen, M. A., De-Los-Santos, M., Jeon, S., Brandt, C., et al. (2021). Personalized big data for type 1 diabetes exercise support. *SportRxiv[Preprint].* doi: 10.31236/osf.io/34vdc

Barke, A., Baudewig, J., Schmidt-Samoa, C., Dechent, P., and Kröner-Herwig, B. (2012). Neural correlates of fear of movement in high and low fear-avoidant chronic low back pain patients: an event-related fMRI study. *Pain* 153, 540–552. doi: 10.1016/j.pain.2011.11.012

Berridge, K. C. (2012). From prediction error to incentive salience: mesolimbic computation of reward motivation. *Eur. J. Neurosci.* 35, 1124–1143. doi: 10.1111/j.1460-9568.2012.07990.x

Brajtman, S. (2003). The impact on the family of terminal restlessness and its management. *Palliat Med.* 17, 454–460. doi: 10.1191/0960327103pm779oa

Brand, R., and Ekkekakis, P. (2018). Affective–Reflective theory of physical inactivity and exercise. *Ger. J. Exerc. Sport Res.* 48, 48–58. doi: 10.1007/s12662-017-0477-9

Buyukdura, J. S., McClintock, S. M., and Croarkin, P. E. (2011). Psychomotor retardation in depression: biological underpinnings, measurement, and treatment. *Prog. Neuropsychopharmacol. Biol. Psychiatry.* 35, 395–409. doi: 10.1016/j.pnpbp.2010.10.019

Casper, R. (2018). Not the function of eating, but spontaneous activity and energy expenditure, reflected in "Restlessness" and a "Drive for Activity" appear to be dysregulated in anorexia nervosa: treatment Implications. *Front. Psychol.* 9, 2303. doi: 10.3389/fpsyg.2018.02303

Casper, R. (2020). Might starvation-induced adaptations in muscle mass, muscle morphology and muscle function contribute to the increased urge for movement and to spontaneous physical activity in anorexia nervosa? *Nutrients* 12, 2060 doi: 10.3390/nu12072060

Casper, R., Voderholzer, U., Naab, S., and Schlegl, S. (2020). Increased urge for movement, physical and mental restlessness, fundamental symptoms of restricting anorexia nervosa? *Brain Behav.* 10, e01556. doi: 10.1002/brb3.1556

Cheniaux, E., Filgueiras, A., Silva Rde, A., Silveira, L. A., Nunes, A. L., and Landeira-Fernandez, J. (2014). Increased energy/activity, not mood changes, is the core feature of mania. *J. Affect. Disord.* 152–154, 256–261. doi: 10.1016/j.jad.2013.09.021

Desmurget, M., and Sirigu, A. (2012). Conscious motor intention emerges in the inferior parietal lobule. *Curr. Opin. Neurobiol.* 22, 1004–1011. doi: 10.1016/j.conb.2012.06.006

Feige, K. (1976). Wesen und problematik der sportmotivation. *Sportunterricht* 5, 4–7.

Ferreira, A., Lamarque, S., Boyer, P., Perez-Diaz, F., Jouvent, R., and Cohen-Salmon, C. (2006). Spontaneous appetence for wheel-running: a model of dependency on physical activity in rat. *Eur. Psychiat.* 21, 580–588. doi: 10.1016/j.eurpsy.2005.02.003

Fietz, M., Touyz, S., and Hay, P. (2014). A risk profile of compulsive exercise in adolescents with an eating disorder: a systematic review. *Adv. Eat. Disord.* 2, 241–263. doi: 10.1080/21662630.2014.894470

Fiuza-Luces, C., Garatachea, N., Berger, N. A., and Lucia, A. (2013). Exercise is the real polypill. *Physiology* 28, 330–358. doi: 10.1152/physiol.00019.2013

Garland, T. Jr., Schutz, H., Chappell, M. A., Keeney, B. K., Meek, T. H., Copes, L. E., et al. (2011). The biological control of voluntary exercise, spontaneous physical activity and daily energy expenditure in relation to obesity: human and rodent perspectives. *J. Exp. Biol.* 214, 206–29. doi: 10.1242/jeb.048397

Gernigon, C., D'arripe-Longueville, F., Delignières, D., and Ninot, G. (2004). A dynamical systems perspective on goal involvement states in sport. *J. Sport Exerc. Psychol.* 26, 572. doi: 10.1123/jsep.26.4.572

Glaviano, N. R., Baellow, A., and Saliba, S. (2019). Elevated fear avoidance affects lower extremity strength and squatting kinematics in women with patellofemoral pain. *Athl. Train. Andamp Sports Health Care.* 11, 192–200. doi: 10.3928/19425864-20181029-01

Hardeman, W., Houghton, J., Lane, K., Jones, A., Naughton, F. (2019). A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity. *Int. J. Behav. Nutr. Phys. Act.* 16, 31. doi: 10.1186/s12966-019-0792-7

Hausenblas, H. A., and Downs, D. S. (2002). Exercise dependence: a systematic review. *Psychol. Sport Exerc.* 3, 89–123. doi: 10.1016/S1469-0292(00)00015-7

Hoare, E., Stavreski, B., Jennings, G. L., and Kingwell, B. A. (2017). Exploring motivation and barriers to physical activity among active and inactive Australian adults. *Sports* 5, 47. doi: 10.3390/sports5030047

Hofmann, W., and Van Dillen, L. (2012). Desire: the new hot spot in self-control research. *Curr. Dir. Psychol. Sci.* 21, 317–322. doi: 10.1177/0963721412453587

Iqbal, N., Lambert, T., and Masand, P. (2007). Akathisia: problem of history or concern of today. *CNS Spectr.* 12, 1–13. doi: 10.1017/S1092852900026201

Janata, P., Peterson, J., Ngan, C., Keum, B., Whiteside, H., and Ran, S. (2018). Psychological and musical factors underlying engagement with unfamiliar music. *Music Percept.* 36, 175–200. doi: 10.1525/mp.2018.36.2.175

Janata, P., Tomic, S. T., and Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *J. Exp. Psycholo. Gen.* 141, 54–75. doi: 10.1037/a0024208

Kaplan, G. B., Greenblatt, D. J., Ehrenberg, B. L., Goddard, J. E., Cotreau, M. M., Harmatz, J. S., et al. (1997). Dose-dependent pharmacokinetics and psychomotor effects of caffeine in humans. *J. Clin. Pharmacol.* 37, 693–703. doi: 10.1002/j.1552-4604.1997.tb04356.x

Kavanagh, D. J., Andrade, J., and May, J. (2005). Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol. Rev.* 112, 446–467. doi: 10.1037/0033-295X.112.2.446

Keys, A., Brožek, J., Henschel, A., Mickelsen, O., Taylor, H. L., Simonson, E., et al. (1950). *The Biology of Human Starvation, Vol. II*. Mineapolis, MN: University of Minnesota Press. doi: 10.5749/j.ctv9b2tqv

Khan, F. H., Ahlberg, C. D., Chow, C. A., Shah, D. R., and Koo, B. B. (2017). Iron, dopamine, genetics, and hormones in the pathophysiology of restless legs syndrome. *J. Neurol.* 264, 1634–1641. doi: 10.1007/s00415-017-8431-1

Levitin, D. J., Grahn, J. A., and London, J. (2018). The psychology of music: rhythm and Movement. *Annu. Rev. Psychol.* 69, 51–75. doi: 10.1146/annurev-psych-122216-011740

Liu, J., Spakowicz, D. J., Ash, G. I., Hoyd, R., Ahluwalia, R., Zhang, A., et al. (2021). Bayesian structural time series for biomedical sensor data: a flexible modeling framework for evaluating interventions. *PLOS Comput. Biol.* 17, e1009303. doi: 10.1371/journal.pcbi.1009303

Madison, G., and Sioros, G. (2014). What musicians do to induce the sensation of groove in simple and complex melodies, and how listeners perceive it. *Front. Psychol.* 5, 894. doi: 10.3389/fpsyg.2014.00894

Mohiyeddini, C., Bauer, S., and Semple, S. (2015). Neuroticism and stress: the role of displacement behavior. *Anxiety Stress Coping,* 28, 391–407. doi: 10.1080/10615806.2014.1000878

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., and Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med. Res. Methodol.* 18, 143. doi: 10.1186/s12874-018-0611-x

Naves-Bittencourt, W., Mendonáa-de-Sousa, A., Stults-Kolehmainen, M. A., Fontes, E. B., Cûrdova, C. U., Demarzo, M. M. P., et al. (2015). Martial arts: mindful exercise to combat stress. *Eur. J. Hum. Mov.* 34, 34–51.

Peters, M. D. J., Marnie, C., Tricco, A. C., Pollock, D., Munn, Z., Alexander, L., et al. (2020). Updated methodological guidance for the conduct of scoping reviews. *JBI Evid. Synth.* 18, 2119–2126. doi: 10.11124/JBIES-20-00167

Ponnada, A., Wang, S., Chu, D., Do, B., Dunton, G., and Intille, S. (2022). Intensive longitudinal data collection using microinteraction ecological momentary assessment: pilot and preliminary results. *JMIR Form Res.* 6, e32772. doi: 10.2196/32772

Rhodes, R. E., McEwan, D., and Rebar, A. L. (2019). Theories of physical activity behaviour change: a history and synthesis of approaches. *Psychol. Sport. Exerc.* 42, 100–109. doi: 10.1016/j.psychsport.2018.11.010

Roberts, G. C., and Treasure, D. (2012). *Advances in Motivation in Sport and Exercise*. Champaign, IL: Human Kinetics. doi: 10.5040/9781492595182

Rowland, T. W. (1998). The biological basis of physical activity. *Med. Sci. Sports Exerc.* 30, 392–399. doi: 10.1097/00005768-199803000-00009

Sandmeir, A., Schoenherr, D., Altmann, U., Nikendei, C., Schauenburg, H., and Dinger, U. (2021). Depression severity is related to less gross body movement: a motion energy analysis. *Psychopathology* 54, 106–112. doi: 10.1159/000512959

Sanger, T. D., Chen, D., Fehlings, D. L., Hallett, M., Lang, A. E., Mink, J. W., et al. (2010). Definition and classification of hyperkinetic movements in childhood. *Mov. Disord.* 25, 1538–1549. doi: 10.1002/mds.23088

SantaBarbara, N. J., Nosrat, S., Whitworth, J. W., and Ciccolo, J. T. (2020). Acute psychological effects of resistance exercise in men with symptoms of muscle dysmorphia: a pilot study. *J. Strength Cond. Res.* doi: 10.1519/JSC.0000000000003615

Sartini, C., Wannamethee, S. G., Iliffe, S., Morris, R. W., Ash, S., Lennon, L., et al. (2015). Diurnal patterns of objectively measured physical activity and sedentary behaviour in older men. *BMC Public Health* 15, 609–609. doi: 10.1186/s12889-015-1976-y

Stults-Kolehmainen, M., Malcolm, L., Diloreto, J., Gunnet-Shoval, K., and Rathbun, E. (2015). Psychological interventions for weight management: a primer for the allied health professional. *ACSM Health Fitness J.* 19, 16–22. doi: 10.1249/FIT.0000000000000150

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J., Gilson, T., Ash, G., McKee, P., et al. (2020). Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front. Psychol.* 11, 568390. doi: 10.3389/fpsyg.2020.568390

Stults-Kolehmainen, M. A., Blacutt, M., Fogelman, N., Gilson, T. A., Stanforth, P. R., Divin, A. L., et al. (2021). Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front. Psychol.* 12, 568286. doi: 10.3389/fpsyg.2021.568286

Stults-Kolehmainen, M. A., Ciccolo, J. T., Bartholomew, J. B., Seifert, J., and Portman, R. S. (2013). Age and gender-related changes in exercise motivation among highly active individuals. *Athletic Insight.* 5, 45–63.

Stults-Kolehmainen, M. A., and Sinha, R. (2014). The effects of stress on physical activity and exercise. *Sports Med.* 44, 81–121. doi: 10.1007/s40279-013-0090-5

Taylor, I. M., Whiteley, S., and Ferguson, R. A. (2022). Disturbance of desire-goal motivational dynamics during different exercise intensity domains. *Scand. J. Med. Sci. Sports,* 32, 798–806. doi: 10.1111/sms.14129

Tricco, A. C., Lillie, E., Zarin, W., O'brien, K. K., Colquhoun, H., Levac, D., et al. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann. Intern. Med.* 169, 467–473. doi: 10.7326/M18-0850

Tripathi, R., Reich, S. G., Scorr, L., Guardiani, E., and Factor, S. A. (2019). Lurasidone-induced tardive syndrome. *Mov. Disord. Clin. Pract.* 6, 601–604. doi: 10.1002/mdc3.12812

Warren, R. E., Deary, I. J., and Frier, B. M. (2003). The symptoms of hyperglycaemia in people with insulin-treated diabetes: classification using principal components analysis. *Diabetes Metab. Res. Rev.* 19, 408–414. doi: 10.1002/dmrr.396

Williams, D. M., and Evans, D. R. (2014). Current emotion research in health behavior science. *Emotion Review.* 6, 277–287. doi: 10.1177/1754073914523052

Williams, D. M., Rhodes, R. E., and Conner, M. T. (2019). Conceptualizing and intervening on affective determinants of health behaviour. *Psychol. Health.* 34, 1267–1281. doi: 10.1080/08870446.2019.1675659

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REVIEW
published: 25 July 2022
doi: 10.3389/fpsyg.2022.885274

Restlessness and an Increased Urge to Move (Drive for Activity) in Anorexia Nervosa May Strengthen Personal Motivation to Maintain Caloric Restriction and May Augment Body Awareness and Proprioception: A Lesson From Leptin Administration in Anorexia Nervosa

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OPEN ACCESS

Edited by:
Genevieve Fridlund Dunton, University of Southern California, United States

Reviewed by:
Sinika Timme, University of Potsdam, Germany
Alexandre A. da Silva, University of Mississippi Medical Center, United States

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *27 February 2022*
Accepted: *20 June 2022*
Published: *25 July 2022*

Citation:
Casper RC (2022) Restlessness and an Increased Urge to Move (Drive for Activity) in Anorexia Nervosa May Strengthen Personal Motivation to Maintain Caloric Restriction and May Augment Body Awareness and Proprioception: A Lesson From Leptin Administration in Anorexia Nervosa. Front. Psychol. 13:885274. doi: 10.3389/fpsyg.2022.885274

Anorexia nervosa (AN), a disorder of voluntary food restriction leading to severe weight loss in female adolescents, remains an enigma. In particular, the appropriation of the starved thin body into the self-concept in AN is a process insufficiently researched and still poorly understood. Healthy humans undergoing starvation experience a slowing of movements and avoid voluntary exercise. By contrast, AN tends to be not infrequently associated with voluntary, sometimes excessive and/or compulsive exercise. Such deliberate exercise, not reported in starvation, seems to be facilitated by an increased urge for movement and physical restlessness, particular to AN. The increased urge to move would reflect spontaneous daily activity, the energy expended for everything that is not sleeping, eating, or voluntary exercise. Our hypothesis is that the starvation-induced increased urge to move and restlessness may promote the development of AN. Reversal of the fasting state, by either high caloric food or by leptin administration, would be expected to reduce restlessness and the increased urge to move along with improvement in other symptoms in AN. This review explores the idea that such restless activation in AN, in itself and through accelerating body weight loss, might foster the integration of the starving body into the self-concept by (1) enhancing the person's sense of self-control and sense of achievement and (2) through invigorating proprioception and through intensifying the perception of the changing body shape. (3) Tentative evidence from studies piloting leptin administration in chronic AN patients which support this hypothesis is reviewed. The findings show that short term administration of high doses of leptin indeed mitigated depressive feelings, inner tension, intrusive thoughts of food, and the increased urge to be physically active, easing the way to recovery, yet had little influence on the patients' personal commitment to remain at a low weight. Full recovery then requires resolution of the individuals' personal unresolved psychological conflicts through psychotherapy and frequently needs specialized treatment approaches to address psychiatric co-morbidities. AN might be conceptualized as a hereditary form of starvation resistance, facilitated by the effects of starvation on fitness allowing for an exceptionally intense personal commitment to perpetuate food restriction.

Keywords: restlessness, drive for activity, leptin, body image, self-image, anorexia nervosa

INTRODUCTION

AN, a disorder of long-term voluntary restricted food intake resulting in recalcitrant pathological weight loss in female adolescents is considered a psycho-biological disorder. Predominantly, AN is, but must not be, a psychiatric disorder. Emotional disturbances and psychiatric co-morbidity vary from person to person and young patients often recover after short-term treatment and lead a normal life (Halvorsen and Heyerdahl, 2006). Psychological features include subjective personal risk factors such as a critical self-image (Steinhausen and Vollrath, 1993) along with distinct personality features depending on the subtype (Casper et al., 1980). In the restricting form, shyness, a sense of being overlooked and not appreciated, may lead to the appropriation of caloric restriction as a way to prove themselves worthy. A family history of psychiatric illness bears on illness severity (Strober et al., 1990).

On the biological side, the significant physiological adjustments to caloric deficiency of virtually every organ system, including the brain, none different from those in simple starvation, have not revealed particular mechanisms which could account for the excessive weight loss observed in AN. On the genetic side, anorexia nervosa (AN) is considered a complex, multifactorial heritable condition with possibly rare and common genetic and environmental determinants (Cui et al., 2013; Boyle et al., 2017; Lee et al., 2019; Watson et al., 2019). Heritability estimates in twin studies consistently support a genetic basis in anorexia nervosa, with the range of 48–74% (Holland et al., 1984; Klump et al., 2001; Kortegaard et al., 2001) Recently, the Anorexia Nervosa Genetics Initiative was launched to increase sample sizes for pinpointing genetic risk factors (Yilmaz et al., 2020).

At this point in research, therefore, reliance on clinically observable signs remains a useful heuristic method to identify aberrant processes in AN.

The name "anorexia nervosa' translates to 'nervous lack of appetite." AN patients, however, endorse hunger feelings (Garfinkel, 1974) and they report conscious and intrusive thoughts and dreams of food (Casper and Davis, 1977), similar to undernourished individuals.

Surprisingly, individuals with AN tend to divulge few signs of distress, asserting that they do not feel changed and therefore oppose treatment for underweight. Adolescent girls with AN tend to live seemingly normal lives, they rise early in the morning, refreshed without complaints of fatigue to engage in their daily activities (Casper, 1990). They continue to function in school, even at their lowest body weight, when cachexia undermines muscle strength (Casper, 2020). This ability to pursue an active, seemingly normal, life, as much as a not infrequent tendency toward excessive physical activity in AN has been commented on since its earliest descriptions (Gull, 1874; Janet, 1903; Bell, 1985), contrasting it to the lassitude and weariness associated with advanced simple starvation (Guetzkow and Bowman, 1946; Keys et al., 1950).

We outline here experimental and clinical evidence that healthy humans undergoing starvation experience a slowing of movements and tend to avoid voluntary exercise. We then present studies that found that total energy expenditure and physical activity levels in AN did not differ from normal controls. Next, we address the data that physical restlessness and an increased urge for movement at low weights are common symptoms in AN. Bearing in mind that AN is a human and personally motivated disorder, we will examine the contribution of a critical self-image and lack of self-esteem to the pursuit of caloric restriction. We suggest that, not only the weight loss, but also the possibly energizing physical sensations (Casper, 2020) associated with an increased urge for movement and physical restlessness may strengthen the patient's self-control and subjective vitality (Ryan and Frederick, 1997), as well as motivation to use dieting to improve the self-image. Next, we discuss experimental studies examining the body image in AN and argue that restless body sensations might contribute to the tendency to overestimate body dimensions and to the selective deficient subjective awareness of the wasted body. Lastly, if the increased urge to move constitutes an integral component of the anorectic symptom constellation, then a reversal of the negative metabolic balance would be expected to reduce the increased urge to move. We will review pilot studies showing that leptin (Metreleptin) administration in high doses signaling a high energy status was associated with significant symptomatic improvement in critical, but not all symptoms in chronic AN patients (Milos et al., 2020; Antel et al., 2021).

DIMINISHED PHYSICAL ACTIVITY AND INERTIA IN EXPERIMENTAL STARVATION CONTRAST WITH REPORTS OF AN INCREASED URGE FOR MOVEMENT AND PHYSICAL RESTLESSNESS AT THE LOWEST WEIGHT IN AN

Physical activity levels in humans are complex and influenced by psychological, social, multiple genetic and environmental factors (Carlsson et al., 2006; Stubbe et al., 2006;

Duncan et al., 2008). Physical activity forms part of the energy balance feedback system that homeo-statically controls body weight. Supporting data have come from overfeeding studies in healthy subjects which showed compensatory changes increasing spontaneous activity or non-exercise activity thermogenesis (NEAT) to dissipate excess energy (Leibel et al., 1995) and from underfeeding studies (Guetzkow and Bowman, 1946; Keys et al., 1950; Consolazio et al., 1967; Heilbronn et al., 2006; Martin et al., 2007; Redman et al., 2008) which show a reduction in physical activity levels to conserve energy.

Fasting or energy depletion triggers compensatory metabolic, endocrine and behavioral responses to limit energy expenditure and stimulate food intake. Measurements in experimental starvation invariably show a "slowing of voluntary movements and curtailment of self-initiated spontaneous activity" and reduced 'drive for activity' measurements. After achieving a 25% weight loss in 6 months, 94% of the men reported "unsteadiness and uncertainty of footing while walking" (Keys et al., 1950). The men also experienced anxious-depressive symptoms, social withdrawal, obsession with food, and sexual dysfunction. In retrospect, these men remembered leaden lethargy and exhaustion (Eckert et al., 2018), all feeling states not reported by AN patients at a greater weight loss. These findings raise the question whether the persistence of normal physical activity in AN is atypical and possibly pathognomonic.

In the past two decades, numerous investigators have addressed primarily the phenomenon of excessive exercise and compulsion to exercise in AN (Davis et al., 1994; Holtkamp et al., 2004; Davis and Kaptein, 2006; El Ghoch et al., 2013; Keyes et al., 2015; Rizk et al., 2015; Schlegl et al., 2018).

Many investigators have attributed the pursuit of exercise in AN to psychological mechanisms suggesting that physical activity is a deliberate attempt to "burn" calories in pursuit of thinness (Davis et al., 1997) or that physical activity is a way of coping with negative affect (Davis et al., 1999; Holtkamp et al., 2006). These factors undoubtedly play a role both in AN and in healthy dieting individuals, yet, exercise normally is not associated with pathological weight loss.

Aside from the tendency to excessive exercise, spontaneous or non-exercise activity, such as standing and walking in AN has been found comparable to non-exercise activity in healthy subjects (Keyes et al., 2015). Assessments through questionnaires and through recordings of wearable devices found that daily activity levels measured as steps or as body movements did not distinguish AN patients from healthy age- and sex-matched controls (Bouten et al., 1996; Van Marken Lichtenbelt et al., 1997; Harris et al., 2008; Hechler et al., 2008; Bratland-Sanda et al., 2010a,b; Hofmann et al., 2014; Keyes et al., 2015).

Another rather neglected observable symptom in AN patients is their greater restlessness, confirmed by Belak et al. (2017) in leg movements of seated AN patients, wearing a shoe-based monitor. Clinical ratings, of adolescent AN patients (Holtkamp et al., 2006) found an inverse relationship between subjective and accelerator measures of physical activity as well as self-rated motor and inner restlessness with plasma leptin levels, pointing to the degree of undernutrition as a crucial factor for maintaining motor activity.

The ability to remain "normally" active in AN raises the question to what extent intrinsic AN-specific biological mechanisms triggered by caloric restriction contribute to physical restlessness? Are AN patients spared the full impact of the low energy levels and fatigue typically reported in starvation states?

In an exploratory study, 83 adolescent patients with acute AN, restricting type, were systematically asked on hospital admission, whether or not they experienced an increased urge to move and physical restlessness at their lowest weight (Casper et al., 2020). Nearly 90% of patients reported either, an increased urge for movement and/or physical restlessness. Two thirds endorsed feeling mentally alert and being able to concentrate. The increased urge to move emerged as a physiological variable related to the degree of weight loss, to feeling active, to movement despite feeling tired, and to exercise intensity and compulsive exercise before hospital admission, but was not related to the severity of the eating disorder or the severity of psychiatric symptoms. Unexpectedly, the increased urge to move coexisted side by side with high levels of physical fatigue and low energy, typical signs of starvation. Physical restlessness, endorsed by 82%, was associated with the degree of weight loss and anxiety levels. Mental restlessness emerged as a disease severity variable indicating widespread strong correlations with signs of starvation and with eating disorder and psychiatric symptomatology. It would be interesting to explore further, how much AN patients are aware of an increased urge to move.

We can infer from these observations that adolescent patients with acute AN at their greatest weight loss feel compelled to move and physically restless despite experiencing fatigue and feeling tired. Since such restless activation has not been reported to exist at the lowest weight in experimental starvation, it might point to dysfunctional physiological adaptations in energy regulating pathways in AN (Casper, 2016).

> *Hypothesis 1*: The ability of AN patients to maintain an active life style and regular daily activities may not only strengthen the resolve to limit food intake, but also impart a sense of self-control and a sense of achievement and thereby improve self-esteem.

AN is a personalized disorder. Patients seize control over the starvation process for self-improvement, to the extent that a reciprocal relationship develops between successful weight control and positive emotions. Personal satisfaction over weight loss is also an important reward in normal dieters. In a healthy person, unlike in AN, the physical discomforts and fatigue of chronic undernutrition and the presence of other rewarding activities, maintaining friendships, enjoying music, taking dance classes, seem to undermine the single-minded pursuit of continuing a fasting regime.

The concepts of self-image and self-esteem refer to a person's basic evaluative feelings about her/himself. Low self-esteem has been described in a number of studies as a characteristic attribute of AN patients (Silverstone, 1990) and has been found to be a predictor of co-morbidity (Karatzias et al., 2010) and poor treatment outcome (Halvorsen and Heyerdahl, 2006). The tendency for self-reliance in teenage AN patients, only 17% experienced friendships as positive (Datta et al., 2021), heightens the personal impact of this solipsistic interaction.

An American and a European study (Casper et al., 1981; Steinhausen and Vollrath, 1993) found nearly identical responses on the Offer self- image questionnaire reflecting a poor self-image and body image in teenage hospitalized AN patients compared to age-matched healthy controls. Findings that the self-concept and body image improve with treatment, but remain unchanged without treatment, highlight the importance of self/body concept disturbances as a core psychological problem in severe AN. This link between self-esteem and body esteem in women with eating disorders, was not found in healthy women (Mendelson et al., 2002). Indeed, internal rewards, the wish for a sense of self-respect, power and independence raising self-esteem have been described to play a decisive role in the fixation on weight loss in AN (Garner and Bemis, 1982; Serpell et al., 1999; Brockmeyer et al., 2013).

We suggest that the propelling force of the increased urge to move and physical restlessness in AN which counteracts the physical discomforts of chronic undernutrition tends to strengthen the resolve of AN patients to extend caloric restriction. Successful reduction in food intake and the ensuing weight loss then enhance the sense of personal efficiency and self-control. Nonetheless, the gradually increasing fear of weight gain in AN betrays some awareness that patients are cognizant that caloric restriction is a spurious and in the long-term dangerous solution to low self-esteem.

> *Hypothesis 2*: The increased urge to move and physical restlessness enhance proprioception and body awareness and thereby counterbalance awareness of the emaciated body and may contribute to body size overestimation in AN.

Altered body perceptions in AN have been the subject of comment and investigation ever since Lasègue (1873) quoted an AN patient as saying, – in response to the comment that her amount of nutrition could not support a toddler,- that she is "neither changed nor thinner, moreover she has never refused a task or suffered fatigue." This patient's response, insisting on sameness despite her emaciation, reflects the contentment with the body's form in AN. In other words, it reflects an insufficient awareness of the increasingly lean body contours in AN (Bruch, 1962). In experimental or simple starvation body image disturbances have not been reported (Keys et al., 1950; Eckert et al., 2018).

We propose here that physical restlessness and an increased urge to move during weight loss not only convey a welcome sense of lightness, but also intensify proprioception and in this way integrate the bodily changes in AN. This hypothesis is supported by findings in healthy populations where movement through physical exercise contributes to positive body-and self-evaluations (Guinn et al., 1997; Hausenblas and Fallon, 2006; Korn et al., 2013). Movement in exercise also modifies proprioception (Bhanpuri et al., 2013; Proske and Allen, 2019). Proprioception is defined here as the sensation of body position and movement, the senses of tension and effort and the sense of balance through mechanically sensitive receptors, with muscle spindles as the principal proprioceptors (Longo and Haggard, 2010; Proske and Gandevia, 2012). Conversely, frequent complaints of unpleasant feelings of heaviness voiced by AN patients on weight gain are associated with a reduction in restlessness and the desire to move (Holtkamp et al., 2003a).

The concept of central representations of the body was first described by Head and Holmes (1911) based on selective loss of sensations after injury. Schilder (1950) used the term "body image" as a construct of the mental representation of the body encompassing imaginative, perceptual, affective and cognitive components. Schilder (1950) views the body image as "the picture of our own body as we perceive it and as we imagine it. It does not merely consist of perception in the common sense, but it comprises elements of representations and thoughts."

The precise definition of the body image and the body schema and whether they ought to be considered different entities are still under discussion (Tuthill and Azim, 2018). Whereas the body image as the cognitive representation of the body is thought of as being based on stored life experience and to underlie perceptual judgment, the body schema is believed to depend on ongoing proprioceptive input and concerned with body movement. The term 'body image' as used in AN research is rarely defined, but seems to be an amalgamation of both definitions. Distortions in the topographical map of the body or in sensorimotor perceptions have not been reported in AN (Phillipou et al., 2016).

The DSM V diagnostic criteria for AN (DSM-V, 2013) define body image changes functionally, as "a disturbance in the way in which one's body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or persistent lack of recognition of the seriousness of the current low body weight."

It is important to remember that not all AN patients initially aim to lose weight. In particular, younger patients often renounce food or reduce their food intake due to maturity fears or out of moral or ethical concerns. Nonetheless, ultimately, AN patients fulfill all three DSM-V criteria for body image changes.

Some researchers (Gutierrez and Carrera, 2020) have argued that body image disturbances in AN are merely epiphenomena of the low body weight. This proposition may be correct, but it is difficult to ascertain, considering the absence of such extreme low weights without disease.

Deficient recognition of the bony contours and lack of alarm over the implications and risks associated with extreme fasting and emaciation are core symptoms which distinguish AN from weight loss for other reasons. A case illustrates this lack of awareness. The only patient ever to seek treatment on her own in our program was a 20-year old young woman, who called, sounding panic-stricken. She described how that very morning a rear view mirror had by chance projected skeletal shoulders which she thought to belong to another person standing behind her. Frightened, she turned around and realized she had seen her own back. At that moment she realized for the first time the extent of her emaciation.

The patient immediately placed the call for a consultation, agreed to hospitalization, cooperated in treatment and fully recovered.

This awareness deficit of the extent of the emaciation in AN seems to be partial to the life-endangering consequences of the low body weight. Risks to health and life from energy deficiency are kept out of awareness or minimized. Unless asked, patients do not mention physical discomfort from constipation or from feeling constantly cold. Surprisingly, awareness of the desired thinness seems to be intact. Excessive thinness is acknowledged through behavior, such as buying size 2 clothes, displaying the bony body in scant clothing in the summer, or the habit of secret mirror gazing and admiring the emaciated body in private.

Numerous PET studies have, so far unsuccessfully, attempted to localize a central defect in body image representations in AN. They report altered structures and networks linked to measures of starvation (Lankenau et al., 1985; Krieg et al., 1989; Favaro et al., 2012; Via et al., 2014) in line with early reports of significant macroscopic brain changes in AN (Enzmann and Lane, 1977), all changes reversible with weight recovery. Normative comparisons do not exist, because healthy normal weight individuals do not suffer the extreme weight loss of AN patients.

The first criterion of DSM V (DSM-V, 2013) "disturbance in the way in which one's body weight or shape is experienced "as well as disturbances in estimating body part boundaries have been supported by empirical findings. A number of studies (Slade and Russell, 1973; Crisp and Kalucy, 1974; Garner et al., 1976; Casper et al., 1979; Touyz et al., 1984; Sachdev et al., 2008; Guardia et al., 2012; Verbe et al., 2021) confirm varying and selective degrees of body size overestimation in AN, in particular for the waist, chest and body depth by 14–30%. Their specificity remains uncertain, because the studies found similar degrees of body size overestimation in healthy age-matched women, indicating fluidity in the assessment of body size. In AN, importantly, the degree of body size overestimation was found to be associated with illness severity, with lack of recognition of the seriousness of the illness, the amount of weight loss, and prognosis and treatment response (Casper et al., 1979). The more accurate the body size estimate, the better the long-term outcome. Thus, body size overestimation, albeit quite common in contemporary healthy females, appears to be a marker of illness severity in AN.

Incomplete consciousness of the bodily changes with severe weight loss and body size overestimation likely contributes to the fear of weight gain which paradoxically gets stronger with increasing weight loss. Alternately, treatment leading to a significant weight increase lessens this fear of weight gain (Calugi et al., 2018; **Figure 1**).

> *Hypothesis 3*: As a component of the starvation-induced anorectic symptom complex associated with hypoleptinemia, the increased urge to move ought to improve along with other symptoms in AN through treatment with leptin (Metreleptin) which produces a high energy metabolic condition.

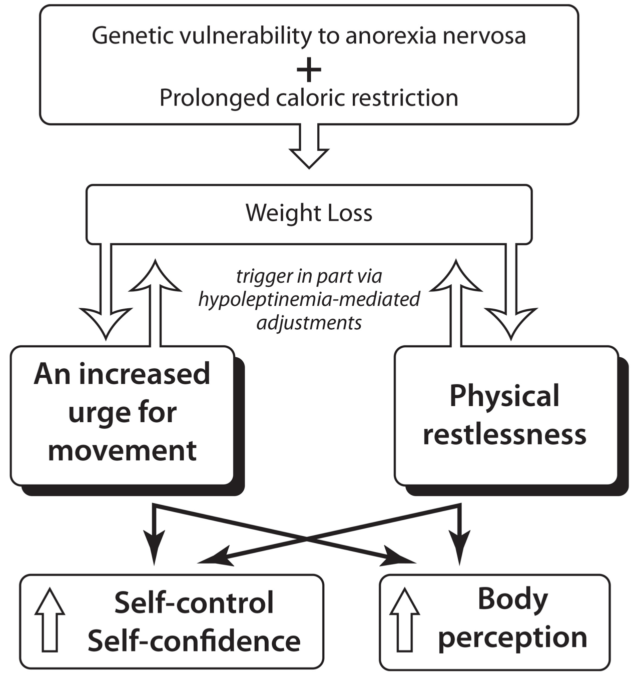

FIGURE 1 | Hypothesis: An increased urge for movement and physical restlessness in Anorexia Nervosa might foster the integration of the starved thin body into the self-concept through enhancing the person's sense of self-control and might through intensifying body perception influence body size estimation.

Leptin is a regulatory hormone secreted into the bloodstream by white adipose tissue. Leptin belongs to the family of class 1A cytokine receptors in brain and the periphery to regulate energy balance, neuroendocrine function, immune function and various metabolic pathways, including growth hormone signaling, insulin sensitivity, and lipogenesis (Salbe et al., 1997; Allison and Myers, 2014). Leptin is also expressed in a variety of other tissues, including the placenta, ovaries, mammary epithelium, bone marrow, and lymphoid tissues (Margetic et al., 2002).

Leptin binds to leptin receptors located throughout the central nervous system and peripheral tissues (Mantzoros et al., 2011), including skeletal muscle (Guerra et al., 2007). Prolactin releasing peptide containing neurons sensitive to leptin in the dorsomedial hypothalamic nucleus seem to mediate thermogenesis and increase energy expenditure (Dodd et al., 2014).

Leptin is a sensor for the adaptation to starvation and signals a state of nutrient deficiency and fat loss. Levels of leptin are directly proportional to adipose tissues and decrease with undernutrition (Blum et al., 1997). The leptin regulatory system is profoundly affected by the metabolism of starvation in AN (Ahima et al., 1996; Hebebrand et al., 1997; Chan et al., 2003; Mars et al., 2006).

The decrease in leptin levels during fasting mediates the suppression of reproductive, thyroid, and growth hormones and the elevation in glucocorticoid levels, in addition to stimulating food intake and limiting energy expenditure (Ahima et al., 1996, 2000).

Transport of leptin to the brain is reduced by fasting (Kastin et al., 2000). In a genome-wide meta-analysis, Kilpeläinen (2016) uncovered several loci associated with circulating leptin levels and Peters et al. (2021) recently reported a correlation between a genetic predisposition to low leptin levels and risk for AN in females.

Depending on the degree and severity of the caloric deficit and weight loss, leptin falls to very low, sometimes undetectable levels in AN (Grinspoon et al., 1996; Hebebrand et al., 1997) and increases significantly with weight gain (Eckert et al., 1998). In fact, leptin plasma levels below 2 μg/l have been found to have high specificity and high sensitivity for acute AN (Focker et al., 2011). Mantzoros et al. (1997) report a significantly higher CSF to plasma leptin ratio in AN patients compared to healthy controls. Leptin plasma levels have been found to be negatively associated with excessive physical activity in acute, but not in recovered, AN patients (Hebebrand et al., 2003; Holtkamp et al., 2003b; Ehrlich et al., 2009).

Regarding leptin parameters in normal populations, light, but not moderate and vigorous, physical activity assessed by accelerometer for 4 weeks were associated with the Q223R polymorphism in the leptin receptor gene of female, but not male, Japanese adults, suggesting a genetic influence on spontaneous physical activity (Murakami et al., 2014). Leptin receptor variants have also been associated with habitual physical activity assessed by self-report in European-derived volunteers (Walsh et al., 2012) and polymorphisms in the dopamine D2 receptor gene have been linked to physical activity levels among white women (Simonen et al., 2003). Considering the regression to prepubertal status in AN, correlations between plasma leptin concentrations with total energy expenditure and physical activity in five-year old children and 8-year-old healthy girls with steps measured by pedometer, respectively, are noteworthy findings (Salbe et al., 1997; Romon et al., 2004). In healthy adolescent girls vigorous physical activity measured by accelerometer over 7 days, increasing the energy expenditure, was negatively associated with leptin concentrations (Jiménez-Pavón et al., 2012). In male soldiers serum leptin decreased to a third of normal levels along with energy deficiency induced by 4 weeks of strenuous military training (Gomez-Merino et al., 2002). Similarly, exercise addiction in young men was found associated with lower plasma leptin levels (Lichtenstein et al., 2015).

In rodents, deletion of the leptin receptor in dopamine neurons induced anxiety like behavior (Liu et al., 2011), while intraperitoneal injection of leptin increased exploration and social behaviors (Liu et al., 2010). Systemic leptin treatment produced antidepressant effects *via* limbic structures (Lu et al., 2006).

The metabolic effects of systemic leptin administration have been tested in congenital leptin deficiency states (Farooqi et al., 2001), lipodystrophy and dysfunction of the hypothalamic–pituitary-gonadal axis. Leptin receptor-expressing pericytes have been found to mediate vessel permeability and promote leptin brain uptake (Butiaeva et al., 2021). Low plasma leptin levels prompted Welt et al. (2004) to treat patients with hypothalamic amenorrhea due to underweight or strenuous exercise restoring ovulatory menstrual cycles in 3 of eight patients, without apparent adverse effects. Chou et al. (2011) conducted a randomized, placebo-controlled trial with human recombinant leptin for 36 weeks. Seven of 10 patients with hypothalamic amenorrhea receiving metreleptin therapy developed menstruation during the course of the study, and two of nine subjects on placebo developed menstruation. In strenuously exercising lean young women with hypothalamic amenorrhea, metreleptin treatment over 1–2 years increased bone mineral density and content in the lumbar spine in the presence of moderate improvement in other endocrine and metabolic parameters (Sienkiewicz et al., 2011).

In response to the long suffering of chronic AN patients and in view of the reported safety profile of Metreleptin, Hebebrand and co-workers (Milos et al., 2020; Antel et al., 2021) designed a pilot study to administer short-term subcutaneous Metreleptin to four patients with severe chronic AN. The daily doses were higher than those in hypothalamic amenorrhea, but given for much shorter periods, between 7 and 22 days, raising leptin plasma concentrations from an extreme low to high levels. Within 24 to 48 h, self-and observer reports documented rapid improvement in an ensemble of AN symptoms: depressed mood, urge for activity, inner tension, repetitive thought of food in ¾ patients (Milos et al., 2020, Antel et al., 2021). The symptom reduction suggests wide-ranging central effects of leptin (Chan et al., 2003; Chan and Mantzoros, 2005). Metreleptin administration which produced high leptin plasma levels within 2 to 7 h, was also associated with greater insight into the condition, greater sociability and in a 16 year old male patient produced normalization of hypogonadotropic hypogonadism. Restlessness was reduced, patients were able to nap and sit still for longer periods. Cessation of leptin administration led to reemergence of symptoms after 5–8 days. Despite reporting "a more realistic assessment of body shape and weight" (Milos et al., 2020), the patients' personal investment in maintaining a low weight showed modest changes and required long-term skilled psychological treatment to encourage weight recovery (Hebebrand et al., 2021). These observations provide tentative support that an acute reversal of the negative metabolic balance through very high peripheral and central circulating leptin levels which are associated with endocrine changes (Rosenbaum et al., 2002; Antel et al., 2021) swiftly, albeit partly, mitigate the anorectic symptom constellation including the maladaptive urge for movement and physical restlessness in AN (**Figure 2**).

CONCLUSION

There is agreement that the etiology of AN involves a complex interplay between polygenic risk variants and specific environmental triggers, principally prolonged caloric restriction.

Taking up Nurse's (2021) admonition that" biology must generate ideas as well as data," we provide here reasonable evidence for the proposition that in individuals genetically

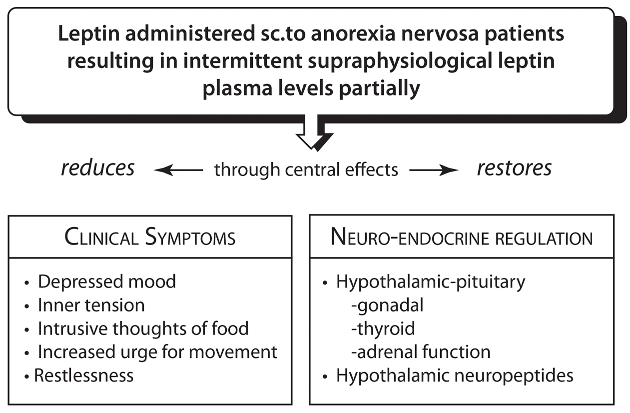

FIGURE 2 | Reversal of hypoleptinemia-mediated adjustments to prolonged severe caloric restriction in anorexia nervosa by Metreleptin (Ahima et al., 1996; Rosenbaum et al., 2002; Welt et al., 2004; Lu et al., 2006; Mantzoros et al., 2011; Licinio et al., 2014; Wang et al., 2015; Chrysafi et al., 2020; Milos et al., 2020; Antel et al., 2021).

vulnerable to AN, restlessness and an increased urge for movement triggered by the negative metabolic balance, and varying in intensity, may directly through forestalling the full impact of starvation and indirectly through movement effects promote the personal decision to continue caloric restriction and hence have a bearing in the development of AN. As AN develops, such "restless activation" not only counteracts the fatigue and lower energy level of the starvation state, but also accelerates weight loss and thereby strengthens personal resolve and the sense of control. Through heightening proprioception, physical restlessness and an increased urge to move might contribute to appropriating the reduced body contours into the self-concept and contribute to neglecting the life-endangering consequences of the severe loss of body weight. High circulating leptin concentrations signaling a positive metabolic balance associated with endocrine changes remarkably swiftly improve several anorectic symptoms, including the physical restlessness and the increased urge to move. AN might be conceptualized as a hereditary form of starvation resistance, facilitated by the effects of starvation on fitness allowing for an exceptionally intense personal commitment to perpetuate food restriction. The suggested hypotheses are testable and could be integrated into the design of future double blind placebo-controlled studies of leptin administration as a therapeutic strategy in AN.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

REFERENCES

Ahima, R. S., Prabakaran, D., Mantzoros, C., Qu, D., Lowell, B., Maratos-Flier, E., et al. (1996). Role of leptin in the neuroendocrine response to fasting. *Nature* 382, 250–252. doi: 10.1038/382250a0

Ahima, R. S., Saper, C. B., Flier, J. S., and Elmquist, J. K. (2000). Leptin regulation of neuroendocrine systems. *Front. Neuroendocrinol.* 21:197. doi: 10.1006/frne.2000.0197

Allison, M. B., and Myers, M. G. Jr. (2014). 20 Years of leptin: connecting leptin signaling to biological function. *J. Endocrinol.* 223, T25–T35. doi: 10.1530/JOE-14-0404

Antel, J., Tan, S., Grabler, M., Ludwig, C., Lohkemper, D., Brandenburg, T., et al. (2021). Rapid amelioration of anorexia nervosa in a male adolescent during metreleptin treatment including recovery from hypogonadotropic hypogonadism. *Eur. Child Adolesc. Psychiatry* 3:7. doi: 10.1007/s00787-021-01778-7

Belak, L., Gianini, L., Klein, D. A., Sazonov, E., Keegan, K., Neustadt, E., et al. (2017). Measurement of fidgeting in patients with anorexia nervosa using a novel shoe-based monitor. *Eat. Behav.* 24, 45–48. doi: 10.1016/j.eatbeh.2016.11.005

Bell, R. (1985). *Holy Anorexia*, Chicago, The University of Chicago Press.

Bhanpuri, N. H., Okamura, A. M., and Bastian, A. J. (2013). Predictive modeling by the cerebellum improves proprioception. *J. Neurosci.* 33, 14301–14306. doi: 10.1523/JNEUROSCI.0784-13.2013

Blum, W. F., Englaro, P., Hanitsch, S., Juul, A., Hertel, N. T., Muller, J., et al. (1997). Plasma leptin levels in healthy children and adolescents: dependence on body mass index, body fat mass, gender, pubertal stage, and testosterone. *J. Clin. Endocrinol. Metab.* 82, 2904–2910. PMID: 9284717

Bouten, C. V., Van Marken Lichtenbelt, W. D., and Westerterp, K. R. (1996). Body mass index and daily physical activity in anorexia nervosa. *Med. Sci. Sports Exerc.* 28, 967–973. doi: 10.1097/00005768-199608000-00005

Boyle, E. A., Li, Y. I., and Pritchard, J. K. (2017). An expanded view of complex traits: From polygenic to Omnigenic. *Cell* 169, 1177–1186. doi: 10.1016/j.cell.2017.05.038

Bratland-Sanda, S., Sundgot-Borgen, J., Ro, O., Rosenvinge, J. H., Hoffart, A., and Martinsen, E. W. (2010a). "I'm not physically active - I only go for walks": physical activity in patients with longstanding eating disorders. *Int. J. Eat. Disord.* 43, 88–92. doi: 10.1002/eat.20753

Bratland-Sanda, S., Sundgot-Borgen, J., Ro, O., Rosenvinge, J. H., Hoffart, A., and Martinsen, E. W. (2010b). Physical activity and exercise dependence during inpatient treatment of longstanding eating disorders: an exploratory study of excessive and non-excessive exercisers. *Int. J. Eat. Disord.* 43, 266–273. doi: 10.1002/eat.20769

Brockmeyer, T., Holtforth, M. G., Bents, H., Kammerer, A., Herzog, W., and Friederich, H. C. (2013). The thinner the better: self-esteem and low body weight in anorexia nervosa. *Clin. Psychol. Psychother.* 20, 394–400. doi: 10.1002/cpp.1771

Bruch, H. (1962). Perceptual and conceptual disturbances in anorexia nervosa. *Psychosom. Med.* 24, 187–194. doi: 10.1097/00006842-196203000-00009

Butiaeva, L. I., Slutzki, T., Swick, H. E., and Bourguignon, C. (2021). Leptin receptor-expressing pericytes mediate access of hypothalamic feeding centers to circulating leptin. *Cell Metbol.* 33, 1433.e5–1448.e5. doi: 10.1016/j.cmet.2021.05.017

Calugi, S., El Ghoch, M., Conti, M., and Dalle Grave, R. (2018). Preoccupation with shape or weight, fear of weight gain, feeling fat and treatment outcomes in patients with anorexia nervosa: a longitudinal study. *Behav. Res. Ther.* 105, 63–68. doi: 10.1016/j.brat.2018.04.001

Carlsson, S., Andersson, T., Lichtenstein, P., Michaelsson, K., and Ahlbom, A. (2006). Genetic effects on physical activity: results from the Swedish twin registry. *Med. Sci. Sports Exerc.* 38, 1396–1401. doi: 10.1249/01.mss.0000228941.17034.c1

Casper, R. (1990). "The dilemma of homonymous symptoms for evaluating comorbidity between affective disorders and eating disorders," in *Comorbidity of Mood and Anxiety Disorders*. eds. J. Maser and C. Cloninger (Washington and London: American Psychiatric Press).

Casper, R. (2016). Restless activation and drive for activity in anorexia nervosa may reflect a disorder of energy homeostasis. *Int. J. Eat. Disord.* 49, 750–752. doi: 10.1002/eat.22575

Casper, R. (2020). Might starvation-induced adaptations in muscle mass, muscle morphology and muscle function contribute to the increased urge for movement and to spontaneous physical activity in Anorexia Nervosa? *Nutrients* 12:2060. doi: 10.3390/nu12072060

Casper, R., and Davis, J. (1977). On the course of anorexia nervosa. *Am. J. Psychiatry* 134, 974–978. PMID: 900307
Casper, R., Eckert, E., Halmi, K., Goldberg, S., and Davis, J. (1980). Bulimia: its incidence and clinical significance in patients with anorexia nervosa. *Arch. Gen. Psychiatry* 37, 1030–1035. doi: 10.1001/archpsyc.1980.01780220068007
Casper, R., Halmi, K., Goldberg, S., Eckert, E., and Davis, J. (1979). Disturbances in body image estimation as related to other characteristics and outcome measures in anorexia nervosa. *Br. J. Psychiatry* 134, 60–66. doi: 10.1192/bjp.134.1.60
Casper, R., Offer, D., and Ostrov, E. (1981). The self-image of adolescents with acute anorexia nervosa. *J. Pediatr.* 98, 656–661. doi: 10.1016/S0022-3476(81)80789-5
Casper, R. C., Voderholzer, U., Naab, S., and Schlegl, S. (2020). Increased urge for movement, physical and mental restlessness, fundamental symptoms of restricting anorexia nervosa? *Brain Behav.* 10:e01556. doi: 10.1002/brb3.1556
Chan, J. L., Heist, K., Depaoli, A. M., Veldhuis, J. D., and Mantzoros, C. S. (2003). The role of falling leptin levels in the neuroendocrine and metabolic adaptation to short-term starvation in healthy men. *J. Clin. Invest.* 111, 1409–1421. doi: 10.1172/JCI200317490
Chan, J. L., and Mantzoros, C. S. (2005). Role of leptin in energy-deprivation states: normal human physiology and clinical implications for hypothalamic amenorrhoea and anorexia nervosa. *Lancet* 366, 74–85. doi: 10.1016/S0140-6736(05)66830-4
Chou, S. H., Chamberland, J. P., Matarese, G., Gao, C., and Stefanakis, R. (2011). Leptin is an effective treatment for hypothalamic amenorrhea. *Proc. Natl. Acad. Sci. U. S. A.* 108, 6585–6590. doi: 10.1073/pnas.1015674108
Chrysafi, P., Perakakis, N., Farr, O. M., Stefanakis, K., Peradze, N., Sala-Vila, A., et al. (2020). Leptin alters energy intake and fat mass but not energy expenditure in lean subjects. *Nat. Commun.* 11:5145. doi: 10.1038/s41467-020-18885-9
Consolazio, C. F., Matoush, L. O., Johnson, H. L., Nelson, R. A., and Krzywicki, H. J. (1967). Metabolic aspects of acute starvation in normal humans (10 days). *Am. J. Clin. Nutr.* 20, 672–683. doi: 10.1093/ajcn/20.7.672
Crisp, A., and Kalucy, R. (1974). Aspects of the perceptual disorder in anorexia nervosa. *Br. J. Med. Psychol.* 47, 349–361. doi: 10.1111/j.2044-8341.1974.tb02300.x
Cui, H., Moore, J., Ashimi, S. S., Mason, B. L., Drawbridge, J. N., Han, S., et al. (2013). Eating disorder predisposition is associated with Esrra and Hdac4 mutations. *J. Clin. Invest.* 123, 4706–4713. doi: 10.1172/JCI71400
Datta, N., Foukal, M., Erwin, S., Hopkins, H., Tchanturia, K., and Zucker, N. (2021). A mixed-methods approach to conceptualizing friendships in anorexia nervosa. *PLoS One* 16:e0254110. doi: 10.1371/journal.pone.0254110
Davis, C., and Kaptein, S. (2006). Anorexia nervosa with excessive exercise: a phenotype with close links to obsessive-compulsive disorder. *Psychiatry Res.* 142, 209–217. doi: 10.1016/j.psychres.2005.11.006
Davis, C., Katzman, D. K., Kaptein, S., Kirsh, C., Brewer, H., Kalmbach, K., et al. (1997). The prevalence of high-level exercise in the eating disorders: etiological implications. *Compr. Psychiatry* 38, 321–326. doi: 10.1016/S0010-440X(97)90927-5
Davis, C., Katzman, D. K., and Kirsh, C. (1999). Compulsive physical activity in adolescents with anorexia nervosa: a psychobehavioral spiral of pathology. *J. Nerv. Ment. Dis.* 187, 336–342. doi: 10.1097/00005053-199906000-00002
Davis, C., Kennedy, S., Ravelski, E., and Dionne, M. (1994). The role of physical activity in the development and maintenance of eating disorders. *Psychol. Med.* 24, 957–967. doi: 10.1017/S0033291700029044
Dodd, G. T., Worth, A. A., Nunn, N., Korpal, A. K., Bechtold, D. A., Allison, M. B., et al. (2014). The thermogenic effect of leptin is dependent on a distinct population of prolactin-releasing peptide neurons in the dorsomedial hypothalamus. *Cell Metab.* 20, 639–649. doi: 10.1016/j.cmet.2014.07.022
DSM-V (2013). Diagnostic and statistical manual of mental disorders. *Am. Psych. Assoc.* 5:307.
Duncan, G. E., Goldberg, J., Noonan, C., Moudon, A. V., Hurvitz, P., and Buchwald, D. (2008). Unique environmental effects on physical activity participation: a twin study. *PLoS One* 3:e2019. doi: 10.1371/journal.pone.0002019
Eckert, E. D., Gottesman, I., Swigart, S. E., and Casper, R. C. (2018). A 57-year follow-up investigation and review of the Minnesota study on human starvation and its relevance to eating disorders. *Arch. Psychol.* 2, 1–19.
Eckert, E., Pomeroy, C., Raymond, N., Kohler, P., Thuras, P., and Bowers, C. (1998). Leptin in Anorexia Nervosa. *J. Clin. Endocrinol. Metab.* 83, 791–795. PMID: 9506729
Ehrlich, S., Burghardt, R., Schneider, N., Broecker-Preuss, M., Weiss, D., Merle, J. V., et al. (2009). The role of leptin and cortisol in hyperactivity in patients with acute and weight-recovered anorexia nervosa. *Prog. Neuro-Psychopharmacol. Biol. Psychiatry* 33, 658–662. doi: 10.1016/j.pnpbp.2009.03.007
El Ghoch, M., Calugi, S., Pellegrini, M., Milanese, C., Busacchi, M., Battistini, N. C., et al. (2013). Measured physical activity in anorexia nervosa: features and treatment outcome. *Int. J. Eat. Disord.* 46, 709–712. doi: 10.1002/eat.22140
Enzmann, D., and Lane, B. (1977). Cranial computed tomography findings in anorexia nervosa. *J. Comput. Assist. Tomogr.* 1, 410–414. doi: 10.1097/00004728-197710000-00005
Farooqi, I. S., Keogh, J. M., Kamath, S., Jones, S., Gibson, W. T., Trussell, R., et al. (2001). Partial leptin deficiency and human adiposity. *Nature* 414, 34–35. doi: 10.1038/35102112
Favaro, A., Santonastaso, P., Manara, R., Bosello, R., Bommarito, G., Tenconi, E., et al. (2012). Disruption of visuospatial and somatosensory functional connectivity in anorexia nervosa. *Biol. Psychiatry* 72, 864–870. doi: 10.1016/j.biopsych.2012.04.025
Focker, M., Timmesfeld, N., Scherag, S., Buhren, K., Langkamp, M., Dempfle, A., et al. (2011). Screening for anorexia nervosa via measurement of serum leptin levels. *J. Neural Transm. (Vienna)* 118, 571–578. doi: 10.1007/s00702-010-0551-z
Garfinkel, P. (1974). Perception of hunger and satiety in anorexia nervosa. *Psychol. Med.* 4, 309–315. doi: 10.1017/S0033291700042999
Garner, D. B., and Bemis, K. M. (1982). A cognitive-behavioral approach to anorexia nervosa. *Cogn. Ther. Res.* 6, 123–150. doi: 10.1007/BF01183887
Garner, D. M., Garfinkel, P. E., Stancer, H. C., and Moldofsky, H. (1976). Body image disturbances in anorexia nervosa and obesity. *Psychosom. Med.* 38, 327–336. doi: 10.1097/00006842-197609000-00005
Gomez-Merino, D., Chennaoui, M., Drogou, C., Bonneau, D., and Guezennec, C. Y. (2002). Decrease in serum leptin after prolonged physical activity in men. *Med. Sci. Sports Exerc.* 34, 1594–1599. doi: 10.1097/00005768-200210000-00010
Grinspoon, S., Gulick, T., Askari, H., Landt, M., Lee, K., Anderson, E., et al. (1996). Serum leptin levels in women with anorexia nervosa. *J. Clin. Endocrinol. Metab.* 81, 3361–3863.
Guardia, D., Cottencin, O., Thomas, P., Dodin, V., and Luyat, M. (2012). Spatial orientation constancy is impaired in anorexia nervosa. *Psychiatry Res.* 195, 56–59. doi: 10.1016/j.psychres.2011.08.003
Guerra, B., Santana, A., Fuentes, T., Delgado-Guerra, S., Cabrera-Socorro, A., Dorado, C., et al. (2007). Leptin receptors in human skeletal muscle. *J. Appl. Physiol.* 102, 1786–1792. doi: 10.1152/japplphysiol.01313.2006
Guetzkow, H. A. B., and Bowman, P. H. (1946). *Men and Hunger: A Psychological Manual for Relief Workers*, Elgin, IL: Brethren Publishing House.
Guinn, B., Semper, T., Jorgensen, L., and Skaggs, S. (1997). Body image perception in female Mexican-American adolescents. *J. Sch. Health* 67, 112–115. doi: 10.1111/j.1746-1561.1997.tb03425.x
Gull, W. (1874). Anorexia Nervosa (Apepsia Hysterica, Anorexia Hysterica). *Clinic. Soc. Trans.* 7, 22–28.
Gutierrez, E., and Carrera, O. (2020). Severe and enduring Anorexia Nervosa: enduring wrong assumptions? *Front. Psychol.* 11:538997. doi: 10.3389/fpsyt.2020.538997
Halvorsen, I., and Heyerdahl, S. (2006). Girls with anorexia nervosa as young adults: personality, self-esteem, and life satisfaction. *Int. J. Eat. Disord.* 39, 285–293. doi: 10.1002/eat.20248
Harris, A. M., Mcalpine, D. E., Shirbhate, R., Manohar, C. U., and Levine, J. A. (2008). Measurement of daily activity in restrictive type anorexia nervosa. *Int. J. Eat. Disord.* 41, 280–283. doi: 10.1002/eat.20486
Hausenblas, H. A., and Fallon, E. A. (2006). Exercise and body image: A meta-analysis. *Psychol. Health* 21, 33–47. doi: 10.1080/14768320500105270
Head, H., and Holmes, G. (1911). Sensory disturbances from cerebral lesions. *Brain* 1, 102–145.
Hebebrand, J., Blum, W. F., Barth, N., Coners, H., Englaro, P., Juul, A., et al. (1997). Leptin levels in patients with anorexia nervosa are reduced in the acute stage and elevated upon short-term weight restoration. *Mol. Psychiatry* 2, 330–334. doi: 10.1038/sj.mp.4000282
Hebebrand, J., Exner, C., Hebebrand, K., Holtkamp, C., Casper, R., Remschmidt, H., et al. (2003). Hyperactivity in patients with anorexia nervosa and in

semi-starved rats: evidence for a pivotal role of hypoleptinemia. *Physiol. Behav.* 79, 25–37. doi: 10.1016/S0031-9384(03)00102-1

Hebebrand, J. A., and Hinney, J. (2021). Kurzzeitige Behandlung von Patientinnen mit Anorexia nervosa mit rekombinant hergestelltem Human-Leptin (Metreleptin): Rasch einsetzende positive Effekte auf Stimmung, Kognition und Verhalten. *Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie* 49, 1–5.

Hechler, T., Rieger, E., Touyz, S., Beumont, P., Plasqui, G., and Westerterp, K. (2008). Physical activity and body composition in outpatients recovering from Anorexia Nervosa and healthy controls. *Adapt. Phys. Act. Q.* 25, 159–173. doi: 10.1123/apaq.25.2.159

Heilbronn, L. K., De Jonge, L., Frisard, M. I., Delany, J. P., Larson-Meyer, D. E., Rood, J., et al. (2006). Effect of 6-month calorie restriction on biomarkers of longevity, metabolic adaptation, and oxidative stress in overweight individuals: a randomized controlled trial. *JAMA* 295, 1539–1548. doi: 10.1001/jama.295.13.1539

Hofmann, T., Elbelt, U., Ahnis, A., Kobelt, P., Rose, M., and Stengel, A. (2014). Irisin levels are not affected by physical activity in patients with Anorexia Nervosa. *Front. Endocrinol.* 4:202. doi: 10.3389/fendo.2013.00202

Holland, A., Hall, A., Murray, R., Russell, G., and Crisp, A. (1984). Anorexia nervosa: A study of 34 twin pairs and one set of triplets. *Br. J. Psychiatry* 145, 414–419. doi: 10.1192/bjp.145.4.414

Holtkamp, K., Hebebrand, J., Mika, C., Grzella, I., Heer, M., Heussen, N., et al. (2003a). The effect of therapeutically induced weight gain on plasma leptin levels in patients with anorexia nervosa. *J. Psychiatr. Res.* 37, 165–169. doi: 10.1016/S0022-3956(02)00100-0

Holtkamp, K., Hebebrand, J., Mika, C., Heer, M., Heussen, N., and Herpertz-Dahlmann, B. (2004). High serum leptin levels subsequent to weight gain predict renewed weight loss in patients with anorexia nervosa. *Psychoneuroendocrinology* 29, 791–797. doi: 10.1016/S0306-4530(03)00143-4

Holtkamp, K., Herpertz-Dahlmann, B., Hebebrand, K., Mika, C., Kratzsch, J., and Hebebrand, J. (2006). Physical activity and restlessness correlate with leptin levels in patients with adolescent anorexia nervosa. *Biol. Psychiatry* 60, 311–313. doi: 10.1016/j.biopsych.2005.11.001

Holtkamp, K., Herpertz-Dahlmann, B., Mika, C., Heer, M., Heussen, N., Fichter, M., et al. (2003b). Elevated physical activity and low leptin levels co-occur in patients with anorexia nervosa. *J. Clin. Endocrinol. Metab.* 88, 5169–5174. doi: 10.1210/jc.2003-030569

Janet, P. (1903). *Obsessions et la Psychasthénie*, Paris, Felix Alcan.

Jiménez-Pavón, D., Ortega, F. B., Artero, E. G., Labayen, I., Vicente-Rodriguez, G., and Huybrechts, I. (2012). Physical activity, fitness, and serum leptin concentrations in adolescents. *J. Pediatr.* 160, 598.e2–603.e2. doi: 10.1016/j.jpeds.2011.09.058

Karatzias, T., Chouliara, Z., Power, K., Collin, P., Yellowlees, A., and Grierson, D. (2010). General psychopathology in anorexia nervosa: the role of psychosocial factors. *Clin. Psychol. Psychother.* 17, 519–527. doi: 10.1002/cpp.701

Kastin, A. J., Akerstrom, V., and Pan, W. (2000). Fasting, but not adrenalectomy, reduces transport of leptin into the brain. *Peptides* 21, 679–682. doi: 10.1016/S0196-9781(00)00195-9

Keyes, A., Woerwag-Mehta, S., Bartholdy, S., Koskina, A., Middleton, B., Connan, F., et al. (2015). Physical activity and the drive to exercise in anorexia nervosa. *Int. J. Eat. Disord.* 48, 46–54. doi: 10.1002/eat.22354

Keys, A., Brozek, J., Henschel, A., Mickelsen, O., and Taylor, H. (1950). *The Biology of Human Starvation*, Minneapolis, University of Minnesota Press.

Kilpeläinen, T. O. E. A. (2016). Genome-wide meta-analysis uncovers novel loci influencing circulating leptin levels. *Nat. Commun.* 7:10494. doi: 10.1038/ncomms10494

Klump, K. L., Miller, K. B., Keel, P. K., Mcgue, M., and Iacono, W. G. (2001). Genetic and environmental influences on anorexia nervosa syndromes in a population-based twin sample. *Psychol. Med.* 31, 737–740. doi: 10.1017/S0033291701003725

Korn, L., Gonen, E., Shaked, Y., and Golan, M. (2013). Health perceptions, self and body image, physical activity and nutrition among undergraduate students in Israel. *PLoS One* 8:e58543. doi: 10.1371/journal.pone.0058543

Kortegaard, L. S., Hoerder, K., Joergensen, J., Gillberg, C., and Kyvik, K. O. (2001). A preliminary population-based twin study of self-reported eating disorder. *Psychol. Med.* 31, 361–365. doi: 10.1017/S0033291701003087

Krieg, J., Lauer, C., and Leinsinger, G. (1989). Brain morphology and regional cerebral blood flow in anorexia nervosa. *Biol. Psychiatry* 25, 1041–1048. doi: 10.1016/0006-3223(89)90292-8

Lankenau, H., Swigar, M. E., Bhimani, S., Luchins, D., and Quinlan, D. M. (1985). Cranial CT scans in eating disorder patients and controls. *Compr. Psychiatry* 26, 136–147. doi: 10.1016/0010-440X(85)90034-3

Lasègue, E. (1873). De l'anorexie hystérique. *Archives Générales de Médecine* 1, 385–403.

Lee, P. H., Anttila, V., Won, H., Feng, Y. C. A., Rosenthal, J., and Zhu, Z. (2019). Genomic relationships, novel loci, and pleiotropic mechanisms across eight psychiatric disorders. *Cell* 179, 1469–1482. doi: 10.1016/j.cell.2019.11.020

Leibel, R. L., Rosenbaum, M., and Hirsch, J. (1995). Changes in energy expenditure resulting from altered body weight. *N. Engl. J. Med.* 332, 621–628. doi: 10.1056/NEJM199503093321001

Lichtenstein, M. B., Andries, A., Hansen, S., Frystyk, J., and Stoving, R. K. (2015). Exercise addiction in men is associated with lower fat-adjusted leptin levels. *Clin. J. Sport Med.* 25, 138–143. doi: 10.1097/JSM.0000000000000110

Licinio, J., Negrao, A. B., and Wong, M. L. (2014). Plasma leptin concentrations are highly correlated to emotional states throughout the day. *Transl. Psychiatry* 4:e475. doi: 10.1038/tp.2014.115

Liu, J., Garza, J. C., Bronner, J., Kim, C. S., Zhang, W., and Lu, X. Y. (2010). Acute administration of leptin produces anxiolytic-like effects: a comparison with fluoxetine. *Psychopharmacology* 207, 535–545. doi: 10.1007/s00213-009-1684-3

Liu, J., Perez, S. M., Zhang, W., Lodge, D. J., and Lu, X. Y. (2011). Selective deletion of the leptin receptor in dopamine neurons produces anxiogenic-like behavior and increases dopaminergic activity in amygdala. *Mol. Psychiatry* 16, 1024–1038. doi: 10.1038/mp.2011.36

Longo, M. R., and Haggard, P. (2010). An implicit body representation underlying human position sense. *Proc. Natl. Acad. Sci. U. S. A.* 107, 11727–11732. doi: 10.1073/pnas.1003483107

Lu, X. Y., Kim, C. S., Frazer, A., and Zhang, W. (2006). Leptin: a potential novel antidepressant. *Proc. Natl. Acad. Sci. U. S. A.* 103, 1593–1598. doi: 10.1073/pnas.0508901103

Mantzoros, C., Flier, J., Lesem, M., Brewerton, T., and Jimerson, D. (1997). Cerebrospinal fluid leptin in anorexia nervosa: correlation with nutritional status and potential role in resistance to weight gain. *J. Clin. Endocrinol. Metab.* 82, 1845–1851. PMID: 9177394

Mantzoros, C. S., Magkos, F., Brinkoetter, M., Sienkiewicz, E., Dardeno, T. A., Kim, S. Y., et al. (2011). Leptin in human physiology and pathophysiology. *Am. J. Physiol. Endocrinol. Metab.* 301, E567–E584. doi: 10.1152/ajpendo.00315.2011

Margetic, S., Gazzola, C., Pegg, G. G., and Hill, R. A. (2002). Leptin: a review of its peripheral actions and interactions. *Int. J. Obes. Relat. Metab. Disord.* 26, 1407–1433. doi: 10.1038/sj.ijo.0802142

Mars, M., De Graaf, C., De Groot, C. P., Van Rossum, C. T., and Kok, F. J. (2006). Fasting leptin and appetite responses induced by a 4-day 65%-energy-restricted diet. *Int. J. Obes.* 30, 122–128. doi: 10.1038/sj.ijo.0803070

Martin, C. K., Heilbronn, L. K., Lilian De Jonge, L., Delany, J. P., Volaufova, J., Anton, S. D., et al. (2007). Effect of calorie restriction on resting metabolic rate and spontaneous physical activity. *Obesity* 15, 2964–2973. doi: 10.1038/oby.2007.354

Mendelson, B. K., Mclaren, L., Gauvin, L., and Steiger, H. (2002). The relationship of self-esteem and body esteem in women with and without eating disorders. *Int. J. Eat. Disord.* 31, 318–323. doi: 10.1002/eat.10011

Milos, G., Antel, J., Kaufmann, L. K., Barth, N., Koller, A., Tan, S., et al. (2020). Short-term metreleptin treatment of patients with anorexia nervosa: rapid on-set of beneficial cognitive, emotional, and behavioral effects. *Transl. Psychiatry* 10:303. doi: 10.1038/s41398-020-00977-1

Murakami, H., Iemitsu, M., Fuku, N., Sanada, K., Gando, Y., Kawakami, R., et al. (2014). The Q223R polymorphism in the leptin receptor associates with objectively measured light physical activity in free-living Japanese. *Physiol. Behav.* 129, 199–204. doi: 10.1016/j.physbeh.2014.02.053

Nurse, P. (2021). Biology must generate ideas as well as data. *Nature* 597:305. doi: 10.1038/d41586-021-02480-z

Peters, T., Antel, J., Naaresh, R., Laabs, B. H., Focker, M., Albers, N., et al. (2021). Suggestive evidence for causal effect of Leptin levels on risk for Anorexia Nervosa: results of a Mendelian randomization study. *Front. Genet.* 12:733606. doi: 10.3389/fgene.2021.733606

Phillipou, A., Abel, L. A., Castle, D. J., Hughes, M. E., Nibbs, R. G., Gurvich, C., et al. (2016). Resting state functional connectivity in anorexia nervosa. *Psychiatry Res. Neuroimaging* 251, 45–52. doi: 10.1016/j.pscychresns.2016.04.008

Proske, U., and Allen, T. (2019). The neural basis of the senses of effort, force and heaviness. *Exp. Brain Res.* 237, 589–599. doi: 10.1007/s00221-018-5460-7

Proske, U., and Gandevia, S. C. (2012). The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiol. Rev.* 92, 1651–1697. doi: 10.1152/physrev.00048.2011

Redman, L. M., Martina, C. K., Williamsona, D. A., and Ravussin, E. (2008). Effect of caloric restriction in non-obese humans on physiological, psychological and behavioral outcomes. *Physiol. Behav.* 94, 643–648. doi: 10.1016/j.physbeh.2008.04.017

Rizk, M., Lalanne, C., Berthoz, S., Kern, L., and Godart, N. (2015). Problematic exercise in Anorexia Nervosa: testing potential risk factors against different definitions. *PLoS One* 10:e0143352. doi: 10.1371/journal.pone.0143352

Romon, M., Lafay, L., Bresson, J. L., Oppert, J. M., Borys, J. M., Kettaneh, A., et al. (2004). Relationships between physical activity and plasma leptin levels in healthy children: the Fleurbaix-Laventie Ville Sante ii study. *Int. J. Obes. Relat. Metab. Disord.* 28, 1227–1232. doi: 10.1038/sj.ijo.0802725

Rosenbaum, M., Murphy, E. M., Heymsfield, S. B., Matthews, D. E., and Leibel, R. L. (2002). Low dose leptin administration reverses effects of sustained weight-reduction on energy expenditure and circulating concentrations of thyroid hormones. *J. Clin. Endocrinol. Metab.* 87, 2391–2394. doi: 10.1210/jcem.87.5.8628

Ryan, R. M., and Frederick, C. (1997). On energy, personality, and health: subjective vitality as a dynamic reflection of well-being. *J. Pers.* 65, 529–565. doi: 10.1111/j.1467-6494.1997.tb00326.x

Sachdev, P., Mondraty, N., Wen, W., and Gulliford, K. (2008). Brains of anorexia nervosa patients process self-images differently from non-self-images: an fmri study. *Neuropsychologia* 46, 2161–2168. doi: 10.1016/j.neuropsychologia.2008.02.031

Salbe, A. D., Nicolson, M., and Ravussin, E. (1997). Total energy expenditure and the level of physical activity correlate with plasma leptin concentrations in five-year-old children. *J. Clin. Invest.* 99, 592–595. doi: 10.1172/JCI119200

Schilder, P. (1950). *The Image and Appearance of the Human Body*, New York: International Universities Press.

Schlegl, S., Dittmer, N., Hoffmann, S., and Voderholzer, U. (2018). Self-reported quantity, compulsiveness and motives of exercise in patients with eating disorders and healthy controls: differences and similarities. *J. Eat. Disord.* 6:17. doi: 10.1186/s40337-018-0202-6

Serpell, L., Treasure, J., Teasdale, J., and Sullivan, V. (1999). Anorexia nervosa: friend or foe? *Int. J. Eat. Disord.* 25, 177–186. doi: 10.1002/(SICI)1098-108X(199903)25:2<177::AID-EAT7>3.0.CO;2-D

Sienkiewicz, E., Magkos, F., Aronis, K. N., Brinkoetter, M., Chamberland, J. P., Chou, S., et al. (2011). Long-term metreleptin treatment increases bone mineral density and content at the lumbar spine of lean hypoleptinemic women. *Metabolism* 60, 1211–1221. doi: 10.1016/j.metabol.2011.05.016

Silverstone, P. H. (1990). Low self-esteem in eating disordered patients in the absence of depression. *Psychol. Rep.* 67, 276–278. doi: 10.2466/pr0.1990.67.1.276

Simonen, R. L., Rankinen, T., Perusse, L., Leon, A. S., Skinner, J. S., Wilmore, J. H., et al. (2003). A dopamine D2 receptor gene polymorphism and physical activity in two family studies. *Physiol. Behav.* 78, 751–757. doi: 10.1016/S0031-9384(03)00084-2

Slade, P., and Russell, G. (1973). Awareness of body dimensions in anorexia nervosa: cross-sectional and longitudinal studies. *Psychol. Med.* 3, 188–199. doi: 10.1017/S0033291700048510

Steinhausen, H., and Vollrath, M. (1993). The self-image of adolescent patients with eating disorders. *Int. J. Eat. Disord.* 13, 221–227. doi: 10.1002/1098-108X(199303)13:2<221::AID-EAT2260130210>3.0.CO;2-C

Strober, M., Lampert, C., Morrell, W., Burroughs, J., and Jacobs, C. (1990). A controlled family study of anorexia nervosa: evidence of familial aggregation and lack of shared transmission with affective disorders. *Int. J. Eat. Disord.* 9, 239–253. doi: 10.1002/1098-108X(199005)9:3<239::AID-EAT2260090302>3.0.CO;2-7

Stubbe, J. H., Boomsma, D. I., Vink, J. M., Cornes, B. K., Martin, N. G., Skytthe, A., et al. (2006). Genetic influences on exercise participation in 37, 051 twin pairs from seven countries. *PLoS One* 1:e22. doi: 10.1371/journal.pone.0000022

Touyz, S. W., Beumont, P. J., Collins, J. K., Mccabe, M., and Jupp, J. (1984). Body shape perception and its disturbance in anorexia nervosa. *Br. J. Psychiatry* 144, 167–171. doi: 10.1192/bjp.144.2.167

Tuthill, J. C., and Azim, E. (2018). Proprioception. *Curr. Biol.* 28, R194–R203. doi: 10.1016/j.cub.2018.01.064

Van Marken Lichtenbelt, W. D., Heidendal, G. A., and Westerterp, K. R. (1997). Energy expenditure and physical activity in relation to bone mineral density in women with anorexia nervosa. *Eur. J. Clin. Nutr.* 51, 826–830. doi: 10.1038/sj.ejcn.1600492

Verbe, J., Lindberg, P. G., Gorwood, P., Dupin, L., and Duriez, P. (2021). Spatial hand representation in anorexia nervosa: a controlled pilot study. *Sci. Rep.* 11:19724. doi: 10.1038/s41598-021-99101-6

Via, E., Zalesky, A., Sanchez, I., Forcano, L., Harrison, B. J., Pujol, J., et al. (2014). Disruption of brain white matter microstructure in women with anorexia nervosa. *J. Psychiatry Neurosci.* 39, 367–375. doi: 10.1503/jpn.130135

Walsh, S., Haddad, C. J., Kostek, M. A., Angelopoulos, T. J., Clarkson, P. M., Gordon, P. M., et al. (2012). Leptin and leptin receptor genetic variants associate with habitual physical activity and the arm body composition response to resistance training. *Gene* 510, 66–70. doi: 10.1016/j.gene.2012.08.020

Wang, W., Liu, S. L., Li, K., Chen, Y., Jiang, B., Li, Y. K., et al. (2015). Leptin: a potential anxiolytic by facilitation of fear extinction. *CNS Neurosci. Ther.* 21, 425–434. doi: 10.1111/cns.12375

Watson, H. J., Yilmaz, Z., Thornton, L. M., Hubel, C., Coleman, J. R. I., Gaspar, H. A., et al. (2019). Genome-wide association study identifies eight risk loci and implicates metabo-psychiatric origins for Anorexia Nervosa. *Nat. Genet.* 51, 1207–1214. doi: 10.1038/s41588-019-0439-2

Welt, C. K., Chan, J. L., Bullen, J., Murphy, R., Smith, P., Depaoli, A. M., et al. (2004). Recombinant human leptin in women with hypothalamic amenorrhea. *N. Engl. J. Med.* 351, 987–997. doi: 10.1056/NEJMoa040388

Yilmaz, Z., Halvorsen, M., Bryois, J., Yu, D., Thornton, L. M., and Zerwas, S. (2020). Examination of the shared genetic basis of anorexia nervosa and obsessive-compulsive disorder. *Mol. Psychiatry* 25, 2036–2046. doi: 10.1038/s41380-018-0115-4

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 29 September 2022
DOI 10.3389/fpsyg.2022.1010596

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology,
a section of the journal Frontiers in Psychology

RECEIVED 03 August 2022
ACCEPTED 16 September 2022
PUBLISHED 29 September 2022

CITATION
Pedersen H, Saeterbakken AH, Fimland MS, Iversen VM, Schoenfeld BJ, Stien N and Andersen V (2022) Effects of one long vs. two short resistance training sessions on training volume and affective responses in resistance-trained women. *Front. Psychol.* 13:1010596. doi: 10.3389/fpsyg.2022.1010596

Effects of one long vs. two short resistance training sessions on training volume and affective responses in resistance-trained women

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The aim of this study was to compare the acute effects of performing a lower body resistance training program in one long or two shorter sessions in 1 day on training volume and affective measures. Employing a randomized-crossover design, 23 resistance-trained women (22 ± 2 years, 166 ± 6 cm, and 66.4 ± 7.5 kg) performed two training days consisting of (i) one long (46 min) or (ii) two short sessions (total of 43 min) separated by 3.5–5 h. Each training day was separated by 4-6 days and consisted of three sets to failure for six exercises. Training volume (number of repetitions lifted) were recorded during the sessions. Rating of perceived exertion for effort (RPE), rating of perceived exertion for discomfort (RPD), session displeasure/pleasure (sPDF) and exercise enjoyment (EES) were measured 10 min after each session. Participants also completed a readiness to train questionnaire (7 questions), 24 h after each session, and which training protocol they preferred, 48 h after the last session. The long session led to higher RPE (+1 point, $p < 0.001$, ES = 1.07), RPD (+1 point, $p = 0.043$, ES = 0.53) and sPDF ($p = 0.010$, ES = 0.59) compared to the short sessions. There was no difference in EES ($p = 0.118$, ES = 0.33). The short sessions had 3% higher training volume than the long session ($p = 0.002$, ES = 0.42). There were no differences in perceived readiness to train 24 h after the sessions (range: $p = 0.166–0.856$ and ES = 0.08–0.32). Twenty-two participants preferred the long session, while one preferred the short sessions. In conclusion, performing a longer, lower body, resistance training session led to greater perceptions of effort, discomfort and session pleasure than splitting the same program into two shorter sessions among resistance-trained women. However, two shorter sessions led to a greater training volume.

KEYWORDS

RPE, RPD, sPDF, EES, perception, training frequency

Introduction

Training frequency is typically defined as the total number of weekly resistance training sessions and is one of several components to consider when designing resistance training programs (Bird et al., 2005; ACSM, 2009). Performing briefer, more frequent sessions could potentially allow for increased training load or more repetitions lifted at same training load compared to longer and less frequent sessions due to reduced fatigue and higher energy utilization (Hartman et al., 2007). Furthermore, it has been reported that a higher training frequency is advantageous for muscle strength if an increased frequency also increases the training volume (Grgic et al., 2018). Of note, the same study also reported that a higher training frequency appeared to be favorable for muscle strength especially in women, compared to a lower training frequency (Grgic et al., 2018).

Training frequency can be increased by adding more training days per week or by increasing the number of daily training sessions. The latter, to divide the daily training program into multiple shorter sessions, is frequently used by athletes (Storey et al., 2012) and has shown promising results (Häkkinen and Kallinen, 1994; Hartman et al., 2007). For example, Hartman et al. (2007) examined nationally competitive male weightlifters and reported that performing two shorter sessions per day over a 5-week training period led to superior increases in muscle strength compared to performing one session per day. Therefore, it is possible that shorter sessions may lead to less fatigue and more work performed.

To the best of our knowledge, only one study has compared the acute effects of performing one long vs. two shorter resistance training sessions in 1 day (Bartolomei et al., 2011). Bartolomei et al. (2011) examined the effects of performing eight sets of 10 repetitions (75 s between sets) at 70% of 1-RM in bench press in resistance-trained men. The participants were divided into two groups: one group completed all sets in the same session while the other group split the sets into two shorter sessions (four sets per session). The results showed that the participants were able to complete the same number of repetitions at a higher training intensity (percentage of 1-RM) and had faster recovery rates when performing two shorter compared to one longer session.

How an activity is perceived might have implications as to whether a person chooses to continue with that activity (Ekkekakis et al., 2005; Williams et al., 2008). For example, shorter sessions lead to the use of higher training loads and promote faster recovery (Bartolomei et al., 2011). Furthermore, longer training sessions increase the perception of effort compared to shorter sessions (Fusco et al., 2020). This increased perception of effort may also lead to an increased perception of discomfort, since effort and discomfort have been shown to be related (Steele et al., 2016). If performing a daily training program in multiple short sessions leads to increased performance/training loads, faster recovery and less perception of effort and discomfort, it is also likely that it will be perceived as more pleasurable and enjoyable. Furthermore, the perception of being ready to train should be greater the following day.

Another argument for dividing the workout into shorter sessions is the aspect of time. Time is one of the most reported barriers for engaging in exercise (Hoare et al., 2017; Hurley et al., 2018) and having time to complete long workouts may be difficult. However, conducting two short sessions throughout the day may be more manageable and therefore be perceived as more pleasurable, enjoyable and preferable than one longer session. Importantly, no previous study has examined the perception of performing one long or two shorter resistance training sessions in 1 day.

Considering this gap in the literature, the aim of this study was to compare the acute effects of performing a lower body resistance-training program in one long or two shorter sessions in 1 day on training volume and different affective measures. We hypothesized that two shorter lower-body resistance-training sessions would lead to greater perceived pleasure, enjoyment, readiness to train and training volume, and lower perceived effort and discomfort, compared to one long session among resistance-trained women. Consequently, we also expected most participants to prefer dividing the workout into two shorter training sessions.

Materials and methods

Study design

We employed a within subject crossover design to compare the training volume and the affective responses from one long vs. two shorter resistance-training sessions for the lower body. The order of the sessions was randomized and counterbalanced. A familiarization session was conducted in advance of the two experimental sessions. The long session consisted of six exercises (in the order they were conducted: the squat, hip thrust, leg extension, leg press, lunge, and leg curl) focusing on the hip and thigh muscles. The same exercises, and exercise order, were performed in the two short sessions, three exercises per session (see Figure 1 for an overview of the different sessions). The two sessions were divided by a rest period of 3.5–5 h. Training volume, defined as repetitions per session (Haff, 2010; Scott et al., 2016) (using ~9 repetition maximum (RM) weights), and training duration was recorded during all sessions. Number of repetitions was used since all other intra-exercise variables (Coratella, 2022) were held constant between the different sessions. Ten minutes after completion of the sessions, participants were asked how they perceived the session related to effort, discomfort, pleasure/displeasure and enjoyment. Twenty-four hours after each session the participants were contacted through phone and asked about their readiness to train. Forty-eight hours after the last session, participants were contacted by mail asked which of the two sessions they would use as their regular training routine, and the main reason for their choice.

Participants

Twenty-three women with 3.9 ± 1.9 years of resistance-training experience were recruited to participate in the study. Their mean ± SD characteristics were; age: 22± 2 years, body mass: 66.4 ± 7.5 kg, stature: 166 ± 6 cm, self-reported 1-RM squat: 84 ± 19 kg, and self-reported 1-RM deadlift: 92 ± 20 kg. The sample size was justified performing a priori power analysis in SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) based on the difference in training load between the groups observed in Bartolomei et al. (2011) (mean ± standard deviation; 59.9 ± 6.5 vs. 48.7 ± 5.3%), an alpha level of 0.5, Pearson product-moment correlation of 0.5 and power of 0.8. Participants were recruited through posters, personal invitations, meetings, and social media. To be included in the study the participants had to be 18–30 years old, have more than 2 years' experience with resistance-training, be familiar with and able to perform the exercises with good technique, and not have any injuries that prohibited maximal exertion. The participants agreed to refrain from alcohol and training of the lower body 48 h in advance of each session. Furthermore, they were asked to avoid all forms of physical training between the two short sessions or within 24 h after the sessions. They were informed orally and in writing about the procedures and provided a written consent before being enrolled in the study. The procedures were processed by the Norwegian Center of Research Data (ref nr 170233) and were conducted according to the Declaration of Helsinki and the ethical guidelines set by the University College's institutional review board.

Procedures

In the familiarization session we assessed participants' anthropometrics and defined the individual standardization and the training load for each exercise (∼9-RM). The 9-RM loading was chosen because it is in the middle of the 6–12RM range recommended for resistance-trained individuals (Garber et al., 2011). Since the participants were experienced with the specific exercises and equipment, they self-reported their 9-RMs. If they were unsure of their 9-RM, they performed progressive sets in that specific exercise until they were able report a specific load. Importantly, regardless of whether 9-RMs were entirely accurate, the same loading was used in all sessions. We also introduced participants to the different affective scales in the following order: subjective experience of the sessions in terms of effort, discomfort, pleasure/displeasure and enjoyment (see measurements for more details).

The first training protocol was performed 3–5 days after the familiarization session and the two training protocols (long session vs. two brief sessions) were separated with 4–6 days. Before each session, the participants conducted a standardized warm-up consisting of 5 min cycling on a low intensity (Borg's RPE scale: 10–11) and two sets of squats lifting nine repetitions at 50% of the self-reported 9-RM. The rest interval between each set was 2 min.

The experimental sessions consisted of three sets per exercise using the same relative load (9-RM) and a rest interval of 2 min between sets and exercises. The only difference between the sessions was that in the long session all exercises were performed consecutively while in the two short sessions the first three and the last three exercises were divided by a rest period of 3.5–5 h.

The participants were instructed to have an external focus (i.e., focusing on moving the weight and not on using the muscles) and perform repetitions to failure in each set, where failure was defined as not being able to lift the weights throughout the range of motion or perform another repetition with proper technique. The repetitions were performed continuously (eccentric-concentric movement) in the participants self-selected/normal, but controlled tempo (i.e., always controlling the weights, no cheating allowed). The same two test leaders were present in all sessions to ensure that the execution of the repetitions (within and between the sets and sessions) was as identical as possible and that the standardizations from the familiarization session was used. An overview of the standardization and range of motion of the different exercises is presented in Table 1. Furthermore, the test leaders counted the repetitions in each set, kept track of time and presented the affective scales to the participants. To keep the sessions as similar to a regular training session as possible, the test leaders did not interfere with the lifting (e.g., spotting, motivating, giving feedback etc.). No inter-set rest was allowed. Since all other intra-exercise variables were held constant (Coratella, 2022), the total number of successful repetitions performed were used as a measurement of the training volume (Haff, 2010; Scott et al., 2016).

Measurements

Affective measures

The perception of the different sessions was assessed through four different scales. None of the participants had any previous experience with the scales. The scales were presented to the participants 10 min after completing the last set. The participants were asked to consider the whole session when giving their answers. All scales were shown to the participants while the test leader read the question which was also included above the

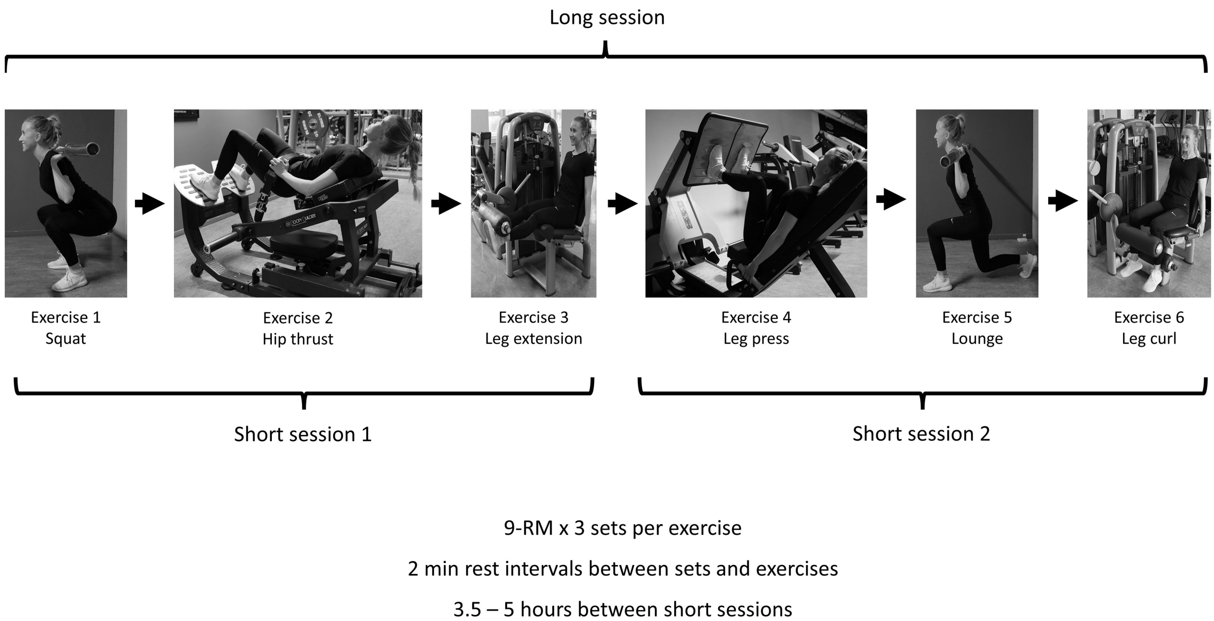

FIGURE 1
An overview of the long and the two short sessions.

scales. The mean of the answers from the two short sessions was used in the analysis. Prior to the study, the scales were translated from the original forms to Norwegian. The scales were translated independently by three of the authors (AHS, HP and VA). The three translations were then compared, discussed, and agreed upon the final versions. A professional translator translated these versions back to English which were compared with the originals. In general, there were only minor differences between the versions, which were adjusted after mutual agreement.

The perception of exertion was differentiated into effort and discomfort (Steele et al., 2016). Effort was measured using the rating of perceived exertion for effort scale (Borg CR-10 RPE), while discomfort was measured using the rating of perceived exertion for discomfort scale (RPD) (Fisher and Steele, 2017). Both scales consist of 11-items and ranges from no effort/discomfort to maximal effort/discomfort. Based on a previous recommendation (Halperin and Emanuel, 2020), the RPE scale was presented to the participants with the following phrase: "*How much of your perceived physical capacity out of your perceived maximum (10 being your maximum) did you invest to complete this workout?*". The RPD scale was presented with the following phrase: "*Based on the completed session, how much discomfort did you feel? The scale ends at 10 which could be described as you could not imagine the sensations relating to physical activity being any more intense?*" (Steele et al., 2016). The upper and lower limit were anchored by the following sentence "*0 can be described as feeling no noticeable sensation relating to the training while 10 would be the most intense training related sensation you could imagine.*" Both scales have shown acceptable reliability (Steele et al., 2016).

The perceived pleasure/displeasure with the session was measured using the session pleasure/displeasure feelings scale (sPDF). The scale is a bipolar 11-point scale stretching from −5 (very bad) to 5 (very good), where 0 is considered neutral and have previously shown good reliability (Unick et al., 2015). The sPDF scale was presented with the following phrase: "*How was your workout?*" (Ribeiro et al., 2019). The upper and lower limits were anchored by the following sentence: "*-5 can be described as perceiving the session as one of the worst/least pleasurable training sessions you have ever conducted while 5 would be one of the best/most pleasurable training sessions you have ever conducted.*"

How much the participants enjoyed the sessions was measured using the exercise enjoyment scale (EES). The scale ranges from one to seven with one being "not at all" and seven being "extraordinary." The scale was presented with the following question: "*How much did you enjoy the exercise session?*" (Schwartz et al., 2021). The upper and lower limit were anchored by the following sentence: "*1 can be described as perceiving the session as one of the least enjoyable training sessions you have ever conducted while 7 would be one of the most enjoyable training sessions you have ever conducted.*" The EES scale has been reported to be valid (Stanley et al., 2009).

Forty-eight hours after the last session, the participants were contacted by e-mail and asked the following questions: "*If you had to choose one of the two training protocols (one long or two short sessions) as your regular training schedule, which would*

TABLE 1 Description of standardizations and execution of the different exercises.

Exercise	Standardization	Execution of the reps/ range of motion
Squat	Barbell resting on the upper trapezius. Shoulder width between the feet Back kept in normal position throughout the lift	Eccentric: Descending from the extended position until the femur is parallel to the floor Concentric: Ascending until the hip- and knee joints are extended.
Hip thrust	Belt resting on the hip Arms resting on the hip Shoulder width between the feet	Eccentric: Descending from the extended position until the plates touch the floor Concentric: Ascending until the hip joint is extended.
Leg extension	Bottom and back in contact with the chair. Arms gripping the handles Footpad resting just above the ankle joint	Eccentric: Descending from the extended position until the plates touch the stack Concentric: Ascending until the knee joints are extended.
Leg press	Bottom and back in contact with the chair at all times. Arms gripping the handles Shoulder width between the feet	Eccentric: Descending from the extended position until a 90-degree angle in the knee joints Concentric: Ascending until the knee joints are extended.
Lunge	Barbell resting on the upper trapezius Shoulder width between the feet Back kept in normal position throughout the lift Same step length in all repetitions	Eccentric: Stepping forward and descending from the extended position until the knee of the back leg is touching the floor Concentric: Ascending and stepping backward until the hip- and knee joints are extended and feet parallel.
Leg curl	Bottom and back in contact with the chair. Arms gripping the handles Footpad resting toward the Achilles tendon	Eccentric: Ascending from the flexed position until the knee joints are extended. Concentric: Descending until 90-degree angle in the knee joints.

you prefer, and what is the main reason for this choice?". The participants answered by replying to the mail. The answers were aggregated and grouped based on the underlying theme of the explanation.

Readiness to train

To evaluate how the different sessions affected the perception of training ability, the participants were contacted 24 h after long session and 24 h after the median of the two short sessions to answer a questionnaire regarding readiness to train (Lombard et al., 2021). The questionnaire consisted of seven questions with responses made from bipolar scales ranging from 1 to 4, 1 to 5 and 1 to 10. The upper and lower limit were anchored by the following sentence: *"1 can be described as not at all/extremely low and 4, 5, 10 (depending on lower/upper end of the scale) can be described as extreme amount/extremely high."* The questions were: Q1*"Do you feel physically strong today?"*, Q2 *"Do you feel mentally strong today?"*, Q3 *"How would you describe your health today?"*, Q4 *"How would you describe your appetite today?"*, Q5 *"How would you describe your sleep quality over the past 24 h?"*, Q6 *"Do you have any muscle soreness today?"* and Q7 *"Rate your motivation to train today"*. The questionnaire has not been validated; however, it has shown to be more sensitive to fatigue than objective measures such as performance in countermovement jump (Lombard et al., 2021).

Statistical analysis

The Shapiro-Wilk test was used to assess normality in the continuous variables training duration and training volume (number of reps). Training duration was found to be normally distributed (p = 0.06–0.15) while training volume was not ($p < 0.01$). Paired t-tests were therefore used to assess differences in training duration while the Wilcoxon signed rank test was used to assess differences for training volume and the ordinal variables (RPE, RPD, sPDF, EES and readiness to train questionnaire). The results for the ordinal variables are presented as median (interquartile range) while the other variables are presented as means ± standard deviations. Cohen's d effect size (ES) was calculated for the continuous variables using the following equation: mean pre– mean post divided by the pooled standard deviations of the two. An effect size of 0.2–0.49, was considered small, 0.5–0.79 medium and ≥ 0.8 large (Cohen, 1998). For the ordinal data effects size was calculated as product-movement r using the following equation: $r = z/\sqrt{n}$, with z being the z-value of the Wilcoxon signed ranked test and n being the number of participants. A product-movement r of 0.1–0.29 was considered small, 0.3–0.49 medium and ≥ 0.5 large (Cohen, 1998). Statistical significance was accepted at $p < 0.05$. The statistical analyses were performed using SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY).

TABLE 2 Affective measures and readiness to train for the long and the short sessions [median (interquartile range)].

	Long session	Short sessions	*P*-value	Effect size
Affective measures				
RPE (0–10)	7 (1)	6 (2)*	<0.01	0.73
RPD (0–10)	6 (2)	5 (2)*	0.04	0.42
sPDF (−5–5)	4 (2)	4 (1)*	0.01	0.54
EES (1–7)	5 (1)	5 (1)	0.12	0.33
Readiness to train				
Do you feel physically strong today? (1–5)	3 (0)	3 (1)	0.57	0.11
Do you feel mentally strong today? (1–5)	3 (0)	3 (1)	0.86	0.04
How would you describe your health today? (1–4)	3 (0)	3 (1)	0.20	0.27
How would you describe your appetite today? (1–5)	3 (2)	3 (1)	0.17	0.29
How would you describe your sleep quality over the past 24 h? (1–4)	3 (1)	3 (1)	0.84	0.04
Do you have any muscle soreness today? (1–10)	3 (2)	2 (2)	0.34	0.20
Rate your motivation to train today (1–10)	3 (1)	3 (2)	0.70	0.08

*= different from long ($p < 0.05$), RPE, rate of perceived exertion effort; RPD, rate of perceived exertion discomfort; sPDF, session pleasure/displeasure; EES, exercise enjoyment.

Result

The median RPE and RPD was on average 1 point higher (RPE; Z = −3.536, $p < 0.001$ and RPD; Z = −2.022, $p = 0.043$, Table 2) in the long compared to the short sessions. Furthermore, the sPDF was also rated higher in the long session compared to the short session (Z = −2.589, $p = 0.010$) while there was no difference between the sessions for EES (Z = −1.565, $p = 0.118$).

The training volume was 3% higher in the two short sessions compared to the long session (169 ± 11 vs. 164 ± 8 repetitions, p = 0.002, ES = 0.42, Table 3) while the training duration was 7% shorter in the short sessions (43 ± 2 vs. 46 ± 4 min, $p = 0.005$, ES = 0.89).

Twenty-four hours after the sessions there were no differences between the protocols in the perception of readiness to train (Z = −1.565– −0.182, p = 0.166–0.856, Table 1). When asked 48 hours after the last session which session they preferred as their regular training routine, 22 chose the long session while one participant chose the two short sessions.

Discussion

This is the first study to examine the acute perceptive effects of performing one long or two shorter resistance training sessions in 1 day. In agreement with our hypothesis, the results showed that in resistance-trained women performing one long session led to a greater perception of effort and discomfort and a reduced training volume compared to two shorter sessions. However, in contrast to our hypothesis, the long session was perceived as more pleasurable than the two short sessions. Furthermore, there was no difference in session enjoyment and readiness to train between the two protocols. When asked about which session they preferred, all except one participant preferred the long session.

A possible explanation for the increased training volume when performing two short sessions is that performing briefer and more frequent sessions allows for more intense sessions and thereby lifting more repetitions per set due to less accumulated fatigue (Hartman et al., 2007). Importantly and surprisingly, the difference was only three percent, and the effect size of this finding was considered small (ES = 0.42). Therefore, the importance of this finding is debatable, especially for the general population, although it might be of relevance for competitive strength training athletes as the cumulated effect can lead to a modest, but practically meaningful increase in training stimuli over time. Of note, the population in the present study was resistance-trained and may therefore be able to sustain the number of repetitions over a relatively long session. Although speculative, the difference might have been greater with a less experienced population.

Although the difference in repetitions became more evident as the sessions progressed, suggesting that the accumulated work ultimately resulted in fatigue and thus a decrement in performance, it was expected that the reduction in repetitions per set should be higher, especially in the long session. Importantly, in some of the exercises (squat and deadlift) there may be more of a technical failure (not able to keep a straight back etc.) compared to an absolute failure (the neuromuscular system not able to lift the weights one more time), which may have affected the ability to keep the number of repetitions relatively stable throughout the session. Further, the participants were not spotted during the lifts which, due to safety reasons, may have affected number of repetitions and consequently fatigue before aborting the set. However, these factors were

TABLE 3 Accumulated number of repetitions for three sets using ~9RM loading for each exercise in the long and short sessions (mean ± standard deviation).

	Squat	Hip thrust	Leg extension	Leg press	Lunge	Leg curl	Total
Long	27 ± 2	27 ± 2	28 ± 3	27 ± 1	27 ± 1	27 ± 2	164 ± 8
Short	27 ± 2	27 ± 1	29 ± 3	28 ± 2	28 ± 3	30 ± 4	169 ± 11*

* = different from long ($p < 0.05$).

kept identical in all sessions. As mentioned, the difference in volume emerged at exercises 3–6 in the long session (Table 3). Consequently, it would be interesting to compare a more extensive training program to observe if the difference becomes more apparent. Our finding is in accordance with Bartolomei et al. (2011), who compared performing eight sets of bench press in one or two sessions. In opposition to our design, they kept the number of repetitions constant and compared the training intensity (percentage of 1-RM). The authors reported a mean loading intensity of 59.9% of 1-RM when dividing the sets into two sessions compared to 48.7% when performing all sets in the same session.

As hypothesized, both the perception of effort and discomfort were increased after the long compared to the two short sessions. When increasing the work and/or work rate, the metabolic and endocrine stress responses also increase (Paz et al., 2017; Weakley et al., 2017). Further, accumulation of different metabolic factors has been shown to increase the sensation of fatigue and pain/discomfort (Pollak et al., 2014) and may therefore explain our results. Notably, effort and discomfort are different perceptions, however, they are reported to be related (Steele et al., 2016), and the increased perception of effort and discomfort observed in our study could, at least partly, explain each other.

Contrary to our hypothesis, the long session was considered more pleasurable despite being perceived as more strenuous and discomforting. The difference in session pleasure may be related to the resistance-trained sample who therefore may enjoy sessions that are perceived as more discomforting and more demanding in regard to effort. This speculation is supported by the fact that 22 out of 23 reported to prefer the long session. Furthermore, the feeling of an intense workout, together with time-efficiency was the most common explanations for that choice. Importantly, time-efficiency is most likely related to the surroundings of the training (not having to travel to the training center twice in a day), and not the training *per se*.

Our finding is in line with the results from a previous study from our lab comparing traditional and superset resistance training among resistance-trained (Andersen et al., 2022). The study indicated that the more strenuous superset session led to higher discomfort and effort among participants, but also tended to be more pleasurable (Andersen et al., 2022).

There was no difference between the two protocols in the perceived readiness to train 24 h after the sessions. Although, the training volume difference was statistically significant, the difference was rather small (3%). Therefore, the difference might have been too small to induce differences in the perception of readiness to train 24 h after the sessions. Our finding differs with that of Bartolomei et al. (2011) reported a faster recovery process when dividing the total training volume into two shorter sessions. Importantly, Bartolomei et al. (2011) measured the recovery process by objective measures, such as isometric bench press and power output in the bench press, which could explain the different findings between the studies. Of note, Bartolomei et al. (2011) did not report any difference in muscle soreness between the protocols 24 h after the sessions.

The study has some limitations that should be considered when drawing practical conclusions. Only resistance-trained women were recruited to this study and the findings therefore may not necessarily be generalizable to other populations. Further, only exercises for the lower body were included in the sessions. The findings may have been different if a greater training volume had been implemented, either by including the upper body or increasing the number of exercises/sets for the lower body. Importantly, we wanted the sessions to have a high ecological validity. Therefore, we designed the program as a typical split workout routine and used a total training volume of 18 working sets for the thigh- and hip muscles, which is relatively high. Although the different scales were presented to the participants in the familiarization session, they were not familiar with them prior to the study and the scores might have been different if they had had more experience with the scales. Importantly, the order of the sessions was randomized and counterbalanced so a potential familiarization effect from the first to the second training protocol would have been evened out. Also, the measures were only assessed after the sessions. It has been shown that people are more positive toward training after the exercise (affective rebound effect) (Ekkekakis et al., 2011). Therefore, the perception of the sessions may have changed throughout the sessions. The load used in the present study was the participants self-reported 9-RM. Consequently, the load lifted may not be their true 9-RM. However, as shown in Table 3, the reported load was close to the number of repetitions actually lifted. Importantly, the same load was used in all sessions to allow for comparisons between the different training programs. Finally, menstrual cycle and nutritional intake was not controlled in the study, which may have influenced the results.

From a practical point of view, splitting the lower body workout into two shorter intra-day sessions produced favorable increases in training volume and reductions in perceived rating of effort and discomfort in resistance-trained women. However, the long session was perceived as more pleasurable and 96% (22 out of 23) of the participants preferred the long session for their normal training routine. The two main reasons for this choice were time-efficiency, i.e., don‘t have to go to the gym twice, and an appreciation of the feeling of having performed a hard/exhausting session. Regarding time-efficiency, for some people it can be easier to schedule two short training sessions rather than one longer session depending on proximity to training facilities and individual time schedules. Thus, from a time-efficiency point of view, and in support of previous findings (Iversen et al., 2021), people should choose between performing one long or two shorter sessions in 1 day depending on what suits their individual calendar and preferences. Importantly, the different conditions did not affect the participants‘ readiness to train more than the other. Although these findings may be exclusive for the sample of the present study (resistance-trained women), it implies that there are several factors that should be considered when designing resistance training programs.

In conclusion, performing a longer, lower body resistance-training session led to greater perceptions of effort, discomfort and session pleasure than splitting the same program into two shorter sessions in resistance-trained young women. However, two shorter intra-day sessions led to modestly higher training volume, defined as number of successful repetitions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

HP and VA came up with the idea and wrote the first draft. All authors helped in developing the methodology, contributed to the article, and approved the submitted version.

Acknowledgments

We would like to thank the participants for their positivity and participation in the study. Further we would like to thank Andrine Turøy and Ida Lindelid for their help in collecting the data.

Conflict of interest

Author BS serves on the scientific advisory board of Tonal Corporation, a manufacturer of fitness equipment.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

ACSM (2009). American college of sports medicine position stand. Progression models in resistance training for healthy adults. *Med. Sci. Sports Exerc.* 41, 687–708. doi: 10.1249/MSS.0b013e3181915670

Andersen, V., Fimland, M. S., Iversen, V. M., Pedersen, H., Balberg, K., Gåsvær, M., et al. (2022). A comparison of affective responses between time efficient and traditional resistance training. *Front. Psychol.* 13, 912368. doi: 10.3389/fpsyg.2022.912368

Bartolomei, S., Malagoli Lanzoni, I., and Di Michele, R. (2011). Two vs. one resistance exercise sessions in one day: acute effects on recovery and performance. *Res. Q. Exerc. Sport.* 2022, 1–6. doi: 10.1080/02701367.2021.1939848

Bird, S. P., Tarpenning, K. M., and Marino, F. E. (2005). Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med*. 35, 841–851. doi: 10.2165/00007256-200535100-00002

Cohen, J. (1998). *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: L. Erlbaum Associates, 567.

Coratella, G. (2022). Appropriate reporting of exercise variables in resistance training protocols: much more than load and number of repetitions. *Sports Med. Open*. 8, 99. doi: 10.1186/s40798-022-00492-1

Ekkekakis, P., Hall, E. E., and Petruzzello, S. J. (2005). Variation and homogeneity in affective responses to physical activity of varying intensities: an alternative perspective on dose-response based on evolutionary considerations. *J. Sports Sci*. 23, 477–500. doi: 10.1080/02640410400021492

Ekkekakis, P., Parfitt, G., and Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Med*. 41, 641–671. doi: 10.2165/11590680-000000000-00000

Fisher, J. P., and Steele, J. (2017). Heavier and lighter load resistance training to momentary failure produce similar increases in strength with differing degrees of discomfort. *Muscle Nerve*. 56, 797–803. doi: 10.1002/mus.25537

Fusco, A., Knutson, C., King, C., Mikat, R. P., Porcari, J. P., Cortis, C., et al. (2020). Session RPE during prolonged exercise training. *Int. J. Sports Physiol. Perform*. 15, 292–294. doi: 10.1123/ijspp.2019-0137

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., et al. (2011). American college of sports medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med. Sci. Sports Exerc*. 43, 1334–1359. doi: 10.1249/MSS.0b013e318213fefb

Grgic, J., Schoenfeld, B. J., Davies, T. B., Lazinica, B., Krieger, J. W., and Pedisic, Z. (2018). Effect of resistance training frequency on gains in muscular strength: a systematic review and meta-analysis. *Sports Med*. 48, 1207–1220. doi: 10.1007/s40279-018-0872-x

Haff, G. G. (2010). Quantifying workloads in resistance training: a brief review. *Strength Cond. J*. 10, 31–40.

Häkkinen, K., and Kallinen, M. (1994). Distribution of strength training volume into one or two daily sessions and neuromuscular adaptations in female athletes. *Electromyogr. Clin. Neurophysiol*. 34, 117–124.

Halperin, I., and Emanuel, A. (2020). Rating of perceived effort: methodological concerns and future directions. *Sports Med*. 50, 679–687. doi: 10.1007/s40279-019-01229-z

Hartman, M. J., Clark, B., Bembens, D. A., Kilgore, J. L., and Bemben, M. G. (2007). Comparisons between twice-daily and once-daily training sessions in male weight lifters. *Int. J. Sports Physiol. Perform*. 2, 159–169. doi: 10.1123/ijspp.2.2.159

Hoare, E., Stavreski, B., Jennings, G. L., and Kingwell, B. A. (2017). Exploring motivation and barriers to physical activity among active and inactive Australian adults. *Sports* 5, 47. doi: 10.3390/sports5030047

Hurley, K. S., Flippin, K. J., Blom, L. C., Bolin, J. E., Hoover, D. L., and Judge, L. W. (2018). Practices, perceived benefits, and barriers to resistance training among women enrolled in college. *Int. J. Exerc. Sci*. 11, 226–238.

Iversen, V. M., Norum, M., Schoenfeld, B. J., and Fimland, M. S. (2021). No time to lift? designing time-efficient training programs for strength and hypertrophy: a narrative review. *Sports Med*. 51, 2079–2095. doi: 10.1007/s40279-021-01490-1

Lombard, W., Starling, L., Wewege, L., and Lambert, M. (2021). Changes in countermovement jump performance and subjective readiness-to-train scores following a simulated soccer match. *Eur. J. Sport Sci*. 21, 647–655. doi: 10.1080/17461391.2020.1757764

Paz, G. A., Robbins, D. W., de Oliveira, C. G., Bottaro, M., and Miranda, H. (2017). Volume load and neuromuscular fatigue during an acute bout of agonist-antagonist paired-set vs. traditional-set training. *J. Strength Cond. Res*. 31, 2777–2784. doi: 10.1519/JSC.0000000000001059

Pollak, K. A., Swenson, J. D., Vanhaitsma, T. A., Hughen, R. W., Jo, D., White, A. T., et al. (2014). Exogenously applied muscle metabolites synergistically evoke sensations of muscle fatigue and pain in human subjects. *Exp. Physiol*. 99, 368–380. doi: 10.1113/expphysiol.2013.075812

Ribeiro, A. S., Dos Santos, E. D., Nunes, J. P., and Schoenfeld, B. J. (2019). acute effects of different training loads on affective responses in resistance-trained men. *Int. J. Sports Med*. 40, 850–855. doi: 10.1055/a-0997-6680

Schwartz, H., Emanuel, A., Rozen, S., I. I., and Halperin, I. (2021). Exploring the acute affective responses to resistance training: A comparison of the predetermined and the estimated repetitions to failure approaches. *PLoS ONE*. 16, e0256231. doi: 10.1371/journal.pone.0256231

Scott, B. R., Duthie, G. M., Thornton, H. R., and Dascombe, B. J. (2016). Training monitoring for resistance exercise: theory and applications. *Sports Med*. 46, 687–698. doi: 10.1007/s40279-015-0454-0

Stanley, D. M., Williams, S., and Cumming, J. (2009). Preliminary validation of a single-item measure of exercise enjoyment: the exercise enjoyment scale. *J. Sport Exerc. Psychol*. 31, S138–S139.

Steele, J., Fisher, J., McKinnon, S., and McKinnon, P. (2016). Differentiation between perceived effort and discomfort during resistance training in older adults: reliability of trainee ratings of effort and discomfort, and reliability and validity of trainer ratings of trainee effort. *J. Trainol*. 6, 1–8. doi: 10.17338/trainology.6.1_1

Storey, A., Wong, S., Smith, H. K., and Marshall, P. (2012). Divergent muscle functional and architectural responses to two successive high intensity resistance exercise sessions in competitive weightlifters and resistance trained adults. *Eur. J. Appl. Physiol*. 112, 3629–3639. doi: 10.1007/s00421-012-2346-4

Unick, J. L., Strohacker, K., Papandonatos, G. D., Williams, D., O'Leary, K. C., Dorfman, L., et al. (2015). Examination of the consistency in affective response to acute exercise in overweight and obese women. *J. Sport Exerc. Psychol*. 37, 534–546. doi: 10.1123/jsep.2015-0104

Weakley, J. J. S., Till, K., Read, D. B., Roe, G. A. B., Darrall-Jones, J., Phibbs, P. J., et al. (2017). The effects of traditional, superset, and tri-set resistance training structures on perceived intensity and physiological responses. *Eur. J. Appl. Physiol*. 117, 1877–1889. doi: 10.1007/s00421-017-3680-3

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., and Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol. Sport Exerc*. 9, 231–245. doi: 10.1016/j.psychsport.2007.04.002

frontiers | Frontiers in Sports and Active Living

TYPE Original Research
PUBLISHED 18 November 2022
DOI 10.3389/fspor.2022.1029144

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Sports and Active Living

RECEIVED 26 August 2022
ACCEPTED 04 November 2022
PUBLISHED 18 November 2022

CITATION
Do B, Rhodes RE, Kanning M, Hewus M and Dunton GF (2022) Examining whether affectively-charged motivations predict subsequent affective response during physical activity: An ecological momentary assessment study.
Front. Sports Act. Living 4:1029144.
doi: 10.3389/fspor.2022.1029144

Examining whether affectively-charged motivations predict subsequent affective response during physical activity: An ecological momentary assessment study

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Background: Evidence suggests positive affective response during physical activity increases the likelihood of engaging in and maintaining regular activity exercise in the future. Elucidating antecedents for a positive affective response may help identify intervention strategies to increase activity. Affectively-charged motivations (e.g., desires, urges, dreading) have been posited as proximal antecedents to physical activity but have yet to be examined in terms of their influence on affective response in real-world settings. The current study used ecological momentary assessment (EMA) to examine within-subject effects of pre-physical activity affectively-charged motivation on subsequent affective response during physical activity.

Methods: Participants included 56 adults ($M = 39.18$ years, $SD = 11.98$; 67.86% female) who completed a 14-day smartphone-based EMA study. Prior to starting physical activity (time *t*), participants self-initiated an event-contingent EMA survey that assessed affectively-charged motivation for physical activity (i.e., rating scale from "dreading it" to "excited to do it"). EMA surveys prompted during subsequent physical activity (time $t + 15$ min) assessed affective response (i.e., feeling good—bad, energized—exhausted, thrilled—miserable, interested—bored, and relaxed—nervous). Multi-level linear regression models examined within-subject effects of pre- physical activity affectively-charged motivations on subsequent affective response during physical activity controlling for between-subjects effects of affectively-charged motivation, age, biological sex, time of day, and day of the week.

Results: Overall, there were $N = 304$ physical activity occasions in the analysis ($M = 5.43$, $SD = 3.97$). When individuals reported more positive affectively-charged motivation for physical activity than usual before physical activity occasions, they reported feeling more energized (Estimate $= 0.22$, $p < 0.001$), good (Estimate $= 0.25$, $p < 0.001$), thrilled (Estimate $= 0.12$, $p = 0.02$), and interested (Estimate = 0.24, $p < 0.001$) during subsequent physical activity. Affectively-charged motivation was not associated with feeling more relaxed (Estimate = 0.11, $p = 0.13$) during subsequent physical activity.

Conclusion: Momentary affectively-charged motivations predicted more positive affective response during subsequent physical activity among active adults. Future research can explore potential sources of intraindividual differences in affectively-charged motivations and further examine these associations with future physical activity behavior. To improve positive affective responses, interventions may boost affectively-charged motivations through real-time mobile prompting in naturalistic settings.

KEYWORDS

affective, physical activity, exercise, motivation, experience sampling method (ESM)/ecological momentary assessment (EMA)

Introduction

Affective constructs have received increased attention and have been applied to conceptual models (1–4), theories, research, and interventions for physical activity (5–7). Consistent with hedonic theories of behavior, affective response during physical activity has been posited as a key determinant of future physical activity behavior (8). Hedonic theories suggest humans tend to maximize pleasure and minimize displeasure, and affective response to a behavior may influence future decisions on whether or not to repeat that behavior (9, 10). Affective response during physical activity has been shown to be associated with future activity levels; research suggests positive affective response during physical activity increases the likelihood of engaging and maintaining physical activity in the future (11). For example, adults who engaged more positive affective response during a moderate-intensity bout of exercise in the laboratory reported more minutes of physical activity at both 6 and 12 months later (12). In practice, these findings translate to a one-unit increase in positive affective response on an 11-point scale being associated with an increase in 38 and 41 min of physical activity per week at 6 and 12 months, respectively (12). The World Health Organization recommends adults engage in at least 150 min of moderate-to-vigorous-intensity physical activity per week for optimal health benefits such as reducing the risk for cardiovascular and metabolic diseases, some cancers, symptoms of depression and anxiety, and premature mortality (13). However, most adults do not meet the recommended levels of activity (14). Therefore, understanding the antecedents to having a positive affective response during physical activity can help identify intervention strategies to promote regular physical activity.

Affectively-charged motivations have been posited as proximal antecedents to physical activity but have yet to be examined in terms of their relevance to affective response to physical activity. While there are varying conceptualizations of motivations for physical activity (4, 15), Stevens and colleagues state affectively-charged motivation for physical activity includes motivational states that have their basis in past affective responses to physical activity, such as hedonic motivation (i.e., desire, dread, craving), intrinsic motivation, and fear (8). Affectively-charged motivation is related to affective response such that people typically crave or desire experiences in which they have had a previous positive affective response (4). Affectively-charged motivation and affective response may be based in hedonism, but they are two distinct constructs that may individually and uniquely contribute to physical activity. It is also unclear whether affectively-charged motivation predicts how one will respond affectively when they engage in subsequent physical activity. Elucidating the proximal antecedents of affective response is critical for understanding how to improve affective response, and in turn increase physical activity behaviors.

Previous literature has examined concurrent determinants of affective response to physical activity. For example, higher positive affective response was reported when engaging in physical activity with other people as compared to being alone, and higher negative affective response was reported when engaging in physical activity indoors as compared to outdoors (16). Robust findings from laboratory studies have also demonstrated the association between physical activity intensity and affective response (17). Findings indicate homogenous negative shifts in affective valence as physical activity intensity increases beyond one's ventilatory threshold, yet there is heterogeneity in affective response to moderate-intensity activity based on fitness levels, body composition, and cognitive factors (18, 19). Despite these findings, there is limited research exploring the interconnection between affective constructs.

Previous research on affective response to physical activity has largely been conducted in laboratory settings; however, research in naturalistic settings is necessary to elucidate these processes in naturally-occurring physical activity in everyday life and how these processes occur on a *moment-to-moment* basis. Ecological momentary assessment (EMA)—a real-time data capture methodology that involves repeatedly assessing participants' current states, behaviors, and context in naturalistic settings—is well-suited to gather data on naturally occurring phenomenon such as affective constructs (20). EMA methods aim to reduce biases related to recall by assessing current states and behaviors, or recent ones. Unlike traditional retrospective study designs, EMA methods can provide information at the momentary level. Additionally, this data can more accurately portray participants' typical context and settings (21). Multiple assessments through EMA can also address research questions about within-person variation in affective determinants and how processes unfold over time. For example, within-person variability in desires, cravings, and wants have been less explored. Results across five validation studies for the Cravings for Rest and Volitional Energy Expenditure scale indicated desires/wants are transient and more of a motivation state rather than a trait (22). Understanding whether there are intraindividual differences in affectively-charged motivation on affective response during physical activity can highlight the importance of targeting affectively-charged motivation in interventions.

Therefore, the objective of the current study was to use EMA to examine the within-subject effects of pre-physical activity affectively-charged motivation on subsequent affective response during physical activity in naturalistic settings among physically active adults. It was hypothesized that on physical activity occasions when individuals reported more pre-physical activity affectively-charged motivation than usual, they would report more positive affective response during subsequent physical activity. Specifically, reporting feeling more excited (vs. dread)—than usual—before a physical activity bout would be associated with reports of feeling more energized, good, thrilled, interested, and relaxed during subsequent physical activity. Feeling good (vs. bad), energized (vs. exhausted), thrilled (vs. miserable), interested (vs. bored), and relaxed (vs. nervous) were selected to assess affective response in order to represent the two fundamental dimensions of affect as suggested by the circumplex model (i.e., valence and arousal) (23).

Materials and methods

Overview and design

An intensive longitudinal study design using a 14-day interval-contingent/fixed time-based and event-contingent EMA study examined affective mechanisms associated with recreational, leisure-time physical activity. Data collection took place between August 2020 and August 2021. All study recruitment and data collection took place remotely to eliminate in-person interactions during the coronavirus disease 2019 (COVID-19) pandemic. This study was conducted in accordance with the Declaration of Helsinki and all aspects of the study were approved by the Institutional Review Board at the University of Southern California (UP-20-00321).

Participants and recruitment

To be eligible for the study, participants needed to: (1) be between the ages of 18–65 years old; (2) able to read and speak in English; (3) use an Android smartphone as their primary personal phone; and (4) currently engage in at least 60 min of structured exercise a week. Exclusion criteria included: (1) cardiovascular, respiratory, muscular, or bone/joint problems that preclude physical activity; (2) taking psychotropic medications; (3) receiving treatment for any psychiatric disorder; (4) inability to answer smartphone-based survey for extending periods of time due to work, care giving, or driving requirements; (5) have a body mass index under 18.5 kg/m^2 or over 50 kg/m^2 (categorized as underweight or morbidly obese); (6) current cigarette smoker; (7) diabetic; (8) unable or unwilling to answer EMA surveys while exercising; (9) been treated for cancer within the past 6 months (e.g., chemotherapy, surgery, radiation); or 10) swim for exercise more than once a week. Inclusion and exclusion criteria were established to: include participants that regularly engage in physical activity to guarantee activity data in naturalistic settings; consider the health and safety of participants; ensure that sufficient data is collected from the smartphone during the 14-day period.

Potential participants were recruited through social media postings, website postings, and advertisements on platforms such as Facebook, Twitter, Instagram, and Reddit. Emails were also sent to potentially eligible participants through ResearchMatch (a national health volunteer registry that was created by several academic institutions and supported by the U.S. National Institutes of Health as part of the Clinical Translational Science Award program). Previous study participants from University of Southern California research studies—who had previously indicated that they were willing to be contacted for future research—were also contacted through email. Interested individuals were asked to complete an electronic interest form, in which study staff assessed for initial eligibility. If participants were considered potentially eligible, they were then immediately prompted to fill out a short questionnaire to further assess eligibility. Eligible participants were then contacted by a study staff member to participate in the study.

Procedures

Eligible participants were invited to complete a baseline session through video conference with study staff. During the baseline session informed consent was obtained and a consent form was electronically signed. Participants were given a link to complete an electronic baseline questionnaire though an online survey platform REDCap (Research Electronic Data Capture) (24). Participants were able to complete the survey on a mobile phone, tablet, or desktop device. Participants received instructions on how to download the study smartphone application on the participant's personal smartphone and answer EMA surveys through a virtual orientation with a study staff member. Participants also wore a waist-worn accelerometer during the 14-day period; however, the data was not used in the current analyses to answer the study objectives. After the study period, participants completed an exit interview through videoconference with a study staff member. Participants received up to 150 USD for study participation with incentives based upon compliance to study procedures.

Measures

Ecological momentary assessment

Participants downloaded a free EMA application and completed 14 consecutive days of EMA on their personal Android smartphone. EMA data were collected through a commercial software mobile phone application for Android smartphones (movisensXS by movisens GmbH; Karlsruhe, Germany). Participants responded to event-contingent EMA surveys. Participants were instructed to manually initiate a "pre-physical activity" EMA survey in the smartphone application before each time that they did physical activity during the 14-day period. The survey took about 1 min to complete. Following the completion of the pre- physical activity EMA survey, participants were instructed to begin their physical activity as planned. The smartphone application automatically prompted additional "during- physical activity" EMA surveys 15 min after the completion of the pre- physical activity survey through an audible noise and or/vibration. Participants were asked to briefly pause their activity, complete the EMA survey if it was safe to do so, and then return to their activity. Each during- physical activity survey took about 30 s to complete. If no entry was made, the application sent one reminder signal in 5 min. After the reminder signal, the EMA survey closed and was no longer accessible to the participant.

Affectively-charged motivations

During the pre-physical activity EMA surveys participants were asked "Do you intend to exercise in the next 15 min?" with answer options "Yes," "No," "Not sure." If "yes" was selected, participants were subsequently asked "How do you feel about exercising in the next 15 min?" A sliding scale from "Dreading it" to "Excited to do it" was provided on the screen. Although participants were not presented numeric values on the screen, the EMA application assigned a numeric value to where the slider was positioned ranging from 0 ("Dreading it") to 100 ("Excited to do it"); higher values indicated more positive affectively-charged motivation. This item was developed by the study investigators/authors.

Pre-physical activity affect

The pre-physical activity EMA prompt assessed momentary affect. Participants were asked "How do you feel right now?" On the same screen, five visual analog scales were presented: "Bad" to "Good," "Exhausted" to "Energized," "Miserable" to "Thrilled," "Bored" to "Interested," and "Relaxed" to "Nervous" (23, 25–27). A numeric value, ranging from 0 to 100, was assigned to the slider position. For the analyses, higher values indicated feeling more good, energized, thrilled, interested, and relaxed.

Affective response

The during-physical activity EMA prompt assessed affective response during physical activity. The first item of the survey asked, "Are you finished exercising?" If participants indicated "No," then affective response during physical activity was measured. Participants were asked "How do you feel right now?" On the same screen, five visual analog scales were presented: "Bad" to "Good," "Exhausted" to "Energized," "Miserable" to "Thrilled," "Bored" to "Interested," and "Relaxed" to "Nervous" (23, 25–27). Each sliding scale did not have visible numeric values; however, the EMA application assigned a numeric value based on the slider position ranging from 0 to 100, with higher values indicating feeling more good, energized, thrilled, interested, and nervous. For the analyses, feeling nervous was reverse coded so a higher value indicated feeling more relaxed.

Participant characteristics

Participants self-reported the following characteristics in the baseline survey: age, sex at birth (male, female), gender identity (male, female, trans male/trans man, trans female/trans woman, genderqueer/gender non-conforming, different identity) race (American Indian or Alaska Native, Asian Indian, Black or African American, Chinese, Filipino, Guamanian or Chamorro, Japanese, Korean, Native Hawaiian, Other Asian, Other Pacific Islander, Samoan, Vietnamese, and White); ethnicity (Hispanic, Latino/a, or Spanish origin, not Hispanic, Latino/a, or Spanish origin); total combined family income for the past 12 months (< $12,000, $12,000–24,999, $25,000–34,999, $35,999–44,999, $45,000–54,999, $55,000–64,999, $65,000–74,999, $75,000–84,999, $85,000–94,999, $95,000–104,999, $105,000–114,999, $115,000–124,999, and >$125,000); and employment status (employed for wages, self-employed, out of work for 1 year or more, out of work for <1 year, homemaker, student, retired, and unable to work). Participants were not required to answer these questions if they preferred not to.

Statistical analyses

The analytic plan was specified prior to the analysis. To test the study objective of examining within-subject effects of pre-physical activity affectively-charged motivation on subsequent affective response during physical activity, multi-level linear regression models were conducted. Affectively-charged motivation was disaggregated into within-subject (Level-1, physical activity occasion) and between-subject (Level-2, participant) levels to partition the variance (28). The within-subject variance represents the deviation from one's own mean on any given physical activity occasion and the between-subject variance represents the individual mean deviation from the grand mean deviation (mean of all observations across all participants) (29). The outcomes—feeling good, energized, thrilled, interested, and relaxed—were examined in separate multi-level models. All models adjusted for the following variables a priori: between-subject effects of affectively-charged motivation, pre-physical activity affect, age, sex at birth (female, male), time of day (morning 6 A.M.-12 P.M.; afternoon 12 P.M.-6 P.M.; evening 6 P.M.-6 A.M.), day of week (weekday, weekend day). All analyses were conducted in SPSS Version 25 and statistical significance was set at $p < 0.05$. Unstandardized regression coefficients, standard errors, and p-values are reported.

Results

Data availability

A total of 720 individuals expressed interest in the study and completed the online eligibility questionnaire. Of this number, 206 individuals were eligible, and 76 individuals subsequently agreed to participate in the study and completed informed consent. A total of 68 participants had some completed EMA data (i.e., responded to at least one EMA survey) during the 14-day period. There were 684 completed pre- physical activity observations and 327 completed during- physical activity observations (i.e., 15 min after the completion of the pre- physical activity EMA prompt) among 66 participants. After matching the pre- physical activity and during- physical activity observations, the final analytic sample included N = 56 participants (Level-2) and N = 304 physical activity occasions (Level-1).

Participant characteristics

Descriptive statistics for participant characteristics are shown in Table 1. Participants ranged in age from 22 to 65 years with an average age of 39.2 (SD = 12.0) years. Most

TABLE 1 Participant characteristics ($N = 56$).

Demographics	n (%)
Age in years (Mean ± SD)	39.2 ± 12.0
Sex at birth	
Female	38 (67.9)
Male	18 (32.1)
Gender identity	
Female	36 (64.3)
Male	18 (32.1)
Trans female/trans woman	1 (1.8)
Trans male/trans man	0 (0)
Genderqueer/gender non-conforming	1 (1.8)
Hispanic, Latino/a, or Spanish origin	
Yes	5 (8.9)
No	51 (91.9)
Race[a]	
American Indian or Alaska Native	2
Asian Indian	6
Black or African American	9
Chinese	2
Filipino	1
Guamanian or Chamorro	0
Japanese	0
Korean	2
Other Asian	1
Other Pacific Islander	0
Native Hawaiian	0
Samoan	0
Vietnamese	1
White	36
Education	
High school graduate	3 (5.4)
Some college or technical school	6 (10.7)
College graduate	47 (83.9)
Work status	
Employed for wages	36 (64.3)
Self-employed	5 (8.9)
Out of work for 1 year or more	2 (3.6)
Out of work for <1 year	3 (5.4)
Homemaker	3 (5.4)
Student	6 (10.7)
Retired	1 (1.8)
Annual household income[b]	
< $35,000	14 (25.5)
$35,000–64,999	17 (30.9)
$65,000–114,999	16 (29.1)
≥ $115,000	8 (14.5)

[a]Participants were able to select all that apply.
[b]Data missing for one participant.

participants selected "female" sex at birth and self-identified as White. About 64% of the sample were employed for wages and 43% reported a total combined family income for the past 12 months of >$65,000. The average number of physical activity occasions per participant was 5.43 (range 1–19) during the 14-day period. The mean affectively-charged motivation [0 ("Dreading it") to 100 ("Excited to do it")] was 75.2 (*SD* = 20.2). Affective response during physical activity scores were: feeling good (M = 77.7, *SD* = 14.4), feeling energized (M = 72.7, *SD* = 17.7), feeling thrilled (M = 71.8, *SD* = 15.4), feeling interested (M = 73.7, *SD* = 17.5), and feeling relaxed (M = 71.1, *SD* = 19.9).

TABLE 2 Multi-level models examining the association between affectively-charged motivation and feeling good and feeling energized.

	Good-bad		Energized-exhausted	
	Estimate (*SE*)	***p***	**Estimate (*SE*)**	***p***
Intercept	77.66 (2.99)	<0.001	65.29 (5.74)	<0.001
Level-1 (Physical activity bout)				
Within-subject affectively-charged motivation	0.25 (0.04)	<0.001	0.22 (0.07)	<0.01
Within-subject pre-physical activity affect[a]	0.15 (0.05)	<0.01	0.09 (0.05)	0.09
Weekday[b]	0.44 (1.07)	0.68	0.09 (1.67)	0.99
Time of day (morning)[c]	0.81 (1.44)	0.58	4.43 (2.41)	0.07
Time of day (afternoon)[d]	0.23 (1.42)	0.87	0.23 (2.34)	0.92
Level-2 (Person)				
Between-subject affectively-charged motivation	0.22 (0.07)	<0.01	0.38 (0.09)	<0.001
Between-subject pre-physical activity affect[a]	0.65 (0.09)	<0.001	0.45 (0.13)	<0.01
Age	−0.05 (0.07)	0.48	0.11 (0.13)	0.41
Sex at birth (female)[e]	4.27 (1.61)	0.01	1.01 (3.21)	0.75

N = 56 participants, N = 304 day-level observations.
[a]Corresponding pre-physical activity affect (i.e., good or energized).
[b]Weekday vs. weekend day.
[c]Morning (6 A.M.−12 P.M.) vs. evening (5 P.M.−6 A.M.).
[d]Afternoon (12 P.M. −5 P.M.) vs. evening (5 P.M. −6 A.M.).
[e]Female vs. male.

TABLE 3 Multi-level models examining the association between affectively-charged motivation and feeling thrilled and feeling interested.

	Thrilled-miserable		Interested-bored	
	Estimate (*SE*)	***p***	**Estimate (*SE*)**	***p***
Intercept	67.69 (4.08)	<0.001	71.04 (4.07)	<0.001
Level-1 (Physical activity bout)				
Within-subject affectively-charged motivation	0.12 (0.05)	0.02	0.24 (0.05)	<0.001
Within-subject pre-physical activity affect[a]	0.29 (0.05)	<0.001	0.20 0.05)	<0.001
Weekday[b]	−0.53 (1.27)	0.67	0.54 (1.34)	0.69
Time of day (morning)[c]	2.68 (1.78)	0.13	1.06 (1.87)	0.57
Time of day (afternoon)[d]	2.22 (1.73)	0.20	0.77 (1.82)	0.67
Level-2 (Person)				
Between-subject affectively-charged motivation	0.23 (0.08)	<0.01	0.19 (0.08)	0.02
Between-subject pre-physical activity affect[a]	0.60 (0.10)	<0.001	0.71 (0.09)	<0.001
Age	0.04 (0.09)	0.67	0.02 (0.09)	0.80
Sex at birth (female)[e]	3.02 (2.21)	0.18	1.53(2.22)	0.50

N = 56 participants, N = 304 day-level observations.
[a]Corresponding pre-physical activity affect (i.e., thrilled or interested).
[b]Weekday vs. weekend day.
[c]Morning (6 A.M.−12 P.M.) vs. evening (5 P.M.−6 A.M.).
[d]Afternoon (12 P.M.−5 P.M.) vs. evening (5 P.M.−6 A.M.).
[e]Female vs. male.

 10.3389/fspor.2022.1029144

Within-subject effects of affectively-charged motivation on affective response during physical activity

A series of multi-level linear regressions examined the within-subject effects of affectively-charged motivation on affective response during subsequent physical activity. Unstandardized coefficients and standard errors are shown in Tables 2–4. Neither day of week (weekend day vs. weekday) or time of day (morning vs. evening and afternoon vs. evening) were significantly associated with affective response in all four models. There were significant within-subject effects such that when individuals reported more positive affectively-charged motivation for physical activity than usual before physical activity occasions, they reported feeling more energized (Estimate = 0.22, $p < 0.001$), good (Estimate = 0.25, $p < 0.001$), thrilled (Estimate = 0.12, $p = 0.02$), and interested (Estimate = 0.24, $p < 0.001$) during subsequent physical activity. Results indicate that for every 10-point increase in affectively-charged motivation (i.e., excited to do it vs. dreading it), their affective response (i.e., feeling energized, good, thrilled, and interested) during subsequent physical activity score increased by about 2 points. Affectively-charged motivation was not associated with feeling more relaxed (Estimate = 0.11, $p = 0.13$) during subsequent physical activity.

TABLE 4 Multi-level models examining the association between affectively-charged motivation and feeling relaxed.

	Relaxed-nervous	
	Estimate (*SE*)	***p***
Intercept	77.79 (5.03)	<0.001
Level-1 (Physical activity bout)		
Within-subject affectively-charged motivation	0.11 (0.07)	0.13
Within-subject pre-physical activity affect[a]	0.42 (0.06)	<0.001
Weekday[b]	−1.82 (1.87)	0.33
Time of day (morning)[c]	−0.42 (2.49)	0.87
Time of day (afternoon)[d]	−1.63 (2.45)	0.51
Level-2 (Person)		
Between-subject affectively-charged motivation	0.15 (0.08)	0.05
Between-subject pre-physical activity affect[a]	0.68 (0.08)	<0.001
Age	−0.12 (0.11)	0.24
Sex at birth (female)[e]	−0.37 (2.68)	0.89

N = 56 participants, N = 304 day-level observations.
[a]Corresponding pre-physical activity affect (i.e., relaxed).
[b]Weekday vs. weekend day.
[c]Morning (6 A.M.−12 P.M.) vs. evening (5 P.M.−6 A.M.).
[d]Afternoon (12 P.M.−5 P.M.) vs. evening (5 P.M.−6 A.M.).
[e]Female vs. male.

Discussion

To our best knowledge, the current study is the first known attempt to assess associations between affectively-charged motivation and subsequent affective response during physical activity in naturalistic settings among physically active adults. Furthermore, EMA data was used to examine interindividual differences in affectively-charged motivations (i.e., within-subject effects) on affective response. Findings indicated greater momentary affectively-charged motivation predicted more positive affective response during subsequent physical activity. On physical activity occasions when individuals reported more positive affectively-charged motivation for physical activity than usual, they reported feeling more energized, good, thrilled, and interested, but not more relaxed, during subsequent physical activity. This study contributes knowledge on proximal antecedents of affective response to physical activity and underscores the importance of examining how variations in motivation for physical activity works in the moment.

Despite the recent call to attention for examining motivation states for movement (15), this area of research has been mostly overlooked. A recently published scoping review protocol on urges to move and motivation states for physical activity among healthy and clinical populations noted that the scope of the literature describing affectively-charged motivational states remains largely unknown (30). Little research has been conducted on measuring desire or craving for physical activity; the vast majority of research on motivation states focused on health behaviors such as alcohol, smoking, substance use, and eating (31–33). However, one published study investigated desires for experiences people's natural environments and findings revealed desire strength was significantly above average for sports participation, and other experiences including sleep, sex, hygiene, social contact, and non-alcoholic drinks (34). Our study's findings contribute to the limited literature base on affectively-charged motivation for physical activity and provide further evidence for motivation states varying from moment-to-moment. Future studies can extend these findings by conducting additional intensive longitudinal studies on affectively-charged motivations in naturalistic settings among different populations and examine potential associations with other affective determinants (e.g., processed affect) and objectively-measured activity.

Given the previous evidence for associations between affective response and future physical activity behaviors (10, 11), intervention strategies which result in positive shifts in affective valence during physical activity need to be developed. The current study's findings suggest that efforts to influence affective response during physical activity may be more effective if affectively-charged motivations are considered or targeted. Stults and colleagues proposed general approaches for increasing desires or urges to move, such as: modifying the reward value of exercise by making it more pleasurable/less punishable, environmental and situational conditions to boost motivation states to move, ‘nudging' people in response to desires/cravings, and taking advantage of urges/desires for other rewarding behaviors to encourage the development of desires to move (15). An example of the latter approach is the gamification of Pokémon GO—which is contingent on physical movement—and therefore may increase the reward value of movement (35). Real-time mobile prompting may also prove to be efficacious for increasing physical activity by targeting momentary affectively-charged motivations in real-time and real-world settings. Given that recommendations have also been applied to affective processing, additional research on distinct techniques for targeting affectively-charged is warranted (7).

Our findings provide support for the associations between affectively-charged motivation and affective response (i.e., feeling good, energized, thrilled, and interested) during physical activity, but associations with feeling relaxed were non-significant. The null associations between affectively-charged motivation and feeling relaxed may be due to the fact that affectively-charged motivation ("feeling excited") is an activating motivation, whereas "feeling relaxed" is a deactivated affective response. While both items are similar in valence (i.e., positive), they differ in their activation state. To build upon these findings, additional research is needed to examine whether these associations predict future physical activity behaviors. Longitudinal research with repeated assessments or experimental designs could elucidate the potential causal pathways in which affectively-charged motivation and affective response influence physical activity (8). Furthermore, studies could determine whether solely targeting affectively-charged motivation or solely targeting affective response, or both simultaneously, is the most successful for promoting future activity. Some intervention strategies—such as evaluative conditioning (i.e., changing attitudes through an object's pairing with a positively valanced stimuli)—may influence multiple affective constructs such as affectively-charged motivation, affective response, and affective processing (7, 8, 36). Considering multiple affective determinants and how they vary from moment-to-moment can strengthen previous physical activity interventions predominantly focused on targeting cognitive factors.

Strengths and limitations

The study had several strengths such as the assessment of multiple affective constructs in naturalistic settings and the ability to examine within-subjects associations through multiple assessments per participant. To our best knowledge, this is the first published study to examine associations of affectively-charged motivations and affective response through EMA in participants' everyday lives. The study extends previous research conducted in laboratory settings, yielding more generalizable findings. However, the study did have some limitations. First, only one item was used to assess affectively-charged motivation for physical activity in the pre-physical activity EMA survey. Future EMA studies could use or adapt items from newer measurement scales; in example, the Cravings for Rest and Volitional Energy Expenditure (CRAVE) assessment measures motivation states (i.e., wants, desires, urges) for physical activity and sedentary behavior "at this very moment (i.e., Right now)" (22). Prior to the development of CRAVE, there has not been a validated instrument to assess affectively-charged motivation specifically to physical activity and previous research often asked participants to retrospectively report their motivations. Future EMA research could incorporate validated measures, and future research needs to seek a consensus on terms and definitions used to describe the constructs of desire, craving, wanting, and dread. Furthermore, conceptual and theoretical models can establish whether these are each unique, individual constructs in regards to the target behavior, or if they fall under distinguished categories such as affectively-charged motivational states, hedonic motivation, or automatic motivation (15). Another study limitation to note is that the study may not have captured all physical activity occasions that occurred during the 14-day study period. Participants were given the option to dismiss the during-physical activity EMA survey prompt, and they may have dismissed a survey if it was unsafe for them to complete the survey while exercising (e.g., biking, running through city streets). One of the study's strengths was the ability to assess self-initiated physical activity occurring in naturalistic settings. However, it may not be feasible or safe to capture all types of physical activity. Lastly, the sample largely consisted of self-identifying females from middle-to-higher income households, who also were already engaging in regular physical activity (i.e., at least 60 min per week). Findings may not be generalizable to other sub-groups such as those who are not currently physically active. In addition, the analytic sample included 56 adults (73% of participants enrolled in the study). However, the intensive longitudinal study design allowed us to examine over 300 physical activity occasions. Additional research is needed to examine these momentary associations in larger, more representative samples.

Conclusion

Overall, study findings suggest momentary affectively-charged motivation predicted more positive affective response during subsequent physical activity in naturalistic settings among active adults. These results contribute to the limited literature on affectively-charged motivation for physical activity and underscore the importance of including affective constructs in research and physical activity programming. Future studies should examine casual pathways in which affectively-charged motivation and affective response predict future engagement in physical activity. Interventions seeking to promote physical activity may benefit by developing targeted strategies to enhance affectively-charged motivation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by University of Southern California Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

BD wrote the first draft of the manuscript and performed the statistical analysis. BD, GD, and MH contributed to the conception and design of the study. BD, RR, MK, MH, and GD contributed to manuscript editing and revision. All authors read and approved the submitted version.

Funding

Funding for this research was provided by a University of Southern California Zumberge Large Interdisciplinary Grant and by the National Institutes of Health, National Heart, Lung, and Blood Institute (3U01HL146327-03S1). This work was also supported by the Achievement Rewards for College Scientists Foundation Los Angeles Founder Chapter.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Brand R, Ekkekakis P. Affective–reflective theory of physical inactivity and exercise. *Ger J Exerc Sport Res.* (2018) 48:48–58. doi: 10.1007/s12662-017-0477-9

2. Cheval B, Boisgontier MP. The theory of effort minimization in physical activity. *Exerc Sport Sci Rev.* (2021) 49:168–78. doi: 10.1249/JES.0000000000000252

3. Rhodes RE. Multi-process action control in physical activity: a primer. *Front Psychol.* (2021) 12:797484. doi: 10.3389/fpsyg.2021.797484

4. Williams DM, Evans DR. Current emotion research in health behavior science. *Emotion Review.* (2014) 6:277–87. doi: 10.1177/1754073914523052

5. Chen C, Finne E, Kopp A, Jekauc D. Can positive affective variables mediate intervention effects on physical activity? a systematic review and meta-analysis. *Front Psychol.* (2020) 11:587757. doi: 10.3389/fpsyg.2020.587757

6. Pears S, Sutton S. Effectiveness of acceptance and commitment therapy (ACT) interventions for promoting physical activity: a systematic review and meta-analysis. *Health Psychol Rev.* (2021) 15:159–84. doi: 10.1080/17437199.2020.1727759

7. Rhodes RE, Gray SM, Husband C. Experimental manipulation of affective judgments about physical activity: a systematic review and meta-analysis of adults. *Health Psychol Rev.* (2019) 13:18–34. doi: 10.1080/17437199.2018.1530067

8. Stevens CJ, Baldwin AS, Bryan AD, Conner M, Rhodes RE, Williams DM. Affective determinants of physical activity: a conceptual framework and narrative review. *Front Psychol.* (2020) 11:587757. doi: 10.3389/fpsyg.2020.568331

9. Kahneman D, Wakker PP, Sarin R. Back to bentham? Explorations of experienced utility. *Quarterly J. Econ.* (1997) 112:375–406. doi: 10.1162/003355397555235

10. Williams DM, Rhodes RE, Conner MT. Psychological hedonism, hedonic motivation, and health behavior. *Affect Deter Health Behav.* (2018) 1:204–17. doi: 10.1093/oso/9780190499037.003.0010

11. Rhodes RE, Kates A. Can the affective response to exercise predict future motives and physical activity behavior? a systematic review of published evidence. *Ann Behav Med.* (2015) 49:715–31. doi: 10.1007/s12160-015-9704-5

12. Williams DM, Dunsiger S, Ciccolo JT, Lewis BA, Albrecht AE, Marcus BH. Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol Sport Exerc.* (2008) 9:231–45. doi: 10.1016/j.psychsport.2007.04.002

13. World Health Organization (2020). *Physical Activity*. Available online at: https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed July 12, 2021).

14. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The physical activity guidelines for Americans. *JAMA.* (2018) 320:2020–8. doi: 10.1001/jama.2018.14854

15. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Gilson TA, Ash GI, McKee PC, et al. Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front Psychol.* (2020) 11:568390. doi: 10.3389/fpsyg.2020.568390

16. Dunton GF, Liao Y, Intille S, Huh J, Leventhal A. Momentary assessment of contextual influences on affective response during physical activity. *Health Psychol.* (2015) 34:1145–53. doi: 10.1037/hea0000223

17. Ekkekakis P, Parfitt G, Petruzzello SJ. The pleasure and displeasure people feel when they exercise at different intensities. *Sports Med.* (2011) 41:641–71. doi: 10.2165/11590680-000000000-00000

18. Ekkekakis P, Hall EE, Petruzzello SJ. Variation and homogeneity in affective responses to physical activity of varying intensities: an alternative perspective on dose – response based on evolutionary considerations. *J Sports Sci.* (2005) 23:477–500. doi: 10.1080/02640410400021492

19. Ekkekakis P, Hall EE, Petruzzello SJ. Practical markers of the transition from aerobic to anaerobic metabolism during exercise: rationale and a case for affect-based exercise prescription. *Preventive Med.* (2004) 38:149–59. doi: 10.1016/j.ypmed.2003.09.038

20. Shiffman S, Stone AA, Hufford MR. Ecological momentary assessment. *Annu Rev Clin Psychol.* (2008) 4:1–32. doi: 10.1146/annurev.clinpsy.3.022806.091415

21. Stone A, Shiffman S, Atienza A, Nebeling L. *The Science of Real-Time Data* Capture: Self-Reports in Health Research. New York, NY: Oxford University Press (2007).

22. Stults-Kolehmainen MA, Blacutt M, Fogelman N, Gilson TA, Stanforth PR, Divin AL, et al. Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front Psychol.* (2021) 12:568286. doi: 10.3389/fpsyg.2021.568286

23. Russell JA. A circumplex model of affect. *J Pers Soc Psychol.* (1980) 39:1161–78. doi: 10.1037/h0077714

24. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* (2009) 42:377–81. doi: 10.1016/j.jbi.2008.08.010

25. Thayer RE. *The Biopsychology of Mood and Arousal*. New York, NY: Oxford University Press (1990).

26. Wilhelm P, Schoebi D. Assessing mood in daily life: structural validity, sensitivity to change, and reliability of a short-scale to measure three basic dimensions of mood. *Eur J Psychol Assess.* (2007) 23:258–67. doi: 10.1027/1015-5759.23.4.258

27. Wolff W, Bieleke M, Martarelli CS, Danckert J. A primer on the role of boredom in self-controlled sports and exercise behavior. *Front Psychol.* (2021) 12:637839. doi: 10.3389/fpsyg.2021.637839

28. Curran PJ, Bauer DJ. The disaggregation of within-person and between-person effects in longitudinal models of change. *Annu Rev Psychol.* (2011) 62:583–619. doi: 10.1146/annurev.psych.093008.100356

29. Hedeker D, Nordgren R. MIXREGLS: a program for mixed-effects location scale analysis. *J Stat Softw.* (2013) 52:1–38. doi: 10.18637/jss.v052.i12

30. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Boullosa D, Janata P, Koo BB, et al. Urges to move and other motivation states for physical activity in clinical and healthy populations: a scoping review protocol. *Front Psychol.* (2022) 13:901272. doi: 10.3389/fpsyg.2022.901272

31. Kavanagh DJ, Statham DJ, Feeney GFX, Young R, Mc D, May J, et al. Measurement of alcohol craving. *Addict Behav.* (2013) 38:1572–84. doi: 10.1016/j.addbeh.2012.08.004

32. May J, Andrade J, Kavanagh DJ, Feeney GFX, Gullo MJ, Statham DJ, et al. The craving experience questionnaire: a brief, theory-based measure of consummatory desire and craving. *Addiction.* (2014) 109:728–35. doi: 10.1111/add.12472

33. Statham DJ, Connor JP, Kavanagh DJ, Feeney GFX, Young R, Mc D, et al. Measuring alcohol craving: development of the alcohol craving experience questionnaire. *Addiction*. (2011) 106:1230–8. doi: 10.1111/j.1360-0443.2011.03442.x

34. Hofmann W, Vohs KD, Baumeister RF. What people desire, feel conflicted about, and try to resist in everyday life. *Psychol Sci.* (2012) 23:582–8. doi: 10.1177/0956797612437426

35. Kaczmarek LD, Misiak M, Behnke M, Dziekan M, Guzik P. The pikachu effect: social and health gaming motivations lead to greater benefits of pokémon GO use. *Comput Human Behav.* (2017) 75:356–63. doi: 10.1016/j.chb.2017.05.031

36. Jones CR, Olson MA, Fazio RH. Evaluative conditioning: the "how" question. *Adv Exp Soc Psychol.* (2010) 43:205–55. doi: 10.1016/S0065-2601(10)43005-1

TYPE Hypothesis and Theory
PUBLISHED 25 January 2023
DOI 10.3389/fpsyg.2023.1021825

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to
Movement Science and Sport Psychology,
a section of the journal
Frontiers in Psychology

RECEIVED 17 August 2022
ACCEPTED 09 January 2023
PUBLISHED 25 January 2023

CITATION
Park KS, Williams DM and Etnier JL (2023)
Exploring the use of music to promote physical activity: From the viewpoint of psychological hedonism.
Front. Psychol. 14:1021825.
doi: 10.3389/fpsyg.2023.1021825

Exploring the use of music to promote physical activity: From the viewpoint of psychological hedonism

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Despite the global efforts to encourage people to regularly participate in physical activity (PA) at moderate-to-vigorous intensity, an inadequate number of adults and adolescents worldwide meet the recommended dose of PA. A major challenge to promoting PA is that sedentary or low-active people experience negative shifts in affective valence (feeling bad versus good) in response to moderate-to-vigorous intensity PA. Interestingly, empirical data indicate that listening to music during acute bouts of PA positively alters affective valence (feeling good versus bad), reduces perceived exertion, and improves physical performance and oxygen utilization efficiency. From the viewpoint of the ancient principle of psychological hedonism – humans have ultimate desires to obtain pleasure and avoid displeasure – we elaborate on three putative mechanisms underlying the affective and ergogenic effects of music on acute bouts of PA: (1) musical pleasure and reward, (2) rhythmic entrainment, and (3) sensory distraction from physical exertion. Given that a positive shift in affective valence during an acute bout of PA is associated with more PA in the future, an important question arises as to whether the affective effect of music on acute PA can be carried over to promote long-term PA. Although this research question seems intuitive, to our knowledge, it has been scarcely investigated. We propose a theoretical model of Music as an Affective Stimulant to Physical Activity (MASPA) to further explain the putative mechanisms underlying the use of music to promote long-term PA. We believe there have been important gaps in music-based interventions in terms of the rationale supporting various components of the intervention and the efficacy of these interventions to promote long-term PA. Our specification of relevant mechanisms and proposal of a new theoretical model may advance our understanding of the optimal use of music as an affective, ergogenic, and sensory stimulant for PA promotion. Future directions are suggested to address the gaps in the literature.

KEYWORDS

affect, exercise, entrainment, motivation, reward, rhythm, pleasure, arousal

1. Introduction

Mounting evidence indicates that regular physical activity (PA) is associated with numerous health benefits (Warburton et al., 2006; Reiner et al., 2013) whereas insufficient PA is found to be the fourth leading cause of global mortality, accounting for approximately 3.2–5 million deaths every year (Lee et al., 2012). As such, serious efforts have been made at a global and national level to encourage people to regularly engage in PA at work, in transit, or for leisure (Haskell et al., 2007; Piercy et al., 2018; Bull et al., 2020). Public health officials recommend moderate-to-vigorous intensity PA (MVPA) for 150–300 min/week for adults and for at least 60 min/day for children and adolescents (Bull et al., 2020). However, it has been reported that approximately 30% of adults and 80% of adolescents worldwide do not reach the recommended levels of MVPA (WHO, 2020), and the rates further decline in obese and elderly populations (Bennie et al., 2019; Du et al., 2019; Lee et al., 2020), especially in high-income countries (Hallal et al., 2012; Piercy et al., 2018). Overweight and obese adults' MVPA rate is 20–50% lower than healthy weight adults (Bennie et al., 2019), and a more progressive decline in PA is seen after ages 60–65 (Troiano et al., 2008; Du et al., 2019) when the health benefits of PA become pronounced. Despite the global and national efforts to communicate the health benefits of PA, the rate of PA is lower than desired, which can bring about harmful sequelae for society and individuals (Kohl et al., 2012).

The psychosocial factors predicting or causing PA behaviors have attracted scientific interest (for reviews, see Marcus et al., 1996; Brand and Cheval, 2019; Biddle et al., 2021; Huffman et al., 2021; Stults-Kolehmainen et al., 2022). Over the past two decades, the motivational role of "*affect*," a gestalt construct with valence (pleasure versus displeasure) and arousal (high versus low) dimensions (Russell, 1980), has received increasing attention as a key factor eliciting motivation for PA (Ekkekakis and Petruzzello, 1999; Ekkekakis, 2003, 2017; Williams, 2008; Rhodes et al., 2009; Rhodes and Kates, 2015; Lee et al., 2016; Murphy and Eaves, 2016; Williams and Bohlen, 2019; Stevens et al., 2020; Stults-Kolehmainen et al., 2020). This is an important direction because a major challenge to promoting PA is that low-active people often experience more negative affective valence than high-active people in response to MVPA (Ekkekakis et al., 2011). This negative affective response is a critical barrier to adoption and maintenance of PA because, according to the ancient principle of psychological hedonism, human behaviors are driven by a propensity to maximize pleasure and minimize displeasure (Cabanac, 1992; Kahneman et al., 1997; Williams, 2018; Williams, 2019; Young, 1952). This means that when people *like* – or at least *do not dislike* – a single session of PA (hereafter referred to as acute PA), they are more likely to repeat it on a regular basis. This notion is supported by a systematic review showing that a positive shift in affective valence during an acute exercise bout predicted PA in the future, whereas negative shifts in affective valence predicted less PA (Rhodes and Kates, 2015). An affect-based approach to PA promotion may be a timely and important strategy (Ekkekakis, 2017; Williams and Bohlen, 2019; Stevens et al., 2020; Stults-Kolehmainen et al., 2020).

Scientists have demonstrated that music can have motivational effects on PA (Karageorghis and Terry, 1997; Karageorghis et al., 1999; Priest et al., 2004; Karageorghis and Priest, 2012a; Bigliassi et al., 2016). A recent meta-analysis of 139 studies revealed that music listening prior to or during acute PA increases positive affective valence ($g = 0.48$, CI [0.39, 0.56]), reduces ratings of perceived exertion (RPE; $g = 0.22$, CI [0.14, 0.30]), enhances physical performance ($g = 0.31$, CI [0.25, 0.36]), and improves oxygen utilization efficiency (VO2max; $g = 0.15$, CI [0.02, 0.27]) compared to PA without music (Terry et al., 2020). Moderation meta-analyses further revealed that the beneficial effects of music on affective valence and RPE are present across the full range of PA intensity (Terry et al., 2020). These findings substantiate the idea that music makes PA more joyous, less arduous, and more energetic and efficient. In other words, music becomes an affective and ergogenic stimulant to PA. This raises a research question about its underlying mechanism: How does music provide such effects on PA? Although conceptual models have been proposed to address this research question (Karageorghis et al., 1999; Karageorghis, 2015; Clark et al., 2016a), these models do not incorporate concurrent theories of motivation and thus lack a thorough theoretical foundation. Hence, in Section 2, we propose a theoretical model to elucidate the putative mechanism underlying the effects of music stimulation for acute PA from the views of psychological hedonism. In our description of the mechanisms, we suggest methodologies of music manipulation (i.e., beat-accentuation, tempo-synchronization, and personally preferred music selection) that may maximize the effects of putative mechanisms.

The evidence that music Increases positive affective valence and reduces RPE during acute bouts of PA implies that music leads to more positive evaluations of PA sessions – to like it more or dislike it less. This raises another research question: Can the affective effects of music on PA be carried over from acute to long-term phases to motivate regular PA? Although the answer seems intuitive, to our knowledge, this research question has been scarcely investigated and a theoretical basis has not been proposed. However, there is some empirical evidence supporting this possibility. A randomized control trial (RCT) revealed promising results that walking-for-exercise with personally-preferred, beat-accented, tempo-synchronous music playlists substantially increased the weekly volume of PA over 3 months compared with the same exercise prescription with non-beat-accented music playlists or without music among midlife-to-older adults in a home-based cardiac rehab program (Alter et al., 2015). We discuss these findings in comparison with other evidence in the literature (Section 3) and elaborate on the long-term implications of the theoretical model to further our understanding of the potential effects of music for increasing and maintaining regular PA – hereafter referred to as long-term PA (Section 4). Given that prior conceptual models of music stimulation are limited to acute PA (Karageorghis et al., 1999; Karageorghis, 2015; Clark et al., 2016a), our theoretical approach is the first of its kind for the specification of putative mechanisms underlying the use of music stimulation for the promotion of long-term PA.

Music-based interventions have been widely developed and implemented in varying fields of science and medicine (Chen et al., 2022) to treat neurologic (for reviews, see Thaut, 2005; Schaefer, 2014; Leggieri et al., 2019), cardiovascular (for a review, see Chair et al., 2021), or psychiatric conditions (for reviews, see Zhao et al., 2016; Aalbers et al., 2017). In particular, music has been frequently employed to activate the motor system as part of rhythmic auditory stimulation (RAS). RAS refers to an application of pulsed rhythmic auditory stimuli (e.g., metronome and/or music) for the facilitation of body movements that are intrinsically rhythmic (e.g., walking; Thaut et al., 2016). Frequently utilized in clinical settings, people with neurodegenerative diseases – most frequently Parkinson's disease (PD) and stroke – or brain injuries have benefited from being trained to synchronize their walking steps to RAS (Thaut, 2005; Thaut et al., 2015). RAS interventions have used varying forms of synchronous stimuli - auditory tempo (beats/min, BPM) matched to individual cadence (steps/min) - such as metronome pulse (see reviews by Lim et al., 2005; Nombela et al., 2013; Ghai et al., 2018), contemporary music (de Bruin et al., 2010; Park et al., 2020, 2021), or contemporary music with sonically-enhanced (accentuated) beats (Thaut et al., 1996; McIntosh et al., 1997; Benoit et al., 2014). The evidence that RAS facilitates rhythmic motor behaviors implies its beneficial application for PA promotion because PA is defined as body movement of skeletal muscles that leads to energy expenditure (Caspersen et al., 1985; Ainsworth et al., 2000). However, this idea has not been systematically investigated or theoretically discussed. Given the growing demand for PA promotion in the realm of public health, it is important to delve into the literature to inform future music-based interventions for PA promotion.

2. Putative mechanisms of music stimulation for acute physical activity

The Theory of Hedonic Motivation (THM) – a theory of psychological hedonism formulated by Williams (2018, 2019) – serves as a theoretical basis for our approach herein. According to the THM, 'liking' and 'disliking' (i.e., Berridge, 2003) represent the neurobiological underpinnings of *hedonic responses* – an organism's *automatic* and *immediate* experience of pleasure versus displeasure (i.e., affective valence) in response to a behavior or immediate behavioral outcome. Moreover, 'wanting' and 'dread' (i.e., Berridge, 2003) represent the neurobiological underpinnings of *hedonic motivation* – a neurobiological process that is automatically triggered by a stimulus and manifests as a felt *hedonic desire* to produce an immediate behavioral outcome that has previously brought immediate pleasure (or relief from displeasure) or a felt *hedonic dread* of producing an immediate behavioral outcome that has previously brought immediate displeasure (or reduced pleasure).

Hedonic motivation is also considered to be an *affectively-charged motivation state* (ACMS), first introduced by Kavanagh et al. (2005), for the conceptualization of *desires*, *wants*, *cravings*, and *urges* for appetitive behaviors (e.g., smoking, drinking, eating). Consistent with the THM, and applied to PA behaviors, Stults-Kolehmainen et al. (2020) conceptualized *urges*, *wants*, *desires*, *dread*, *craving*, and *aversion* as "ACMS and associated feelings that signal a pressing need to approach or avoid a state of muscular movement (or, conversely a state of rest)" (p. 2). Stults-Kolehmainen et al. (2020) further proposed the WANT model (Wants and Aversions for Neuromuscular Tasks), a descriptive, circumplex model of ACMS to move and rest on a continuum of approach and avoidance orientation. In accordance with neurobiological evidence (Desmurget and Sirigu, 2012), the WANT model enunciates that urges, cravings, and dread to move/rest are more intense motivational states than desires, wants, and aversions to move/rest. We adopt this conceptualization in our theoretical approach proposed herein.

Our approach is that hedonic response and hedonic motivation are the core psychological mechanisms underlying affective, ergogenic, and motivational effects of music on PA. Adding music to PA evokes hedonic responses (e.g., positive affect, reduced RPE, exercise enjoyment, arousal, etc.) and this leads to hedonic motivation or ACMS for continuing movement during acute bouts of PA. We propose a theoretical model named "Music as an Affective Stimulant for Physical Activity" (MASPA) to explain this process (see Figure 1). The model contains the following components as the putative psychological mechanisms in acute bouts of PA: (1) musical pleasure and reward, (2) rhythmic entrainment, and (3) sensory distraction from physical exertion. In the following sections, we elaborate on each element of the mechanisms based on relevant theories and empirical evidence from behavioral and neurobiological studies.

2.1. Musical pleasure and reward

Many people take pleasure in listening to music. Neurobiological studies have demonstrated that the reward system in the brain is the core of this experience. In a non-musical context, as explained by the *incentive salient hypothesis* (Berridge and Robinson, 1998, 2016; Berridge, 1999, 2007), the cardinal reward stimuli in humans such as money, sex, or food convey feelings of pleasure (liking) and thus motivate the individual to seek the same stimuli again (wanting), although "wanting" can occur without "liking" on some occasions (Berridge, 2007; Berridge and Robinson, 2016). A meta-analysis of 87 neuroimaging studies confirmed the role of the mesolimbic dopaminergic system in processing these fundamental rewards in humans (Sescousse et al., 2013). Interestingly, the mesolimbic dopaminergic system in the human brain is activated by music listening especially when music stimuli are perceived as intensely pleasurable (Zatorre and Salimpoor, 2013; Koelsch, 2014; Zatorre, 2015). This means that – like other reward stimuli in humans – music listening evokes positive hedonic experiences (liking) and this leads to hedonic motivation (wanting) for keeping up with the hedonic experiences. The term, *musical pleasure*, has been derived from these findings to represent music-evoked pleasure responses (Gebauer et al., 2012; Zatorre, 2015; Goupil and Aucouturier, 2019).

Musical pleasure is often accompanied by an arousal response that is defined as physiological activation of the autonomic nervous system (Frijda, 2009) and is another core dimension of the circumplex model of affect (Russell, 1980). One powerful experience of highly-aroused musical pleasure is "thrills." A *thrill* is "a subtle nervous tremor caused by intense emotion or excitement (as pleasure, fear, etc.), producing a slight shudder or tingling through the body; a penetrating influx of feeling or emotion" (Oxford English Dictionary, 2022). Questionnaire data have shown that this phenomenon is commonly experienced with physical sensations such as shivers or goose pimples by multiple groups of music listeners (Goldstein, 1980; Sloboda, 1991; Panksepp, 1995). The term, *chills*, rather than thrills, was suggested by Panksepp (1995) for its more common use by college-aged adults, and this nomenclature has been followed by successive researchers (Rickard, 2004; Grewe, 2005; Grewe et al., 2007, 2009; Salimpoor et al., 2009). Musical chills have been found to be composed of subjectively reported musical pleasure (Salimpoor et al., 2009) as well as objectively measured changes in physiological arousal such as increased heart rate (HR), respiration, electrodermal activity, and muscle tension as well as decreased body temperature (Blood and Zatorre, 2001; Grewe, 2005; Grewe et al., 2007, 2009; Salimpoor et al., 2009, 2011).

Zatorre and colleagues have demonstrated neurochemical correlates of musical pleasure and chills. The first neuroimaging study with positron emission tomography (PET) – a technique showing the chemical and functional changes in the brain – reported evidence of neural responses to intense musical pleasure by comparing brain activities while listening to self-chosen pleasurable music compared to other-chosen neutral music (Blood and Zatorre, 2001). Results showed that subjective ratings of chill intensity were associated with changes in HR, muscle tension, and respiration depth as well as cerebral blood flow changes in the mesolimbic dopaminergic circuits. They conducted a subsequent PET study with [^{11}-C]raclopride – a technique measuring dopamine release in cerebral tissues – and revealed endogenous dopamine release in the reward circuits when healthy adults listened to self-chosen pleasurable music versus other-chosen neutral music, and the magnitude of the mesolimbic dopamine activity was associated with the frequency and intensity of chills and the degree of pleasure (Salimpoor et al., 2011). More recently, researchers conducted a double-blind pharmacological trial with oral administration of a dopamine precursor (levodopa) that caused greater responses in musical pleasure, chills, and reward compared with a dopamine antagonist (risperidone) and a placebo (lactose; Ferreri et al., 2019). These findings show that

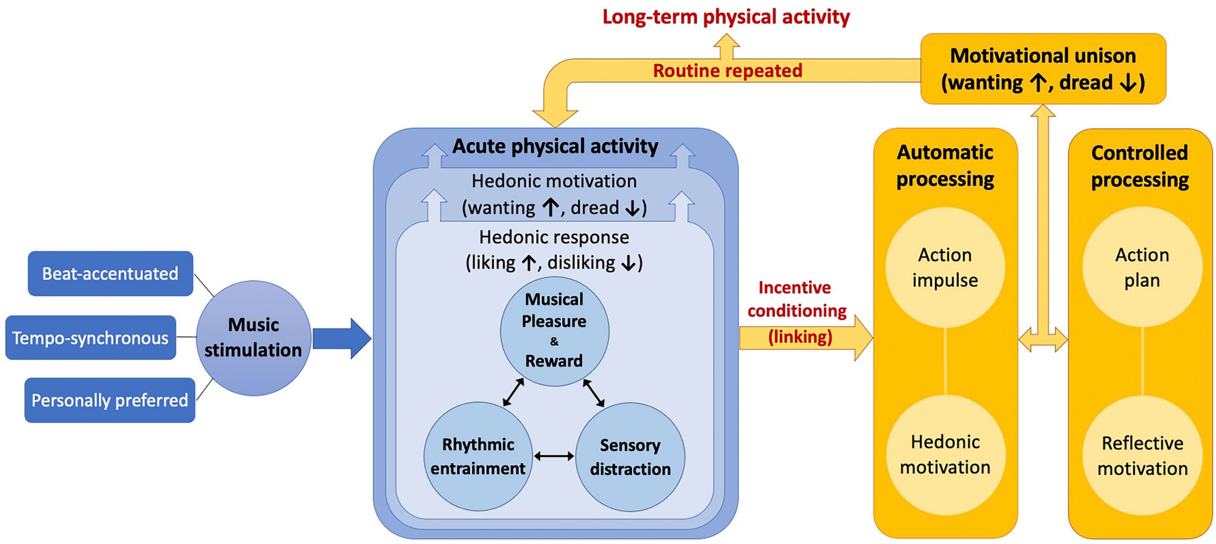

FIGURE 1
A theoretical model named "Music as an Affective Stimulant for Physical Activity" (MASPA). Acute phase of physical activity is depicted in blue whereas long-term phase of physical activity is illustrated in yellow. Regularly repeating acute routine can lead to long-term physical activity.

people like to listen to music (hedonic responses) and thus they seek more music-related activities (hedonic motivation) and dopamine modulates this process.

The findings we described above have been accrued in non-PA contexts. In PA settings, Terry et al.'s (2020) meta-analysis confirms that listening to music prior to or during acute PA evokes more positive hedonic responses than non-music PA. This finding derived from 29 studies assessing core affective valence during acute bouts of PA in laboratory settings. Arousal responses to music can also occur in PA settings. Although empirical studies are scarce, Karageorghis and colleagues have provided some evidence to uphold this perspective. When high-active adults completed 6-min of vigorous-intensity cycle ergometry under different conditions, subjective ratings of arousal were higher when exercising with synchronous music compared with a synchronous metronome and a no-music control (Lim et al., 2014). When male athletes listened to different music stimuli before performing a hand-grip dynamometer test, fast-tempo/loud music increased perceived arousal and affective valence and improved grip strength performance more than fast-tempo/quiet, slow-tempo/loud, slow-tempo/quiet, and no-music control conditions (Karageorghis et al., 2018). Music can evoke physiological arousal without changes in affective valence, yet whether this can lead to hedonic motivation is uncertain. For example, fast, loud music typically has increased sound pressure levels that intensify arousal regardless of how the music is hedonically appraised (Van Dyck, 2019). From the viewpoint of THM, music-evoked arousal can contribute to hedonic motivation for PA only if it is combined with feelings of pleasure. For example, if certain music evokes high arousal along with positive valence (e.g., eager anticipation, excitement), it can lead to a desire for continuing or repeating the behavior associated with such music. On the other hand, if certain music evokes high arousal combined with negative valence (e.g., anxiety, nervousness), it may lead to a dread of the behavior associated with such music.

As depicted in Figure 1, we propose that musical pleasure serves as the core of hedonic responses to music in PA contexts – similar to non-PA contexts – and this activates the reward system in the brain eliciting hedonic motivation for continuing PA. Future studies may test this mechanism by assessing important markers of musical pleasure, physiological arousal, self-perceived subjective arousal, and/or the frequency and intensity of chills in response to music stimulation during acute PA. This motivational enhancement could lead to the ergogenic effects of music on PA, evidenced by improved physical performance in the meta-analysis (Terry et al., 2020). In other words, music listening makes a PA session more enjoyable and thus enables the PA participant to work more or harder. Because music preference varies by individual factors such as age (Priest et al., 2004), we suggest the use of personally-preferred music playlists that would elicit more hedonic and arousal responses and hedonic motivation for music-based PA, in agreement with views of exercise scientists (Karageorghis and Priest, 2012a,b; Clark et al., 2016a,b; Hutchinson et al., 2018) and neuroscientists (Blood and Zatorre, 2001; Salimpoor et al., 2009, 2011).

2.2. Rhythmic entrainment

Music is composed of ordered sounds (*notes*) and silences that recur in time. To untangle the architectonics of music, we here define the key elements of the temporal organization of music – *pulse*, *beat*, *meter*, and *rhythm*. A *pulse* is one of a series of periodic, precisely equivalent stimuli (e.g., metronome ticks) that delineate equal units in the temporal continuum (Cooper and Meyer, 1960). Pulses are referred to as *beats* when being counted within a metric context. *Meter* refers to "the measurement of the number of pulses between regularly recurring accents – marked for consciousness – relative to others" (Cooper and Meyer, 1960, p. 4), which indicates that meter exists only when music listeners perceive beats accented relative to others (Large and Kolen, 1994). *Rhythm* is traditionally defined as "the way in which one or more unaccented beats are grouped in relation to an accented one" (Cooper and Meyer, 1960, p. 6) or more simply, "the serial pattern of variable note durations in a melody." (Schulkind, 1999, p. 896) Although this definition counts rhythm as an objective property of music, it can also be subjective in that rhythmic experience occurs based on the intricate interactions between other components of music (e.g., pitch, tempo, harmony, timbre), individual differences in capacity and perception, and environments. From a psychological viewpoint, rhythm represents the patterns of durational proportions that are phenomenally present in music, whereas meter involves the initial perception and ensuing anticipation of a series of beats that are extracted from the rhythmic structure of music as it unfolds in time (London, 2012).

London (2012) defines meter as a "musically-specific form of *entrainment*, the synchronization of attention and/or other behaviors (especially motor behaviors) with periodic rhythms in the environment." (p. 10) Entrainment allows the listener to focus attention on the salient temporal events in music which is important because attention is selective by its nature. It should be noted that the periodicity of meter enables anticipation that fosters entrainment. The motivational effects of music on motor behaviors in humans have been explained in extensive literature reviews, which all point to entrainment as the key principle – from evolutionary and psychological perspectives (Levitin et al., 2018) and from a multi-disciplinary approach combining the principles of physics and neurobiological modeling of brain and oscillatory activities (Damm et al., 2020). Entrainment to musical rhythm has been demonstrated in various motor behaviors including bouncing and clapping (Tranchant et al., 2016), walking (Wittwer et al., 2013; Franěk et al., 2014; Metcalfe, 2016), running (Simpson and Karageorghis, 2006; Terry et al., 2012; Bood et al., 2013; Van Dyck et al., 2015), and free dancing (Burger et al., 2013). Rhythmic motor entrainment to music is a behavior primarily observed in humans but also evident in some animals (Wilson and Cook, 2016). In humans, this psychophysical phenomenon universally appears across cultures, regions, and eras (Cross, 2001) in people of all ages from infants (Zentner and Eerola, 2010) to children (Provasi and Bobin-Bègue, 2003) and young to older adults (Thaut et al., 1992; Metcalfe, 2016; Rose et al., 2021) and in individuals with neurologic impairments (Thaut et al., 2015).

Neuroscientists have demonstrated neural representation of rhythmic entrainment in the brain. According to Large and colleagues' neural resonance theory (NRT), nonlinear coupling of two oscillatory neutral networks – the auditory system receiving the physical properties of music stimulus and the motor system that integrates sensory inputs from the auditory system – leads to a common oscillatory activity at the beat frequency of music, and such entrained oscillations lead to the formation of rhythm perception (Large and Snyder, 2009). The research team tested the NRT through a series of experiments with electroencephalography (EEG) and magnetoencephalograms (MEG) recordings (Snyder and Large, 2005; Large et al., 2015; Tal et al., 2017). They demonstrated that neural activity increased in the auditory cortex at the same frequency as auditory beats and they determined that such neural oscillation is entrained to the beats because increased neural activity was found even at times when there were missing beats, and the strength of neural responses was correlated with individuals' speed in perceiving the pulse. According to *the action simulation for auditory prediction hypothesis*, stimulation of rhythmic movement in the motor planning regions of the brain provides neural signals to the auditory system where anticipation of upcoming beats is made (Patel and Iversen, 2014). In support of this notion, brain studies with functional magnetic resonance imaging (fMRI) have observed bilateral activation of the motor regions in the brain during beat perception tasks without overt motor actions (Grahn and Brett, 2007; Chen et al., 2008).

Rhythmic entrainment may underlie the effects of music on exercise performance. Terry et al. (2020) revealed that (a) *tempo-synchronous music* yielded marginally more beneficial effects on performance of acute PA ($g = 0.44$, CI [0.22, 0.65]) than *tempo-asynchronous music* ($g = 0.31$, CI [0.24, 0.38]) and that (b) fast-tempo music ($g = 0.38$, CI [0.30, 0.45]) led to more beneficial effects on exercise performance than slow/medium tempo music ($g = 0.21$, CI [0.14, 0.27]). These findings imply the ergogenic effects of rhythmic entrainment. However, Terry et al. (2020) noted that studies using tempo-synchronous music in PA contexts are relatively rare compared to tempo-asynchronous music, and thus the specific role of entrainment in enhancing exercise performance or promoting long-term PA has not been fully tested. Future studies need to address this gap in the literature. Although we discussed its role in altering physical performance, rhythmic motor entrainment to music can be also accompanied by affective responses. We discuss this idea in the following section.

2.3. Rhythmic entrainment as an affective response to music

Rhythmic entrainment typically appears in motor behaviors and is also considered to be a part of the psychological mechanisms underlying affective or emotional responses to music (Juslin and Västfjäll, 2008; Trost and Vuilleumier, 2013; Juslin et al., 2014; Trost et al., 2017). A classic example of coupling motor and affective responses to music is seen from people moving along with pleasant feelings when listening to their favorite songs. Zentner and Eerola (2010) provided critical behavioral evidence that preverbal infants demonstrated increased rhythmic movements when hearing musical or rhythmic stimuli (e.g., Mozart, Saint-Saëns, children's song, or drumbeats) compared with non-musical stimuli (e.g., adult speech). Interestingly, it was further reported that (a) infants' rhythmic motions coincided with positive affect, evidenced by a noticeable correlation between the duration of movement and the duration of smiles ($r = 0.30$ and 0.37 in two experiments) and that (b) infants' duration of smiles showed meaningful correlations with their degree of music-movement synchronization accuracy ($r = 0.42$ and 0.26 in two experiments). These findings indicate that humans are predisposed to rhythmically engage in music with a concurrent display of positive affective states. Zentner and Eerola (2010) noted that "this association raises the possibility that surges in positive affect may facilitate, and perhaps even motivate, rhythmic engagement with metrically regular sound patterns." (p. 5771).

The co-occurrence of affective and motor responses to music has been further explained by a sensorimotor phenomenon called *groove*. Janata et al. (2012) defined groove as "[an] aspect of the music that induces a pleasant sense of wanting to move along with music." (p. 54) and also the feeling of being in the groove as having "the urge to move in response to music, combined with the positive affect associated with the coupling of sensory and motor processes while engaging with music (referred to as sensorimotor coupling) in a seemingly effortless way" (p. 56). Groove is considered to be a subjectively-felt sensation and also a type of ACMS for the initiation and maintenance of body movements in response to music (Stults-Kolehmainen et al., 2020). According to the WANT model (Stults-Kolehmainen et al., 2020), this urge to move with music is considered to be a stronger motivational state than a simple desire or want to move. Janata et al. (2012) described a pleasurable drive toward motor actions as the key concept of groove based on the findings that high-groove music stimuli were perceived as more enjoyable and induced a greater amount of spontaneous movements across all body parts (most notably head and feet) during a hand-tapping task, compared with low-and moderate-groove music. Janata et al. (2012) further found that faster-tempo music (115.6 ± 8 BPM) is more groove-inducing than slower-tempo music (90.8 ± 6.6 BPM) and that groove ratings are closely associated with ratings of enjoyment ($r = 0.82$) and familiarity ($r = 0.57$). In an online survey, young-to-midlife adults reported the degree of wanting to move and the feelings of pleasure they experienced while listening to a series of drumbeats in varying ranges of rhythmic patterns (Witek et al., 2014). The results showed a strong correlation between the ratings of wanting to move and the experience of pleasure ($r = 0.964$).

Neuroimaging evidence supports that rhythmic motor entrainment to music occurs as part of affective responses in the brain. In an fMRI study, Kornysheva et al. (2010) showed that listening to preferred musical rhythm that was rated as more beautiful and pleasant resulted in increased activation of motor-related brain regions such as the premotor cortex and cerebellum compared with non-preferred musical rhythm. In another fMRI study, Trost et al. (2014) demonstrated that listening to a consonant musical beat (rated as pleasant and more arousing) resulted in faster detection of beat-synchronous targets and activation of motor-and reward-related brain areas during a visuomotor attentional task in comparison with a dissonant musical beat (rated as unpleasant and less arousing). Recently, Matthews et al. (2020) demonstrated that listening to musical rhythm rated as more pleasant and groove-inducing was associated with activation of reward-and motor-related regions, compared with musical rhythm rated as less pleasant and groove-inducing. To sum up, neuroimaging evidence substantiates the notion that rhythmic motor entrainment to music co-occurs with pleasure and reward responses. Simply stated, people want to move with music (hedonic motivation) because they like doing so (hedonic response). This evidence of affective benefits of entrainment suggests the use of synchronous music not only for performance enhancement as implied in Terry et al.'s (2020) meta-analysis but also to maximize hedonic responses and hedonic motivation for PA. Because evidence is lacking to test the specific role of entrainment in PA settings, future studies may address this by decomposing the effects of beat accentuation and/or tempo synchronization.

It should be recognized that affective and motor responses to music do not necessarily co-occur. There is music that induces pleasure but that does not necessarily generate motor reactions. For instance, it's relaxing and pleasing to listen to Mozart's symphonies, but such music may not be a popular choice for vigorous dance or workout sessions. The opposite case is also possible in that there are music or auditory stimuli that facilitate motor actions with little change in affective responses. An example of this case would be metronome pulses frequently used as a type of RAS for gait rehabilitation among people with PD (Lim et al., 2005; Ghai et al., 2018; Forte et al., 2021), stroke (Yoo and Kim, 2016; Ghai and Ghai, 2019), cerebral palsy (Ghai et al., 2018) and multiple sclerosis (Ghai and Ghai, 2018). None of these studies have considered participants' hedonic responses to RAS in that their primary purpose was to stimulate the motor system. To benefit PA behaviors, however, music would be more pleasurable and motivational than isochronous pulse, as demonstrated by a study (Lim et al., 2014) in which synchronous and asynchronous music stimuli elicited greater positive affect than a synchronous metronome pulse. Gait studies also demonstrated that (1) walking with a synchronous music excerpt led to greater gait velocity and stride length than a synchronous metronome pulse (Wittwer et al., 2013) and (2) personally preferred, synchronous music evoked greater pleasure and enjoyment and more vigorous walking (greater gait velocity, stride length, and arm swing) than a synchronous, isochronous drumbeat among people with PD (Park et al., 2020). For our purpose – an affect-based approach to PA promotion – it would be effectual to use music stimulation that is personally preferred and beat-accentuated in order to maximize its effects on the affective and motor systems.

Another important construct to consider is familiarity. Personally-preferred music can induce feelings of *familiarity* based upon the extent to which a music excerpt is known to an individual (North and Hargreaves, 1998; Park et al., 2019), which can be beneficial for PA. Empirical data have shown that ratings of familiarity with a sample of music excerpts are strongly correlated with ratings of liking of the same excerpts (North and Hargreaves, 1995). In PA settings, familiarity with music has been found to beneficially influence walking behaviors (Leow et al., 2015; Park et al., 2019). This could be because familiar music facilitates rhythmic motor entrainment by having listeners more easily anticipate the timing of the beats of music to which motor events are synchronized (Damm et al., 2020; Matthews et al., 2020). A systematic review of 23 neuroimaging studies revealed that motor-related regions in the brain are the top clusters of neural activation when listening to familiar music (Freitas et al., 2018). In an acute gait trial among older adults with PD, walking in time with the salient beats of self-chosen familiar music stimulation immediately resulted in greater gait velocity, stride length, arm swing range of motion, and perceived enjoyment compared with walking with metronome pulses (Park et al., 2020) and enhancing familiarity *via* repeated listening to unfamiliar music led to increased gait parameters and enjoyment ratings (Park et al., 2021). Follow-up analyses further revealed that changes in gait parameters were associated with the degrees of perceived enjoyment, familiarity, and beat salience (Park et al., 2020; Park, 2022). Enhancing personalization and familiarity of music stimulation could bolster affective responses and ACMS for PA.

2.4. Sensory distraction from physical exertion

Physical exertion during PA serves as an *afferent* sensory stimulus, which delivers neuronal signals from the body to the brain through the somatosensory pathways. Some examples of this somatosensory feedback are increased HR, sweating, and muscle fatigue. In the brain, the strength of the somatosensory stimulus is perceived and can be expressed as RPE (Rejeski, 1985). The sensory stimulus from external sources (e.g., music) can distract the perception of sensory signals from the internal system (i.e., body; Damm et al., 2020). Indeed, shifting attention away from unpleasant stimuli by listening to music is a well-known non-pharmacological intervention for pain management (i.e., audio-analgesia; Kühlmann et al., 2018; Lin et al., 2020; Yu et al., 2020). Therefore, music reduces feelings of physical exertion and fatigue by redirecting the nerve impulses from somatosensory pathways to auditory pathways (Bigliassi et al., 2017). In an EEG study, Bigliassi et al. (2016) demonstrated that music listening improved the performance of an isometric maximal ankle-dorsiflexion task while decreasing theta waves (4–7 Hz) in the frontal, central, and parietal regions of the brain, which is indicative of reduction in fatigue (Craig et al., 2012). The research team further demonstrated that music listening, during an acute bout of light-to-moderate cycle ergometry, led to the reallocation of attentional focus toward external stimuli, increased the use of dissociative thoughts, and reduced neural connectivity across sensorimotor cortices in the frontal and central regions of the brain, which represent exercise thoughts and feelings (Bigliassi et al., 2017). A meta-analytic review summarized evidence from 54 studies and confirmed that music listening prior to or during PA lead to lower perceived exertion compared to PA without music (Terry et al., 2020). These findings indicate that music stimulation for PA can inhibit the feelings of discomfort and fatigue coming from physical exertion, which can help make people less likely to dislike a PA session.

Sensory-distractive effects of music co-occur with feelings of pleasure. This view was substantiated by a study in which music listening evoked positive affect in addition to attentional switching from associative to dissociative thoughts during an ankle-dorsiflexion task (Bigliassi et al., 2016). It was hypothesized that the effect of music on RPE and affect can be hindered during high-intensity PA because of the strong somatosensory signals of physical discomfort (Karageorghis et al., 2009). However, in their meta-analysis, Terry et al. (2020) demonstrated that the beneficial effects of music on RPE and affective valence were not moderated by PA intensity, implying that reduced exertion and increased positive affect can be gained by music stimulation across different intensities of PA. Evidence indicates that perceived exertion is inversely associated with positive affect among low-active people (Hardy and Rejeski, 1989; Williams et al., 2008). By simultaneously reducing RPE and enhancing pleasure, music stimulation can make a PA session more enjoyable and less painful.

3. Music-based interventions to promote long-term physical activity

Empirical data is lacking to support or refute the effects of music on long-term PA. A systematic review (Clark et al., 2012) identified a few trials comparing participants' attendance rate in music-based vs. non-music-based exercise interventions in people with chronic obstructive pulmonary disease (COPD; Bauldoff et al., 2002, 2005) and dementia (Mathews et al., 2001). Although the benefits of music were implicated in these interventions, no arrangement was made for the tempo or rhythm of music to influence PA and significant differences in long-term PA were not found. A recent systematic review (Chair et al., 2021) identified 3 RCTs that examined the effects of music-based exercise interventions on long-term PA in patients with coronary heart disease (Ståhle et al., 1999; Alter et al., 2015; Clark et al., 2017). Although Ståhle et al. (1999) reported increases in self-reported PA levels 12-months after a music-based group exercise intervention compared with usual care controls in older adults after an acute coronary syndrome, the causal effects of music on PA adherence was not addressed because non-music exercise was not used as the usual care intervention.

The RCT by Alter et al. (2015) provides critical evidence that music can benefit long-term PA. Alter et al. randomly assigned midlife-to-older adults to one of three walking-for-exercise groups for a 12-week home-based cardiac rehabilitation program: (1) walking with personalized, synchronous music playlists with accentuated beats (playlists with RAS); (2) walking with personalized, synchronous music playlists without accentuated beats (playlists only); and (3) walking without music (controls). Results showed that playlists with RAS led to nearly twofold increases in accelerometer-measured weekly volumes of PA and caloric expenditure during the intervention period, compared to the other two groups. Interestingly, the higher average of weekly PA was observed at all intensities (light, moderate, and vigorous) and maintained over 12 weeks, and the weekly volume of PA was closely associated with the weekly play-counts of the playlists ($r = 0.61$). The methodology used for RAS, especially beat accentuation, may have played the key role in the treatment effects in that playlists without RAS had little effect on PA outcomes. This view would be supported by prior evidence that music with accentuated beats was found to facilitate beat perception and music-motor synchronization (Chen et al., 2006; Burger et al., 2013).

In addition to beat accentuation, temporal synchronization between music and exercise motions may also play an important role. This assertion would be upheld by minimal effects of music in other studies. In an RCT, older adults who were discharged from a cardiac rehabilitation program and got encouraged to walk-for-exercise with a personally-preferred, *tempo-asynchronous* music playlist demonstrated trivial differences in the rate of meeting PA recommendations and accelerometer-measured PA over 26 weeks compared with controls who received the same PA guidelines without music after the same rehabilitation program (Clark et al., 2017). In another RCT, patients with COPD who participated in an 8-week walking intervention with upbeat, tempo-asynchronous music playlists showed little differences in pedometer-measured total walking distance (19.1 ± 16.7 miles vs. 15.4 ± 8 miles) and self-reported volume of PA compared with patients who received the same walking intervention without music (Bauldoff et al., 2002). These findings indirectly suggest that rhythmic entrainment derived from tempo synchronization may be a key consideration in the beneficial effects of music for long-term PA.

Based on our review of empirical evidence, there are important gaps in music-based interventions in terms of their rationale and efficacy to promote PA. The methodologies employed by Alter et al. (2015) for music playlists with RAS – beat accentuation, tempo synchronization, and preference-based personalization – may play a collective role in facilitating PA and thus more studies are needed to test its efficacy. The sample – cardiac rehabilitation patients – may have also served as an important target of the music-based exercise intervention because cardiac rehabilitation is associated with high attrition rates and poor adherence to self-paced PA (Alter et al., 2015) thus allowing the intervention to appear highly efficacious because of the low starting point. Future studies can replicate this methodology to test its efficacy among the same or other populations with cardiac or neurologic conditions as well as other populations in need of PA promotion (e.g., overweight/obese, elderly, or athletes).

4. Putative mechanisms of music stimulation for long-term physical activity

The mechanism linking the acute effects of music to long-term PA has not been specified in the current literature. We depict this process by proposing the MASPA model as illustrated in Figure 1. This model takes into consideration the THM to further account for how music influences long-term PA. Our premise is that long-term PA is the repeated performance of acute PA on a relatively regular basis, which is often offered in the form of a behavioral intervention or exercise training. As we described above, music stimulation can induce hedonic responses during acute PA. In a long-term context, these hedonic responses serve as the inputs into the process of psychological hedonism to generate hedonic motivation, an output of psychological hedonism, directly influencing decision-making for repeating another bout of PA in the future. *Incentive conditioning* represents a "linking" process between previous hedonic responses and hedonic motivation for upcoming PA. For example, if people dislike a PA session, this negative hedonic response is linked to their reduced motivation for upcoming PA, so they are more likely to avoid another bout of PA, which decreases the chance of adopting or maintaining long-term PA. On the other hand, if they like a PA session, this positive hedonic response is linked to enhanced motivation for upcoming PA and thus they are more likely to perform another PA bout, which increases the chance of adopting or maintaining long-term PA.

We recognize that human behaviors are not entirely driven by hedonic motivation. The THM is a dual-processing model viewing behavioral outcomes as the consequence of interactions between automatic/impulsive processing and controlled/reflective processing. Williams (2018) noted that a*utomatic processing of affect* involves the learning of associations between a stimulus and affective responses (incentive conditioning). This 'linking' process is automatically triggered when facing a relevant stimulus or cue, consequently leading to hedonic motivation for a behavior. By contrast, *controlled processing of affect* involves anticipated affective responses to the target behavior or behavioral outcome as a function of consciously and reflectively formulated if-then expectancies. Such anticipated affective responses occur based on deliberate evaluations of previous affective responses and thus include expectations of proximal and distal affective consequences of a behavior, generating reflective motivation for a behavior. In sum, hedonic motivation occurs automatically and impulsively as a function of hedonic response and is distinguished from reflective motivation that is formulated by deliberate and controlled affective evaluation.

It should be noted that hedonic motivation and reflective motivation often work in combination for the same behavior, but sometimes contend especially in the context of healthy behaviors. According to the Affective-Reflective Theory of physical inactivity and exercise (Brand and Ekkekakis, 2018), automatic evaluation of a PA bout triggers *action impulses* that form the basis for reflective evaluation as a deliberate process generating *action plans*. Stults-Kolehmainen et al. (2020) considered action impulse as a form of ACMS for motor behaviors by defining it as "the readiness potential and/or the conscious awareness of wanting to move." (p. 8). Ideally, action impulses and action plans need to be in unison but often they are not because, on many occasions, MVPA is automatically avoided based on negative affect. For example, going for a run typically leads to instant discomfort or displeasure coming from physical exertion whereas watching TV on a reclining sofa leads to instant comfort or pleasure by eliminating physical exertion. Hence, many people are often hedonically motivated to spend time on a couch to seek pleasure and find an excuse for skipping a run for the day to avoid displeasure (action impulse). This dread of MVPA often occurs although, for most people, MVPA is part of their exercise program (action plan) to attain its positive health benefits and a sense of accomplishment after overcoming displeasure associated with physical exertion. Therefore, enhancing affective evaluation may be an effective strategy to align action impulses with action plans to unite hedonic motivation and reflective motivation for PA.

In the acute phase of our theoretical model (marked as blue in Figure 1), we explain that music stimulation can help acute PA be associated with pleasure (or not associated with displeasure) as a function of musical pleasure and reward, rhythmic entrainment, and/or sensory distraction from physical exertion. After acute PA, the hedonic response to a PA session is more likely to be positively evaluated (or not negatively evaluated) and linked to hedonic motivation (action impulse) – in accordance with reflective motivation (action plan) – for upcoming PA, increasing the probability of engaging in PA again, possibly on a regular basis, leading to long-term PA (marked as yellow in Figure 1). The methodologies of music manipulation we suggest, beat-accentuation, tempo-synchronization, and personally-preferred music selection, can maximize the acute mechanisms of hedonic response and hedonic motivation for a PA session and consequently increase the chance of long-term behavior change. Simply stated, exercising in sync with personally-preferred, beat-accented music playlists can help people like a PA session more – or dislike it less – and thus increase the probability of regularly repeating it. Such a strategy for enhancing hedonic motivation can greatly benefit people for accomplishing PA behavior change.

This model is testable in future studies. The mediating role of musical pleasure during acute PA can be measured with scales such as the Feeling Scale (Hardy and Rejeski, 1989), the Felt Arousal Scale (Svebak and Murgatroyd, 1985), or Affective Grid (Russell et al., 1989) as well as PA enjoyment scales (Kendzierski and Decarlo, 1991; Stanley and Cumming, 2010) and their association with concurrent ACMS (e.g., wants, urges, desires, carvings, vs. aversion, dread) for PA and sedentary behaviors can be measured using the CRAVE (Cravings for Rest and Volitional Energy Expenditure) scale (Stults-Kolehmainen et al., 2021). To further test the long-term implications of the model, researchers can assess the effects of music stimulation on desire/dread for future PA and/or actual PA behaviors. Replication of the RCT by Alter et al. (2015) in other populations may greatly advance this area of science. The mechanism of rhythmic entrainment can be assessed through subjective ratings of perceived auditory-motor synchronization (Matthews et al., 2022) and/or by analyzing time series of music and motion tracking data and their association with concurrent and/or future motivation for PA and/or PA behaviors. The mechanism of sensory distraction from physical exertion has been tested by RPE (Rejeski, 1985) and its association with PA behaviors and/or PA motivation. The associations between hedonic responses, hedonic motivation, and long-term PA can be assessed using ecological momentary assessment (EMA). EMA involves repeated sampling of individuals' real-time behaviors and experiences in natural environments, minimizing recall bias and maximizing ecological validity, and allowing for an examination of microprocesses of human behaviors in real-world contexts (Shiffman et al., 2008).

Moreover, the music methodologies we propose, beat accentuation, tempo synchronization, and personalization of music preference, can also be manipulated to test their effects on hedonic responses, hedonic motivation, and acute and long-term PA. Manipulating the temporal elements of music (e.g., tempo, beat, and rhythm) can allow researchers to test the mechanism of rhythmic entrainment and its association with other mechanisms in PA settings. It is also possible to manipulate individual music preference to test the mechanisms of musical pleasure (liking) and reward (wanting) responses. By manipulating tempo and/or loudness of music, arousal responses to music can be tested. Few studies have manipulated these components of music to assess affective responses to music and ensuing motivational or behavioral outcomes in PA settings. Future studies may address this gap in the literature.

Baseline PA level, the stage of exercise behavioral change, or age could be potential moderators of the causal effects of music with RAS on long-term PA behaviors. Given that negative affect has been observed during exercise bouts mainly at an intensity above the ventilatory or lactate threshold (Ekkekakis et al., 2011) especially in overweight/obese people (Ekkekakis and Lind, 2006; Ekkekakis et al., 2010), our theoretical model is more likely to be effective in low-active/sedentary individuals, overweight/obese people, or older adults who are expected to have low adherence to PA based on more conflicts between hedonic motivation and reflective motivation due to negative affect. Future studies can test the theoretical model with varying exercise modalities. The methodologies used for music playlists with RAS can also be combined with jogging/running, high-intensity interval training, dance, or group/individual exercise programs to enhance affective responses and hedonic motivation.

It is important to note that we built this theoretical model in consideration of previously proposed conceptual models addressing the music-PA relationship (Karageorghis, 2015; Clark et al., 2016a; Terry et al., 2020). Importantly, we are not suggesting rejection of these models but reconsidering current theoretical approaches to music-based PA interventions from the acute phase primarily for performance enhancement to the long-term phase of behavioral change. For this new perspective, we here take a theoretical approach and attempt to integrate elements from disparate literatures that have not been linked to one another within the fields of public health and behavioral medicine.

5. Conclusion

Physical inactivity is epidemic and jeopardizes global health. We here suggest affective, motoric, and sensory engagement in music as an innovative approach to promote PA. From a psychological and neurobiological standpoint, we expounded the putative mechanisms underlying motivational benefits of music for acute and long-term PA. Past research has shown that exercising with personally preferred, beat-accentuated, tempo-synchronous music playlists remarkably improved the amounts of PA at all intensities over 12 weeks (Alter et al., 2015). This proof-of-concept evidence of long-term PA preliminarily upholds the notion that certain types of musical stimulation could be effective beyond a single session of PA possibly for behavior change. Despite the strong preliminary data, a theoretical basis elucidating the psychological mechanism underlying the effects of music stimulation on acute and long-term PA has been lacking. Hence, this theoretical discussion is important to fill the gap in the current literature and to promote the evidence-based development and implementation of music-based interventions for PA promotion. Our notion is that the beneficial effects of music stimulation on acute and long-term PA is primarily based on hedonic principles. In other words, certain types of music can serve as an affective stimulant to help people like their workout sessions and consequently promote 'wanting' responses for PA to be repeated on a regular basis. Our discussion may inform future music-based interventions to gain additional success for PA promotion.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

KSP conceived of the hypothesis with input from DW and JE. KSP drafted an early version of the manuscript. DW and JE revised and completed the writing of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aalbers, S., Fusar-Poli, L., Freeman, R. E., Spreen, M., Ket, J. C., Vink, A. C., et al. (2017). Music therapy for depression. *Cochrane Database Syst. Rev.* 2017:CD004517. doi: 10.1002/14651858.cd004517.pub3

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., et al. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Med. Sci. Sports Exerc.* 32, S498–S516. doi: 10.1097/00005768-200009001-00009

Alter, D. A., O'Sullivan, M., Oh, P. I., Redelmeier, D. A., Marzolini, S., Liu, R., et al. (2015). Synchronized personalized music audio-playlists to improve adherence to physical activity among patients participating in a structured exercise program: a proof-of-principle feasibility study. *Sports Med. - Open* 1:23. doi: 10.1186/s40798-015-0017-9

Bauldoff, G. S., Hoffman, L. A., Zullo, T. G., and Sciurba, F. C. (2002). Exercise maintenance following pulmonary rehabilitation: effect of distractive stimuli. *Chest* 122, 948–954. doi: 10.1378/chest.122.3.948

Bauldoff, G. S., Rittinger, M., Nelson, T., Doehrel, J., and Diaz, P. T. (2005). Feasibility of distractive auditory stimuli on upper extremity training in persons with chronic obstructive pulmonary disease. *J. Cardiopulm. Rehabil. Prev.* 25, 50–55. doi: 10.1097/00008483-200501000-00011

Bennie, J. A., De Cocker, K., Teychenne, M. J., Brown, W. J., and Biddle, S. J. H. (2019). The epidemiology of aerobic physical activity and muscle-strengthening activity guideline adherence among 383,928 U.S. adults. *Int. J. Behav. Nutr. Phys. Act.* 16:34. doi: 10.1186/s12966-019-0797-2

Benoit, C.-E., Dalla Bella, S., Farrugia, N., Obrig, H., Mainka, S., and Kotz, S. A. (2014). Musically cued gait-training improves both perceptual and motor timing in Parkinson's disease. *Front. Hum. Neurosci.* 8:656. doi: 10.3389/fnhum.2014.00494

Berridge, K. C. (1999). "Pleasure, pain, desire, and dread: hidden Core process of emotion" in *Well-being: Foundations of hedonic psychology*. eds. N. Schwarz, E. Diener and D. Kahneman (New York: Russell Sage Foundation), 525–557.

Berridge, K. C. (2003). Pleasures of the brain. *Brain Cogn.* 52, 106–128. doi: 10.1016/S0278-2626(03)00014-9

Berridge, K. C. (2007). The debate over dopamine's role in reward: the case for incentive salience. *Psychopharmacology* 191, 391–431. doi: 10.1007/s00213-006-0578-x

Berridge, K. C., and Robinson, T. E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Res. Rev.* 28, 309–369. doi: 10.1016/S0165-0173(98)00019-8

Berridge, K. C., and Robinson, T. E. (2016). Liking, wanting, and the incentive-sensitization theory of addiction. *Am. Psychol.* 71, 670–679. doi: 10.1037/amp0000059

Biddle, S. J. H., Mutrie, N., Gorely, T., and Faulkner, G. (2021). *Psychology of Physical Activity: Determinants, Well-Being, and Interventions. 4th Edn.* New York: Routledge.

Bigliassi, M., Karageorghis, C. I., Wright, M. J., Orgs, G., and Nowicky, A. V. (2017). Effects of auditory stimuli on electrical activity in the brain during cycle ergometry. *Physiol. Behav.* 177, 135–147. doi: 10.1016/j.physbeh.2017.04.023

Bigliassi, M., Silva, V. B., Karageorghis, C. I., Bird, J. M., Santos, P. C., and Altimari, L. R. (2016). Brain mechanisms that underlie the effects of motivational audiovisual stimuli on psychophysiological responses during exercise. *Physiol. Behav.* 158, 128–136. doi: 10.1016/j.physbeh.2016.03.001

Blood, A. J., and Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proc. Natl. Acad. Sci. U. S. A.* 98, 11818–11823. doi: 10.1073/pnas.191355898

Bood, R. J., Nijssen, M., Van Der Kamp, J., and Roerdink, M. (2013). The power of auditory-motor synchronization in sports: enhancing running performance by coupling cadence with the right beats. *PLoS One* 8:e70758. doi: 10.1371/journal.pone.0070758

Brand, R., and Cheval, B. (2019). Theories to explain exercise motivation and physical inactivity: ways of expanding our current theoretical perspective. *Front. Psychol.*:1147. doi: 10.3389/fpsyg.2019.01147

Brand, R., and Ekkekakis, P. (2018). Affective–reflective theory of physical inactivity and exercise. *Ger. J. Exerc. Sport Res.* 48, 48–58. doi: 10.1007/s12662-017-0477-9

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., et al. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* 54, 1451–1462. doi: 10.1136/bjsports-2020-102955

Burger, B., Thompson, M. R., Luck, G., Saarikallio, S., and Toiviainen, P. (2013). Influences of rhythm-and timbre-related musical features on characteristics of music-induced movement. *Front. Psychol.* 4:183. doi: 10.3389/fpsyg.2013.00183

Cabanac, M. (1992). Pleasure: the common currency. *J. Theor. Biol.* 155, 173–200. doi: 10.1016/S0022-5193(05)80594-6

Caspersen, C. J., Powell, K. E., and Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 100, 126–131. PMID: 3920711

Chair, S. Y., Zou, H., and Cao, X. (2021). A systematic review of effects of recorded music listening during exercise on physical activity adherence and health outcomes in patients with coronary heart disease. *Ann. Phys. Rehabil. Med.* 64:101447. doi: 10.1016/j.rehab.2020.09.011

Chen, W. G., Iversen, J. R., Kao, M. H., Loui, P., Patel, A. D., Zatorre, R. J., et al. (2022). Music and brain circuitry: strategies for strengthening evidence-based research for music-based interventions. *J. Neurosci.* 42, 8498–8507. doi: 10.1523/JNEUROSCI.1135-22.2022

Chen, J. L., Penhune, V. B., and Zatorre, R. J. (2008). Listening to musical rhythms recruits motor regions of the brain. *Cereb. Cortex* 18, 2844–2854. doi: 10.1093/cercor/bhn042

Chen, J. L., Zatorre, R. J., and Penhune, V. B. (2006). Interactions between auditory and dorsal premotor cortex during synchronization to musical rhythms. *NeuroImage* 32, 1771–1781. doi: 10.1016/j.neuroimage.2006.04.207

Clark, I. N., Baker, F. A., Peiris, C. L., Shoebridge, G., and Taylor, N. F. (2017). Participant-selected music and physical activity in older adults following cardiac rehabilitation: a randomized controlled trial. *Clin. Rehabil.* 31, 329–339. doi: 10.1177/0269215516640864

Clark, I. N., Baker, F. A., and Taylor, N. F. (2016a). The modulating effects of music listening on health-related exercise and physical activity in adults: a systematic review and narrative synthesis. *Nord. J. Music. Ther.* 25, 76–104. doi: 10.1080/08098131.2015.1008558

Clark, I. N., Baker, F. A., and Taylor, N. F. (2016b). Older Adults' music listening preferences to support physical activity following cardiac rehabilitation. *J. Music. Ther.* 53, 364–397. doi: 10.1093/jmt/thw011

Clark, I. N., Taylor, N. F., and Baker, F. A. (2012). Music interventions and physical activity in older adults: a systematic literature review and meta-analysis. *J. Rehabil. Med.* 44, 710–719. doi: 10.2340/16501977-1025

Cooper, G. W., and Meyer, L. B. (1960). *The rhythmic structure of music*, Chicago, IL: The University of Chicago Press.

Craig, A., Tran, Y., Wijesuriya, N., and Nguyen, H. (2012). Regional brain wave activity changes associated with fatigue. *Psychophysiology* 49, 574–582. doi: 10.1111/j.1469-8986.2011.01329.x

Cross, I. (2001). Music, cognition, culture, and evolution. *Ann. N. Y. Acad. Sci.* 930, 28–42. doi: 10.1111/j.1749-6632.2001.tb05723.x

Damm, L., Varoqui, D., De Cock, V. C., Dalla Bella, S., and Bardy, B. (2020). Why do we move to the beat? A multi-scale approach, from physical principles to brain dynamics. *Neurosci. Biobehav. Rev.* 112, 553–584. doi: 10.1016/j.neubiorev.2019.12.024

de Bruin, N., Doan, J. B., Turnbull, G., Suchowersky, O., Bonfield, S., Hu, B., et al. (2010). Walking with music is a safe and viable tool for gait training in Parkinson's disease: the effect of a 13-week feasibility study on single and dual task walking. *Parkinson's Dis.* 2010, 1–9. doi: 10.4061/2010/483530

Desmurget, M., and Sirigu, A. (2012). Conscious motor intention emerges in the inferior parietal lobule. *Curr. Opin. Neurobiol.* 22, 1004–1011. doi: 10.1016/j.conb.2012.06.006

Du, Y., Liu, B., Sun, Y., Snetselaar, L. G., Wallace, R. B., and Bao, W. (2019). Trends in adherence to the physical activity guidelines for Americans for aerobic activity and time spent on sedentary behavior among US adults, 2007 to 2016. *JAMA Netw. Open* 2:e197597. doi: 10.1001/jamanetworkopen.2019.7597

Ekkekakis, P. (2003). Pleasure and displeasure from the body: perspectives from exercise. *Cognit. Emot.* 17, 213–239. doi: 10.1080/02699930302292

Ekkekakis, P. (2017). People have feelings! Exercise psychology in paradigmatic transition. *Curr. Opin. Psychol.* 16, 84–88. doi: 10.1016/j.copsyc.2017.03.018

Ekkekakis, P., and Lind, E. (2006). Exercise does not feel the same when you are overweight: the impact of self-selected and imposed intensity on affect and exertion. *Int. J. Obes.* 30, 652–660. doi: 10.1038/sj.ijo.0803052

Ekkekakis, P., Lind, E., and Vazou, S. (2010). Affective responses to increasing levels of exercise intensity in Normal-weight, overweight, and obese middle-aged women. *Obesity* 18, 79–85. doi: 10.1038/oby.2009.204

Ekkekakis, P., Parfitt, G., and Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities. *Sports Med.* 41, 641–671. doi: 10.2165/11590680-000000000-00000

Ekkekakis, P., and Petruzzello, S. J. (1999). Acute aerobic exercise and affect. *Sports Med.* 28, 337–374. doi: 10.2165/00007256-199928050-00005

Ferreri, L., Mas-Herrero, E., Zatorre, R. J., Ripollés, P., Gomez-Andres, A., Alicart, H., et al. (2019). Dopamine modulates the reward experiences elicited by music. *Proc. Natl. Acad. Sci.* 116, 3793–3798. doi: 10.1073/pnas.1811878116

Forte, R., Tocci, N., and De Vito, G. (2021). The impact of exercise intervention with rhythmic auditory stimulation to improve gait and mobility in Parkinson disease: an umbrella review. *Brain Sci.* 11:685. doi: 10.3390/brainsci11060685

Franěk, M., van Noorden, L., and Režný, L. (2014). Tempo and walking speed with music in the urban context. *Front. Psychol.* 5:1361. doi: 10.3389/fpsyg.2014.01361

Freitas, C., Manzato, E., Burini, A., Taylor, M. J., Lerch, J. P., and Anagnostou, E. (2018). Neural correlates of familiarity in music listening: a systematic review and a neuroimaging meta-analysis. *Front. Neurosci.* 12:168. doi: 10.3389/fnins.2018.00686

Frijda, N. H. (2009). Emotion experience and its varieties. *Emot. Rev.* 1, 264–271. doi: 10.1177/1754073909103595

Gebauer, L., Kringelbach, M. L., and Vuust, P. (2012). Ever-changing cycles of musical pleasure: the role of dopamine and anticipation. *Psychomusicol.: J. Res. Music Cogn.* 22, 152–167. doi: 10.1037/a0031126

Ghai, S., and Ghai, I. (2018). Effects of rhythmic auditory cueing in gait rehabilitation for multiple sclerosis: a mini systematic review and meta-analysis. *Front. Neurol.* 9:386. doi: 10.3389/fneur.2018.00386

Ghai, S., and Ghai, I. (2019). Effects of (music-based) rhythmic auditory cueing training on gait and posture post-stroke: a systematic review & dose-response meta-analysis. *Sci. Rep.* 9:2183. doi: 10.1038/s41598-019-38723-3

Ghai, S., Ghai, I., Schmitz, G., and Effenberg, A. O. (2018). Effect of rhythmic auditory cueing on parkinsonian gait: a systematic review and meta-analysis. *Sci. Rep.* 8:506. doi: 10.1038/s41598-017-16232-5

Goldstein, A. (1980). Thrills in response to music and other stimuli. *Psychobiology* 8, 126–129. doi: 10.3758/BF03326460

Goupil, L., and Aucouturier, J.-J. (2019). Musical pleasure and musical emotions. *Proc. Natl. Acad. Sci. U. S. A.* 116, 3364–3366. doi: 10.1073/pnas.1900369116

Grahn, J. A., and Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *J. Cogn. Neurosci.* 19, 893–906. doi: 10.1162/jocn.2007.19.5.893

Grewe, O. (2005). How does music arouse "chills"? Investigating strong emotions, combining psychological, physiological, and Psychoacoustical methods. *Ann. N. Y. Acad. Sci.* 1060, 446–449. doi: 10.1196/annals.1360.041

Grewe, O., Kopiez, R., and Altenmüller, E. (2009). Chills as an indicator of individual emotional peaks. *Ann. N. Y. Acad. Sci.* 1169, 351–354. doi: 10.1111/j.1749-6632.2009.04783.x

Grewe, O., Nagel, F., Kopiez, R., and Altenmüller, E. (2007). Emotions over time: synchronicity and development of subjective, physiological, and facial affective reactions to music. *Emotion* 7, 774–788. doi: 10.1037/1528-3542.7.4.774

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., and Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 380, 247–257. doi: 10.1016/S0140-6736(12)60646-1

Hardy, C. J., and Rejeski, W. J. (1989). Not what, but how one feels: the measurement of affect during exercise. *J. Sport Exerc. Psychol.* 11, 304–317. doi: 10.1123/jsep.11.3.304

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., et al. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med. Sci. Sports Exerc.* 39, 1423–1434. doi: 10.1249/mss.0b013e3180616b27

Huffman, M. K., Reed, J. B., Carpenter, T. K., and Amireault, S. (2021). Maintenance motives for physical activity among older adults: a systematic review and meta-analysis. *Health Psychol. Rev.* 15, 593–612. doi: 10.1080/17437199.2020.1858926

Hutchinson, J. C., Jones, L., Vitti, S. N., Moore, A., Dalton, P. C., and O'Neil, B. J. (2018). The influence of self-selected music on affect-regulated exercise intensity and remembered pleasure during treadmill running. *Sport Exerc. Perform. Psychol.* 7, 80–92. doi: 10.1037/spy0000115

Janata, P., Tomic, S. T., and Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *J. Exp. Psychol. Gen.* 141, 54–75. doi: 10.1037/a0024208

Juslin, P. N., Harmat, L., and Eerola, T. (2014). What makes music emotionally significant? Exploring the underlying mechanisms. *Psychol. Music* 42, 599–623. doi: 10.1177/0305735613484548

Juslin, P. N., and Västfjäll, D. (2008). Emotional responses to music: the need to consider underlying mechanisms. *Behav. Brain Sci.* 31, 559–575. doi: 10.1017/S0140525X08005293

Kahneman, D., Wakker, P. P., and Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *Q. J. Econ.* 112, 375–406. doi: 10.1162/003355397555235

Karageorghis, C. I. (2015). "The scientific application of music in exercise and sport: towards a new theoretical model" in *Sport and exercise psychology*. ed. A. M. Lane. *2nd Edn.* (London, UK: Routledge), 288–334.

Karageorghis, C. I., Cheek, P., Simpson, S. D., and Bigliassi, M. (2018). Interactive effects of music tempi and intensities on grip strength and subjective affect. *Scand. J. Med. Sci. Sports* 28, 1166–1175. doi: 10.1111/sms.12979

Karageorghis, C. I., Mouzourides, D. A., Priest, D.-L., Sasso, T. A., Morrish, D. J., and Walley, C. L. (2009). Psychophysical and ergogenic effects of synchronous music during treadmill walking. *J. Sport Exerc. Psychol.* 31, 18–36. doi: 10.1123/jsep.31.1.18

Karageorghis, C. I., and Priest, D.-L. (2012a). Music in the exercise domain: a review and synthesis (part I). *Int. Rev. Sport Exerc. Psychol.* 5, 44–66. doi: 10.1080/1750984x.2011.631026

Karageorghis, C. I., and Priest, D.-L. (2012b). Music in the exercise domain: a review and synthesis (part II). *Int. Rev. Sport Exerc. Psychol.* 5, 67–84. doi: 10.1080/1750984x.2011.631027

Karageorghis, C. I., and Terry, P. C. (1997). The psychophysical effects of music in sport and exercise: a review. *J. Sport Behav.* 20, 54–68.

Karageorghis, C. I., Terry, P. C., and Lane, A. M. (1999). Development and initial validation of an instrument to assess the motivational qualities of music in exercise and sport: the Brunel music rating inventory. *J. Sports Sci.* 17, 713–724. doi: 10.1080/026404199365579

Kavanagh, D. J., Andrade, J., and May, J. (2005). Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol. Rev.* 112, 446–467. doi: 10.1037/0033-295X.112.2.446

Kendzierski, D., and Decarlo, K. J. (1991). Physical activity enjoyment scale: two validation studies. *J. Sport Exerc. Psychol.* 13, 50–64. doi: 10.1123/jsep.13.1.50

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nat. Rev. Neurosci.* 15, 170–180. doi: 10.1038/nrn3666

Kohl, H. W., Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., et al. (2012). The pandemic of physical inactivity: global action for public health. *Lancet* 380, 294–305. doi: 10.1016/S0140-6736(12)60898-8

Kornysheva, K., von Cramon, D. Y., Jacobsen, T., and Schubotz, R. I. (2010). Tuning-in to the beat: aesthetic appreciation of musical rhythms correlates with a premotor activity boost. *Hum. Brain Mapp.* 31, NA–64. doi: 10.1002/hbm.20844

Kühlmann, A. Y. R., De Rooij, A., Kroese, L. F., Van Dijk, M., Hunink, M. G. M., and Jeekel, J. (2018). Meta-analysis evaluating music interventions for anxiety and pain in surgery. *Br. J. Surg.* 105, 773–783. doi: 10.1002/bjs.10853

Large, E. W., Herrera, J. A., and Velasco, M. J. (2015). Neural networks for beat perception in musical rhythm. *Front. Syst. Neurosci.* 9:159. doi: 10.3389/fnsys.2015.00159

Large, E. W., and Kolen, J. F. (1994). Resonance and the perception of musical meter. *Connect. Sci.* 6, 177–208. doi: 10.1080/09540099408915723

Large, E. W., and Snyder, J. S. (2009). Pulse and meter as neural resonance. *Ann. N. Y. Acad. Sci.* 1169, 46–57. doi: 10.1111/j.1749-6632.2009.04550.x

Lee, H. H., Dunsiger, S., Connell Bohlen, L., Boyle, H. K., Emerson, J. A., and Williams, D. M. (2020). Age moderates the effect of self-paced exercise on exercise adherence among overweight adults. *J. Aging Health* 32, 154–161. doi: 10.1177/0898264318812139

Lee, H. H., Emerson, J. A., and Williams, D. M. (2016). The exercise–affect–adherence pathway: an evolutionary perspective. *Front. Psychol.*:1285. doi: 10.3389/fpsyg.2016.01285

Lee, I.-M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., and Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 380, 219–229. doi: 10.1016/s0140-6736(12)61031-9

Leggieri, M., Thaut, M. H., Fornazzari, L., Schweizer, T. A., Barfett, J., Munoz, D. G., et al. (2019). Music intervention approaches for Alzheimer's disease: a review of the literature. *Front. Neurosci.* 13:132. doi: 10.3389/fnins.2019.00132

Leow, L. A., Rinchon, C., and Grahn, J. (2015). Familiarity with music increases walking speed in rhythmic auditory cuing. *Ann. N. Y. Acad. Sci.* 1337, 53–61. doi: 10.1111/nyas.12658

Levitin, D. J., Grahn, J. A., and London, J. (2018). The psychology of music: rhythm and movement. *Annu. Rev. Psychol.* 69, 51–75. doi: 10.1146/annurev-psych-122216-011740

Lim, H. B. T., Karageorghis, C. I., Romer, L. M., and Bishop, D. T. (2014). Psychophysiological effects of synchronous versus asynchronous music during cycling. *Med. Sci. Sports Exerc.* 46, 407–413. doi: 10.1249/MSS.0b013e3182a6378c

Lim, I., van Wegen, E., de Goede, C., Deutekom, M., Nieuwboer, A., Willems, A., et al. (2005). Effects of external rhythmical cueing on gait in patients with Parkinson's disease: a systematic review. *Clin. Rehabil.* 19, 695–713. doi: 10.1191/0269215505cr906oa

Lin, C.-L., Hwang, S.-L., Jiang, P., and Hsiung, N.-H. (2020). Effect of music therapy on pain after orthopedic surgery—a systematic review and meta-analysis. *Pain Pract.* 20, 422–436. doi: 10.1111/papr.12864

London, J. (2012). *Hearing in time: Psychological aspects of musical meter*, New York, NY: Oxford University Press.

Marcus, B. H., King, T. K., Clark, M. M., Pinto, B. M., and Bock, B. C. (1996). Theories and techniques for promoting physical activity behaviours. *Sports Med.* 22, 321–331. doi: 10.2165/00007256-199622050-00005

Mathews, R. M., Clair, A. A., and Kosloski, K. (2001). Keeping the beat: use of rhythmic music during exercise activities for the elderly with dementia. *Am. J. Alzheimer's Dis. Other Dement.* 16, 377–380. doi: 10.1177/153331750101600608

Matthews, T. E., Witek, M. A. G., Lund, T., Vuust, P., and Penhune, V. B. (2020). The sensation of groove engages motor and reward networks. *NeuroImage* 214:116768. doi: 10.1016/j.neuroimage.2020.116768

Matthews, T. E., Witek, M. A. G., Thibodeau, J. L. N., Vuust, P., and Penhune, V. B. (2022). Perceived motor synchrony with the beat is more strongly related to groove than measured synchrony. *Music. Percept.* 39, 423–442. doi: 10.1525/mp.2022.39.5.423

McIntosh, G. C., Brown, S. H., Rice, R. R., and Thaut, M. H. (1997). Rhythmic auditory-motor facilitation of gait patterns in patients with Parkinson's disease. *J. Neurol. Neurosurg. Psychiatry* 62, 22–26. doi: 10.1136/jnnp.62.1.22

Metcalfe, T. (2016). The contribution of different musical variables to the effect of background music on motor behavior. *Psychomusicol.: Music Mind Brain* 26, 132–138. doi: 10.1037/pmu0000137

Murphy, S. L., and Eaves, D. L. (2016). Exercising for the pleasure and for the pain of it: the implications of different forms of hedonistic thinking in theories of physical activity behavior. *Front. Psychol.* 7:843. doi: 10.3389/fpsyg.2016.00843

Nombela, C., Hughes, L. E., Owen, A. M., and Grahn, J. A. (2013). Into the groove: can rhythm influence Parkinson's disease? *Neurosci. Biobehav. Rev.* 37, 2564–2570. doi: 10.1016/j.neubiorev.2013.08.003

North, A. C., and Hargreaves, D. J. (1995). Subjective complexity, familiarity, and liking for popular music. *Psychomusicol.: J. Res. Music Cogn.* 14:77.

North, A. C., and Hargreaves, D. J. (1998). Complexity, prototypicality, familiarity, and the perception of musical quality. *Psychomusicol.: J. Res. Music Cogn.* 17, 77–80. doi: 10.1037/h0094058

Oxford English Dictionary (2022). "thrill, n.3", OED Online. Oxford University Press [Accessed Sep 16, 2022.

Panksepp, J. (1995). The emotional sources of "chills" induced by music. *Music. Percept.* 13, 171–207. doi: 10.2307/40285693

Park, K. S. (2022). Decomposing the effects of familiarity with music cues on stride length and variability in persons with Parkinson's disease: on the role of covariates. *Int. J. Environ. Res. Public Health* 19:10793. doi: 10.3390/ijerph191710793

Park, K. S., Hass, C. J., Fawver, B., Lee, H., and Janelle, C. M. (2019). Emotional states influence forward gait during music listening based on familiarity with music selections. *Hum. Mov. Sci.* 66, 53–62. doi: 10.1016/j.humov.2019.03.004

Park, K. S., Hass, C. J., and Janelle, C. M. (2021). Familiarity with music influences stride amplitude and variability during rhythmically-cued walking in individuals with Parkinson's disease. *Gait Posture* 87, 101–109. doi: 10.1016/j.gaitpost.2021.04.028

Park, K. S., Hass, C. J., Patel, B., and Janelle, C. M. (2020). Musical pleasure beneficially alters stride and arm swing amplitude during rhythmically-cued walking in people with Parkinson's disease. *Hum. Mov. Sci.* 74:102718. doi: 10.1016/j.humov.2020.102718

Patel, A. D., and Iversen, J. R. (2014). The evolutionary neuroscience of musical beat perception: the action simulation for auditory prediction (ASAP) hypothesis. *Front. Syst. Neurosci.* 8:57. doi: 10.3389/fnsys.2014.00057

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., et al. (2018). The physical activity guidelines for Americans. *JAMA* 320, 2020–2028. doi: 10.1001/jama.2018.14854

Priest, D. L., Karageorghis, C. I., and Sharp, N. C. (2004). The characteristics and effects of motivational music in exercise settings: the possible influence of gender, age, frequency of attendance, and time of attendance. *J. Sports Med. Phys. Fitness* 44(1), 77–86.

Provasi, J., and Bobin-Bègue, A. (2003). Spontaneous motor tempo and rhythmical synchronisation in 2½- and 4-year-old children. *Int. J. Behav. Dev.* 27, 220–231. doi: 10.1080/01650250244000290

Reiner, M., Niermann, C., Jekauc, D., and Woll, A. (2013). Long-term health benefits of physical activity – a systematic review of longitudinal studies. *BMC Public Health* 13:813. doi: 10.1186/1471-2458-13-813

Rejeski, W. J. (1985). Perceived exertion: an active or passive process? *J. Sport Psychol.* 7, 371–378. doi: 10.1123/jsp.7.4.371

Rhodes, R. E., Fiala, B., and Conner, M. (2009). A review and meta-analysis of affective judgments and physical activity in adult populations. *Ann. Behav. Med.* 38, 180–204. doi: 10.1007/s12160-009-9147-y

Rhodes, R. E., and Kates, A. (2015). Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. *Ann. Behav. Med.* 49, 715–731. doi: 10.1007/s12160-015-9704-5

Rickard, N. S. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. *Psychol. Music* 32, 371–388. doi: 10.1177/0305735604046096

Rose, D., Ott, L., Guérin, S. M. R., Annett, L. E., Lovatt, P., and Delevoye-Turrell, Y. N. (2021). A general procedure to measure the pacing of body movements timed to music and metronome in younger and older adults. *Sci. Rep.* 11:3264. doi: 10.1038/s41598-021-82283-4

Russell, J. A. (1980). A circumplex model of affect. *J. Pers. Soc. Psychol.* 39, 1161–1178. doi: 10.1037/h0077714

Russell, J. A., Weiss, A., and Mendelsohn, G. A. (1989). Affect grid: a single-item scale of pleasure and arousal. *J. Pers. Soc. Psychol.* 57, 493–502. doi: 10.1037/0022-3514.57.3.493

Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., and Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nat. Neurosci.* 14, 257–262. doi: 10.1038/nn.2726

Salimpoor, V. N., Benovoy, M., Longo, G., Cooperstock, J. R., and Zatorre, R. J. (2009). The rewarding aspects of music listening are related to degree of emotional arousal. *PLoS One* 4:e7487. doi: 10.1371/journal.pone.0007487

Schaefer, R. S. (2014). Auditory rhythmic cueing in movement rehabilitation: findings and possible mechanisms. *Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci.* 369:20130402. doi: 10.1098/rstb.2013.0402

Schulkind, M. D. (1999). Long-term memory for temporal structure: evidence form the identification of well-known and novel songs. *Mem. Cogn.* 27, 896–906. doi: 10.3758/bf03198542

Sescousse, G., Caldú, X., Segura, B., and Dreher, J.-C. (2013). Processing of primary and secondary rewards: a quantitative meta-analysis and review of human functional neuroimaging studies. *Neurosci. Biobehav. Rev.* 37, 681–696. doi: 10.1016/j.neubiorev.2013.02.002

Shiffman, S., Stone, A. A., and Hufford, M. R. (2008). Ecological momentary assessment. *Annu. Rev. Clin. Psychol.* 4, 1–32. doi: 10.1146/annurev.clinpsy.3.022806.091415

Simpson, S. D., and Karageorghis, C. I. (2006). The effects of synchronous music on 400-m sprint performance. *J. Sports Sci.* 24, 1095–1102. doi: 10.1080/02640410500432789

Sloboda, J. A. (1991). Music structure and emotional response: some empirical findings. *Psychol. Music* 19, 110–120. doi: 10.1177/0305735691192002

Snyder, J. S., and Large, E. W. (2005). Gamma-band activity reflects the metric structure of rhythmic tone sequences. *Cogn. Brain Res.* 24, 117–126. doi: 10.1016/j.cogbrainres.2004.12.014

Ståhle, A., Mattsson, E., Rydén, L., Unden, A.-L., and Nordlander, R. (1999). Improved physical fitness and quality of life following training of elderly patients after acute coronary events. A 1 year follow-up randomized controlled study. *Eur. Heart J.* 20, 1475–1484. doi: 10.1053/euhj.1999.1581

Stanley, D. M., and Cumming, J. (2010). Are we having fun yet? Testing the effects of imagery use on the affective and enjoyment responses to acute moderate exercise. *Psychol. Sport Exerc.* 11, 582–590. doi: 10.1016/j.psychsport.2010.06.010

Stevens, C. J., Baldwin, A. S., Bryan, A. D., Conner, M., Rhodes, R. E., and Williams, D. M. (2020). Affective determinants of physical activity: a conceptual framework and narrative review. *Front. Psychol.* 11:568331. doi: 10.3389/fpsyg.2020.568331

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Boullosa, D., Janata, P., Koo, B. B., et al. (2022). Urges to move and other motivation states for physical activity in clinical and healthy populations: a scoping review protocol. *Front. Psychol.* 13:901272. doi: 10.3389/fpsyg.2022.901272

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Gilson, T. A., Ash, G. I., McKee, P. C., et al. (2020). Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front. Psychol.* 11:568390. doi: 10.3389/fpsyg.2020.568390

Stults-Kolehmainen, M. A., Blacutt, M., Fogelman, N., Gilson, T. A., Stanforth, P. R., Divin, A. L., et al. (2021). Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front. Psychol.* 12:568286. doi: 10.3389/fpsyg.2021.568286

Svebak, S., and Murgatroyd, S. (1985). Metamotivational dominance: a multimethod validation of reversal theory constructs. *J. Pers. Soc. Psychol.* 48, 107–116. doi: 10.1037/0022-3514.48.1.107

Tal, I., Large, E. W., Rabinovitch, E., Wei, Y., Schroeder, C. E., Poeppel, D., et al. (2017). Neural entrainment to the beat: the "missing-pulse" phenomenon. *J. Neurosci.* 37, 6331–6341. doi: 10.1523/jneurosci.2500-16.2017

Terry, P. C., Karageorghis, C. I., Curran, M. L., Martin, O. V., and Parsons-Smith, R. L. (2020). Effects of music in exercise and sport: a meta-analytic review. *Psychol. Bull.* 146, 91–117. doi: 10.1037/bul0000216

Terry, P. C., Karageorghis, C. I., Saha, A. M., and D'Auria, S. (2012). Effects of synchronous music on treadmill running among elite triathletes. *J. Sci. Med. Sport* 15, 52–57. doi: 10.1016/j.jsams.2011.06.003

Thaut, M. H. (2005). The future of music in therapy and medicine. *Ann. N. Y. Acad. Sci.* 1060, 303–308. doi: 10.1196/annals.1360.023

Thaut, M. H., Hoemberg, V., and von Wild, K. (2016). *Handbook of Neurologic Music Therapy*. Oxford, UK: Oxford University Press.

Thaut, M. H., McIntosh, G. C., and Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: rhythmic entrainment and the motor system. *Front. Psychol.* 5, 1–6. doi: 10.3389/fpsyg.2014.01185

Thaut, M. H., McIntosh, G. C., Prassas, S. G., and Rice, R. R. (1992). Effect of rhythmic auditory cuing on temporal stride parameters and EMG patterns in Normal gait. *Neurorehabil. Neural Repair* 6, 185–190. doi: 10.1177/136140969200600403

Thaut, M. H., McIntosh, G. C., Rice, R. R., Miller, R. A., Rathbun, J., and Brault, J. M. (1996). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. *Mov. Disord.* 11, 193–200. doi: 10.1002/mds.870110213

Tranchant, P., Vuvan, D. T., and Peretz, I. (2016). Keeping the beat: a Large sample study of bouncing and clapping to music. *PLoS One* 11, e0160178–e0160119. doi: 10.1371/journal.pone.0160178

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., and McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Med. Sci. Sports Exerc.* 40, 181–188. doi: 10.1249/mss.0b013e31815a51b3

Trost, W., Frühholz, S., Schön, D., Labbé, C., Pichon, S., Grandjean, D., et al. (2014). Getting the beat: entrainment of brain activity by musical rhythm and pleasantness. *NeuroImage* 103, 55–64. doi: 10.1016/j.neuroimage.2014.09.009

Trost, W., Labbé, C., and Grandjean, D. (2017). Rhythmic entrainment as a musical affect induction mechanism. *Neuropsychologia* 96, 96–110. doi: 10.1016/j.neuropsychologia.2017.01.004

Trost, W., and Vuilleumier, P. (2013). "Rhythmic entrainment as a mechanism for emotion induction by music: a neurophysiological perspective" in *The emotional power of music: Multidisciplinary perspectives on musical arousal, expression, and social control*. eds. T. Cochrane, B. Fantini and K. R. Scherer (New York, NY: Oxford University Press), 213–225.

Van Dyck, E. (2019). Musical intensity applied in the sports and exercise domain: an effective strategy to boost performance? *Front. Psychol.* 10:1145. doi: 10.3389/fpsyg.2019.01145

Van Dyck, E., Moens, B., Buhmann, J., Demey, M., Coorevits, E., Dalla Bella, S., et al. (2015). Spontaneous entrainment of running cadence to music tempo. *Sports Med. - Open* 1:15. doi: 10.1186/s40798-015-0025-9

Warburton, D. E., Nicol, C. W., and Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *Can. Med. Assoc. J.* 174, 801–809. doi: 10.1503/cmaj.051351

WHO (2020). Fact sheets: Physical activity. Available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity [Accessed Aug 10, 2022].

Williams, D. M. (2008). Exercise, affect, and adherence: an integrated model and a case for self-paced exercise. *J. Sport Exerc. Psychol.* 30, 471–496. doi: 10.1123/jsep.30.5.471

Williams, D. M. (2018). "Psychological hedonism, hedonic motivation, and health behavior" in *Affective determinants of health behavior*. eds. D. M. Williams, R. E. Rhodes and M. T. Conner (New York, NY: Oxford University Press), 204–234.

Williams, D. M. (2019). "The theory of hedonic motivation" in *Darwinian hedonism and the epidemic of unhealthy behavior*. ed. D. M. Williams (Cambridge, UK: Cambridge University Press), 139–146.

Williams, D. M., and Bohlen, L. C. (2019). "Motivation for exercise: reflective desire versus hedonic dread" in *APA handbook of sport and exercise psychology*, vol. *2* (Washington DC, USA: American Psychological Association), 363–385.

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., and Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol. Sport Exerc.* 9, 231–245. doi: 10.1016/j.psychsport.2007.04.002

Wilson, M., and Cook, P. F. (2016). Rhythmic entrainment: why humans want to, fireflies can't help it, pet birds try, and sea lions have to be bribed. *Psychon. Bull. Rev.* 23, 1647–1659. doi: 10.3758/s13423-016-1013-x

Witek, M. A. G., Clarke, E. F., Wallentin, M., Kringelbach, M. L., and Vuust, P. (2014). Syncopation, body-movement and pleasure in groove music. *PLoS One* 9:e94446. doi: 10.1371/journal.pone.0094446

Wittwer, J. E., Webster, K. E., and Hill, K. (2013). Music and metronome cues produce different effects on gait spatiotemporal measures but not gait variability in healthy older adults. *Gait Posture* 37, 219–222. doi: 10.1016/j.gaitpost.2012.07.006

Yoo, G. E., and Kim, S. J. (2016). Rhythmic auditory cueing in motor rehabilitation for stroke patients: systematic review and meta-analysis. *J. Music. Ther.* 53, 149–177. doi: 10.1093/jmt/thw003

Young, P. T. (1952). The role of hedonic processes in the organization of behavior. *Psychol. Rev.* 59, 249–262. doi: 10.1037/h0057176

Yu, R., Zhuo, Y., Feng, E., Wang, W., Lin, W., Lin, F., et al. (2020). The effect of musical interventions in improving short-term pain outcomes following total knee replacement: a meta-analysis and systematic review. *J. Orthop. Surg. Res.* 15:465. doi: 10.1186/s13018-020-01995-x

Zatorre, R. J. (2015). Musical pleasure and reward: mechanisms and dysfunction. *Ann. N. Y. Acad. Sci.* 1337, 202–211. doi: 10.1111/nyas.12677

Zatorre, R. J., and Salimpoor, V. N. (2013). From perception to pleasure: music and its neural substrates. *PNAS Nexus* 110, 10430–10437. doi: 10.1073/pnas.1301228110

Zentner, M., and Eerola, T. (2010). Rhythmic engagement with music in infancy. *Proc. Natl. Acad. Sci. U. S. A.* 107, 5768–5773. doi: 10.1073/pnas.1000121107

Zhao, K., Bai, Z. G., Bo, A., and Chi, I. (2016). A systematic review and meta-analysis of music therapy for the older adults with depression. *Int. J. Geriatr. Psychiatry* 31, 1188–1198. doi: 10.1002/gps.4494

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 01 February 2023
DOI 10.3389/fpsyg.2023.1049356

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to
Movement Science and Sport Psychology,
a section of the journal
Frontiers in Psychology

RECEIVED 20 September 2022
ACCEPTED 05 January 2023
PUBLISHED 01 February 2023

CITATION
Timme S, Brand R and Raboldt M (2023)
Exercise or not? An empirical illustration of the role of behavioral alternatives in exercise motivation and resulting theoretical considerations.
Front. Psychol. 14:1049356.
doi: 10.3389/fpsyg.2023.1049356

Exercise or not? An empirical illustration of the role of behavioral alternatives in exercise motivation and resulting theoretical considerations

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Objective: Individuals' decisions to engage in exercise are often the result of in-the-moment choices between exercise and a competing behavioral alternative. The purpose of this study was to investigate processes that occur in-the-moment (i.e., situated processes) when individuals are faced with the choice between exercise and a behavioral alternative during a computerized task. These were analyzed against the background of interindividual differences in individuals' automatic valuation and controlled evaluation of exercise.

Method: In a behavioral alternatives task 101 participants were asked whether they would rather choose an exercise option or a behavioral alternative in 25 trials. Participants' gaze behavior (first gaze and fixations) was recorded using eye-tracking. An exercise-specific affect misattribution procedure (AMP) was used to assess participants' automatic valuation of exercise before the task. After the task, self-reported feelings towards exercise (controlled evaluation) and usual weekly exercise volume were assessed. Mixed effects models with random effects for subjects and trials were used for data analysis.

Results: Choosing exercise was positively correlated with individuals' automatic valuation (r=0.20, p=0.05), controlled evaluation (r=0.58, p<0.001), and their weekly exercise volume (r=0.43, p<0.001). Participants showed no bias in their initial gaze or number of fixations towards the exercise or the non-exercise alternative. However, participants were 1.30 times more likely to fixate on the chosen alternative first and more frequently, but this gaze behavior was not related to individuals' automatic valuation, controlled evaluation, or weekly exercise volume.

Conclusion: The results suggest that situated processes arising from defined behavioral alternatives may be independent of individuals' general preferences. Despite one's best general intention to exercise more, the choice of a non-exercise alternative behavior may seem more appealing in-the-moment and eventually be chosen. New psychological theories of health behavior change should therefore better consider the role of potentially conflicting alternatives when it comes to initiating physical activity or exercise.

KEYWORDS

eye-tracking, dual-process models, situated processes, motivation, physical activity

1. Introduction

Promoting exercise is one of the most critical public health priorities, considering being insufficiently active increases the risk of death by 20–30% compared to being sufficiently active (World Health Organization, 2020). Understanding the psychological processes that guide the choice to be physically active is key to more effectively promoting regular exercise behavior. In the past 20 years, exercise psychology has been largely dominated by a focus on social-cognitive and humanistic/organismic frameworks that conceptualize behavior change as a mostly unidirectional process, such that a behavior is done based on mentally imagined goals (e.g., the idea of going for a run, which may have positive consequences or fit particularly well with our subjective values; Rhodes et al., 2019; Ekkekakis and Brand, 2021). This framework is based on the assumption that individuals form expectations (e.g., that exercise is important and doable) from which the intention to exercise culminates (Rhodes et al., 2019). Intention as a primary antecedent of behavior is one of the cornerstones of the social-cognitive framework, yet empirical evidence reveals a consistent intention-behavior gap (Rhodes and de Bruijn, 2013). Possible reasons for this gap are negative exercise-related automatic tendencies that are contrary to the intention (Brand and Ekkekakis, 2021), such as negative automatic associations (Schinkoeth and Antoniewicz, 2017), affective valuations (Schinkoeth and Brand, 2020), habit or identity (Rhodes, 2017, 2021).

Only recently, dual-process models that emphasize the role of automatic processes in addition to controlled cognitive processes (e.g., forming an intention from expectations about the future), have been applied to exercise psychology. According to a recent review, dual-process models are 'the most recent and understudied framework for understanding physical activity' (Rhodes et al., 2019, p. 100). Moreover, there is at least one other characteristic of dual-process models that needs to be emphasized. The dual-process framework implies that automatically activated momentary processes are essentially predetermined by the situation and therefore also referred to as *situated* processes (Brand and Ekkekakis, 2018). They may conflict with behavioral plans and must be analyzed in terms of their importance for behavioral regulation.

Examples of dual-process theories that address the role of *situated processes* within exercise and physical activity behavior include the Affective-Reflective Theory of Physical Inactivity and Exercise (ART; Brand and Ekkekakis, 2018) and the Theory of Effort Minimization in Physical Activity (TEMPA; Cheval and Boisgontier, 2021). The two have been recently contrasted in a theoretical article with an argument that provides the foundation for the current study (Brand and Cheval, 2019). Both theories are grounded in the idea that in-the-moment when individuals have to make a choice between one behavior (e.g., do exercise) or a competing behavioral alternative (e.g., remain physically inactive), a *momentary conflict* may arise before a choice is made. According to the ART, there are situated automatic affective processes that have been learned through previous experiences with exercise that can prevent individuals from rationally considering becoming physically active (a negative affective valuation of exercise) or steer us toward it (a positive affective valuation of the behavior). The TEMPA assumes that a hard-wired evolutionary process is default, which accounts for an ever-present behavioral tendency to avoid and economize physical activity and may conflict with more rational considerations.

Multiple experimental studies support the perspective of dual-process theories that when individuals are confronted with an exercise-related stimulus an immediate psychological response (e.g., affective reaction or approach/avoidance tendency) is triggered (Rebar et al., 2016; Schinkoeth and Antoniewicz, 2017). Previous studies have typically measured automatic (e.g., Chevance et al., 2017) and controlled processes first (e.g., Kiviniemi et al., 2007), which were then either correlated with remembered usual exercise behavior (e.g., Bluemke et al., 2010) or used to predict exercise behavior in subsequent weeks (e.g., Antoniewicz and Brand, 2016). Findings from these studies suggest that those who are more active tend to focus more on exercise stimuli. Despite previous literature on interindividual differences (e.g., automatic processes) and distal behavior outcomes (e.g., usual exercise volume), less is known about potentially conflicting situated processes that occur in-the-moment an individual is asked to choose a behavior. For example, some may have a strong automatic preference for exercise, but when confronted with a competing non-exercise behavioral option, the behavioral alternative may seem even more attractive in that particular moment and eventually be chosen.

Harris and Bray (2019, 2021) examined single situated exercise decisions. Participants had to choose between an exercise vs. a non-exercise task (e.g., seated "free time" with smartphone) after completing either a high-or low-cognitive demand task. The high cognitive demand task resulted in increased mental fatigue, which in turn decreased likelihood of choosing to exercise. These findings emphasize the importance of situated factors (e.g., mental fatigue) in an individual's in-the-moment choice whether or not to exercise.

In a recent study, Cheval et al. (2020) took situated processes into account by employing a paradigm in which eye-tracking was used to examine participants' gaze behavior while they viewed mutually exclusive behaviors. The authors found that physically active individuals were generally more likely to focus their attention on physical activity stimuli than on stimuli representing a sedentary alternative.

The study presented here builds on these findings, but examines situated gaze in a more complete behavioral situation: We monitored participants' gaze behavior when they have to *choose* between an exercise-related stimulus and a stimulus displaying a non-exercise alternative, and analyze their choices on the background of previously measured interindividual differences in self-reported exercise behavior, automatic valuation of exercise and self-reported feelings towards exercise.

In other fields, such as consumer psychology, process tracing methods are frequently used to capture situated processes in order to assess which factors play a role during behavioral decision-making (e.g., information search strategy). For example, eye-tracking has often been used to assess attentional processes during behavioral or consumer choices. Commonly used measures are *first gaze* (i.e., first fixated location) and number of *fixations* (i.e., temporally closely spaced fixated locations for a period of time). First gaze has shown a weak and inconsistent association with choice behavior. Schotter et al. (2010) demonstrated that participants were slightly more likely to choose the item they fixated on first. In contrast, Krajbich et al. (2010) found that the probability of fixating an item first was unaffected by their initially preferred ratings. A more homogenous pattern of results emerges for number of fixations. Previous research supports the idea that the more time we spend on an item, the more likely we are to choose it (Krajbich et al., 2010; Cavanagh et al., 2014). However, researchers disagree on whether this relation is causal, leaving open the question of whether we direct our attention on what we like or we will like what we focus our attention on (Orquin and Mueller Loose, 2013).

The present study aimed to extend insights on the processes occurring when individuals are confronted with competing behavioral alternatives. We administered eye-tracking in a computerized task where participants were asked to choose between an exercise and a non-exercise alternative in a series of hypothetical situations. Gaze behavior was tracked to examine how much attention was paid to each behavioral alternative in each situation of choice. This allowed us to measure both interindividual (e.g., who is generally more likely to look at exercise) and intraindividual processes (e.g., which of the behavioral alternatives is more likely to be fixated) and use them as proxies for situated processes that would likely occur in real life situations.

According to the TEMPA, one could assume an initial bias towards the non-exercise alternative (Cheval and Boisgontier, 2021). With the ART conceptualizing the automatic response as a learned process (Brand and Ekkekakis, 2018) one would assume that individuals who (have learned to like and do) exercise more regularly will have an initial bias towards the exercise alternative. Based on findings from consumer psychology, we expected that individuals would be more likely to initially direct their gaze toward the chosen alternative and fixate this alternative more often. Whilst the current study emphasized the examination of gaze behavior as situated processes within individuals, we recognize that interindividual differences in automatic and controlled processes are also relevant to exercise behavior (e.g., Schinkoeth and Antoniewicz, 2017; Rhodes et al., 2019). In line with the constructs of the ART (Brand and Ekkekakis, 2018), we included analyses of the association of automatic valuation of exercise, self-reported feelings towards exercise (controlled evaluation) and exercise behavior with gaze behavior on a subject-level as well. Based on previous findings (Cheval et al., 2020) we expect individuals with higher levels of self-reported exercise behavior (and more positive automatic and controlled (e)valuations of exercise) to display higher attentional focus (first gaze and fixations) on exercise-related stimuli. By simultaneously considering inter-and intraindividual varying processes when individuals are confronted with exercise-related choices, this study introduces a new approach to investigate situated processes in exercise psychology.

2. Materials and methods

2.1. Participants

106 students from the University of Potsdam took part in this study. Participants were recruited through the university's participant pool. Five participants were removed from the analysis due to technical problems during data collection, resulting in a total sample of $N=101$ participants ($M_{age}=23.6$, $SD_{age}=3.6$, 48.5% females). Most of the participants were enrolled in a sports science ($n=80$) or psychology ($n=21$) program. All participants provided written consent before the experiment, fulfilled the screening criteria (i.e., no confounding activities such as intensive exercise or alcoholic beverages beforehand), and reported having a normal or corrected-to-normal vision without color blindness. Participants were compensated for their participation with additional (non-obligatory) course credit. The study was conducted following the ethical standards laid out in the Declaration of Helsinki and the local institution's ethical guidelines. Data, analysis code, and stimulus material are available.[1]

2.2. Measures

2.2.1. Behavioral alternatives task

For the behavioral alternatives task, we adapted the idea of the Situated Decisions to Exercise Questionnaire (SDEQ) by Brand and Schweizer (2015) in a computerized task presented with iMotions™ software (version 8.0). After reading a prototypical everyday situation (vignette; e.g., a friend has asked you if you would either like to work out with him tonight or have a lazy evening), five randomized pairs of pictures representing conflicting behavioral alternatives (exercise vs. non-exercise) were presented. In each of the trials, participants were forced to choose one of the presented behavioral alternatives they would engage in (see Figure 1). Two vignettes each described situations where the activities would be done alone (vignettes 1 and 5) or together with others (vignettes 2 and 3), respectively. One vignette described an ambivalent situation where the individual could choose to do the behavior alone or in a group (vignette 4). Thus, participants completed 5 vignettes with 5 randomized pairs of pictures resulting in a total of 25 trials. The pictures were presented side-by-side on the left and right sides of the computer screen. The side of the screen was randomized for the exercise and non-exercise alternative. Choices had to be made within 10 s by clicking on either the 'E' (left behavioral alternative) or 'I' (right behavioral alternative) button on a keyboard.

A 10-s time constraint with manual advance was set. To prevent participants from engaging excessively in deliberate thinking, they were asked to choose based on their initial thought as fast as possible. Between the trials, participants had to focus on a fixation cross for 5 s.

In total, 50 different pictures were used in the task: 25 representing exercise and 25 representing non-exercise. The exercise activities were selected according to the results of a representative survey on common sports and exercise activities among the Berlin population (Dierker et al., 2018). The results of that survey indicated biking, running, fitness, swimming, and hiking as the five most frequent activities. Since primarily moderate-or vigorous-intensity activities should be displayed in the current study, hiking was not considered; however, additional fitness activities were included based on exercise trends (e.g., CrossFit, rollerblading). For the non-exercise alternative, a broad range of alternatives were selected such as reading, listening to music, and lying in the park. Images were mainly provided by a license-free image database,[2] and four images were self-taken by the authors. All images were presented in grayscale (16 bit) with a minimum resolution of 1,024 × 768 pixels and processed so that brightness distribution and contrasts were matched. The exercise and non-exercise images had to fulfill the following requirements: a similar perspective, the same number of individuals on the images with no visible facial expressions, no sexual stimuli, and no labels.

Intraindividual differences in gaze behavior and choice behavior for the behavioral alternatives were repeatedly measured and analyzed for each choice trial during the task. Since these measures can differ from situation to situation within individuals, they were used as a proxy for situated processes.

2.2.1.1. Gaze behavior

Gaze behavior (*first gaze* and *fixations*) was measured with the Gazepoint GP3 eye-tracker at a sampling frequency of 60 Hz. For each

1 https://osf.io/ubrj7/

2 pixabay.com

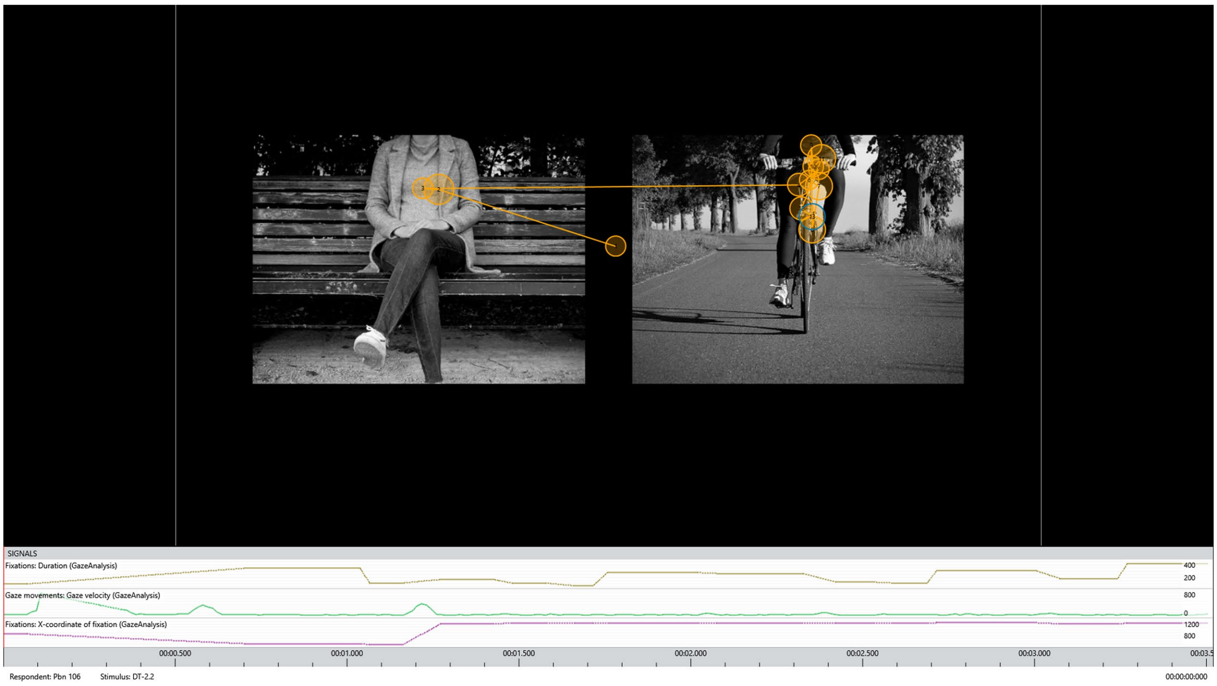

FIGURE 1
Representative gaze replay of a single participant with circles representing fixations and lines representing saccades. Fixation duration is indicated by circle size. Screenshot reproduced with permission from iMotions (8.0).

trial, a *first gaze* toward the exercising picture was coded as 1, whereas a first gaze toward the non-exercise picture was coded as 0. *Fixations* are a period during which the eyes are locked on a specific location in the visual field, measured by the eye tracker as a series of very close gaze points in time and range. The I-VT algorithm was used to classify eye movements above the velocity threshold of 30°/s as a fixation (Olsen, 2012). Number of fixations was separately computed for the exercising and the non-exercise alternative.

2.2.1.2. Choice

For each trial, choosing the exercise alternative (*choice*) was coded as 1, whereas choosing the non-exercise alternative was coded as 0.

2.2.2. Interindividual differences

Interindividual differences in participants' automatic valuation of exercise was assessed before the task, whereas self-reported feelings towards exercise and exercise behavior were assessed after completing the task.

2.2.2.1. Automatic valuation of exercise

The affective misattribution procedure (AMP; Payne et al., 2005) was used as a proxy for an automatic-affective valuation of exercise. The AMP uses supraliminal presentations of primes (of the affective target stimuli, e.g., exercise) followed by a neutral Chinese ideograph. It is assumed that participants misattribute their spontaneous affective response to the primes for evaluation of the Chinese ideographs (Payne and Lundberg, 2014). In this study, an adapted version of the standard AMP (Payne et al., 2005) was presented with Inquisit 5.0 software. The same exercise and non-exercise pictures from the behavioral alternatives task were used as target primes, and grey squares were used as neutral primes. Primes were presented for 75 ms followed by a 125 ms black screen and by the presentation of the Chinese ideograph for 200 ms. Then, a grey mask picture was shown until participants evaluated the ideograph as "pleasant" or "unpleasant" by pressing the "E" or "I" key, respectively, on a standard QWERTZ keyboard. Participants were instructed to ignore the prime stimulus (Payne and Lundberg, 2014) and completed 100 randomly presented trials, lasting approximately five minutes total. The AMP score was calculated as the difference between the proportions of ideographs evaluated as pleasant after the exercise primes vs. the non-exercise primes divided by 100, resulting in a score between -1 and 1 (Payne et al., 2005). Positives scores indicated more ideographs following an exercise prime were evaluated as pleasant, whereas negatives scores indicated more ideograph following a non-exercise prime were evaluated as pleasant. The AMP score was z-transformed before further analyses. The internal consistency of the AMP in this sample (split-half; $p = 0.81$) is similar to that found in previous studies (>0.80; e.g., Zenko and Ekkekakis, 2019). We chose the AMP score as an implicit measure of automatic-affective valuation of exercise due to its inherent core affective and valuative properties. The AMP is based on the theoretical idea to elicit a spontaneous, automatic, affective judgement. This is conceptually close to the construct of automatic-affective valuation of exercise according to the ART (Brand and Ekkekakis, 2018; in contrast, for example, implicit association tests are based much more on the assumption of mental representations). Many studies from different research areas have already used the AMP to draw conclusions about automatic affective reactions to a wide range of behaviors, including drinking decisions (Payne et al., 2008), moral decisions (Hofmann and Baumert, 2010) and eating behavior (e.g., Hofmann et al., 2010). According to a meta-analysis (Cameron et al., 2012), the AMP can be used to predict behavior with an average effect size of $r = 0.35$. Few original studies in exercise psychology have used the AMP, but had comparable results (Karpen et al., 2012; Antoniewicz and Brand, 2014).

2.2.2.2. Self-reported feelings towards exercise

Self-reported feelings associated with exercise was used as a proxy for controlled evaluation of exercise. Participants indicated how they felt about exercising on a continuous 7-point scale ("absolutely negative" to "absolutely positive"). Scores for self-reported positive feelings were z-standardized. Research has shown that single-item measures to capture exercise-related feelings are highly correlated with multi-item measured of the same construct ($r = 0.56$ to 0.70; Brito et al., 2022).

2.2.2.3. Self-reported exercise volume

Self-reported exercise volume was measured through questions from the International Physical Activity Questionnaire (short form; Craig et al., 2003) as a proxy for a behavioral component. Participants were asked about their usual exercise behavior in their free time. Exercising was defined as activities that are deliberately pursued in a way that makes one breathe faster and break a sweat (e.g., swimming, jogging, going to the gym, tennis, soccer). Participants indicated their weekly frequency and duration of exercise sessions according to this definition. Average weekly exercise volume (sessions per week × duration per session) was calculated. One participant who reported an average duration of 360 minutes per session was excluded from the analyses involving self-reported exercise volume but retained for all other analyses.

2.3. Procedure

Participants were tested in single-person lab sessions lasting for approximately 45 min. The laboratory was dimmed with artificial lightning (i.e., no sunlight). Participants were seated 60 cm in front of a Benq Senseq FP222WA, 22″ monitor. The monitor was connected to the investigator's laptop. The investigator could thereby monitor the experiment, but was out of the participant's sight.

First, participants completed the AMP and then manually advanced to the behavioral alternatives task. Before initiating behavioral alternatives task, calibration of the screen-based Gazepoint eye-tracker was done by the iMotions™ software. Participants were instructed to minimize head movements during eye-tracking recording. After successful calibration, participants completed the behavioral alternatives task. After the task, participants answered a follow-up questionnaire to control for possible confounders (e.g., excessive exercise before the experiment, demographics) and to assess the exercise-related controlled and behavioral component. Finally, participants were thanked and debriefed.

2.4. Data analysis

The data were analyzed using generalized mixed models with the lme4-package (Bates et al., 2015) in R-software (R Core Team, 2021). Logistic mixed-effects models were used to predict the odds of first gaze (exercise vs. non-exercise) and linear mixed-effects models to predict the number of fixations on the behavioral alternatives. Participants and trials were included as crossed random effects to account for the crossed data structure and the non-independence of observations. Assuming a medium sized effect (based on a meta-analysis on the effect of visual attention on choice; Bhatnagar and Orquin, 2022), simulation studies revealed that in a fully crossed design with 25 trials 90 participants or more would result into 80% power (Westfall et al., 2014). To account for study attrition and data loss we aimed for a sample of at least 100 participants.

First, unconditional means models with the respective dependent variable (first gaze, exercise fixations, non-exercise fixation) were computed. Second, choice (0 = non-exercise, 1 = exercise) was added to model to test the relationship between gaze and choice behavior. Third, interindividual variables (i.e., automatic valuation of exercise, self-reported feelings towards exercise, and self-reported exercise volume) were separately introduced into the models to examine interindividual differences in gaze behavior.

3. Results

3.1. Choices in the behavioral alternatives task

In the behavioral alternatives task, choosing the exercise alternative was more likely than choosing the non-exercise alternative ($OR = 1.85$, 95% CI [1.39; 2.47], $p < 0.001$). In other words, there was a 65% chance of choosing exercise across all trials and participants. Choosing the exercise alternative in the behavioral alternatives task correlated with self-reported exercise volume ($r = 0.43$, 95% CI [0.20, 0.53], $p < 0.001$), with self-reported positive feelings towards exercise ($r = 0.58$, 95% CI [0.43, 0.70], $p < 0.001$) and with the automatic valuation of exercise as measured with the AMP ($r = 0.20$, 95% CI [0.00, 0.38], $p = 0.05$). Correlations and descriptive statistics of all main variables are presented in Table 1.

3.2. Gaze behavior

3.2.1. First gaze

There was no significant difference in whether participants fixated the exercise or the non-exercise alternative first ($OR = 1.29$, 95% CI [0.89, 1.88], $p = 0.18$), suggesting there was no initial bias towards the non-exercise alternative. However, the initial gaze fixation was more likely on the alternative that was then chosen by the participant ($OR = 1.30$, 95% CI [1.04, 1.62], $p = 0.02$). Self-reported exercise volume ($OR = 1.00$, 95% CI [1.00, 1.00], $p = 0.39$), self-reported positive feelings towards exercise ($OR = 0.99$, 95% CI [0.90, 1.08], $p = 0.77$), and automatic valuation of exercise ($OR = 0.98$, 95% CI [0.89, 1.07], $p = 0.66$) did not contribute significantly to explaining variance in first gaze.

3.2.2. Fixations

Analyses revealed that individuals had more fixations on the chosen alternative compared to the non-chosen alternative ($b_{\text{non-ex}} = 1.07$, 95% CI [0.78, 1.36], $p < 0.001$, $b_{\text{ex}} = -0.79$, 95% CI [−1.05, −0.53], $p < 0.001$). Figure 2 illustrates this effect, showing participants had more fixations on non-exercise (compared to exercise) when choosing non-exercise (orange line) and more fixations on exercise (compared to non-exercise) when choosing exercise (blue line). In each trial, exercise was fixated on average 3.99 times (95% CI [3.66, 4.31]) and non-exercise 3.90 times (95% CI [3.56, 4.24]) before one of the two alternatives were selected.

TABLE 1 Means, standard deviations, and correlations of the main variables.

Variable	*M*	*SD*	1	2	3	4	5	6
(1) Exercise volume	358.36	283.39						
(2) Controlled evaluation	6.33	0.86	0.43**					
			[0.26, 0.58]					
(3) Automatic-affective valuation	0.02	0.17	0.15	0.17				
			[−0.04, 0.34]	[−0.03, 0.35]				
(4) First gaze (exercise)	13.68	2.06	0.14	0.01	−0.06			
			[−0.05, 0.33]	[−0.19, 0.21]	[−0.25, 0.14]			
(5) Exercise fixations	4.00	2.67	−0.02	−0.07	−0.10	0.16		
			[−0.22, 0.18]	[−0.26, 0.13]	[−0.29, 0.09]	[−0.03, 0.35]		
(6) Nonexercise fixations	3.92	2.73	−0.04	−0.23*	−0.13	0.04	0.82**	
			[−0.23, 0.15]	[−0.41, −0.04]	[−0.32, 0.07]	[−0.16, 0.23]	[0.74, 0.88]	
(7) General decision tendency	0.62	0.20	0.43**	0.58**	0.20*	0.09	−0.13*	−0.34**
			[0.25, 0.58]	[0.43, 0.70]	[0.00, 0.38]	[−0.11, 0.28]	[−0.31, −0.07]	[−0.50, −15]

M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < 0.05$. ** indicates $p < 0.01$.

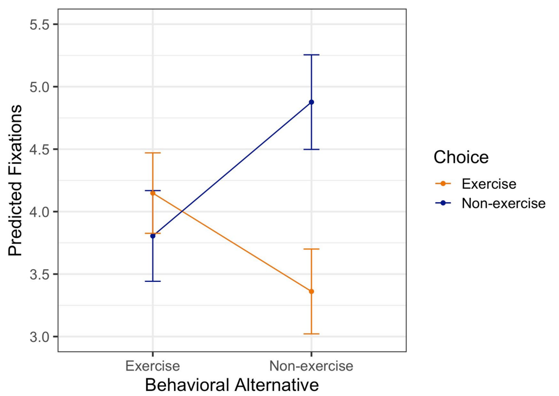

FIGURE 2
Predicting fixations on the exercise and the non-exercise behavioral alternative with choice behavior. The orange line shows the model-predicted fixations when exercise was chosen. The blue line shows the model predicted fixations when non-exercise was chosen.

There was no significant difference in the number of fixations on the exercise vs. the non-exercise alternative accordingly ($b = -0.09$, 95% CI [−0.34, 0.17], $p = 0.51$).

Automatic valuation of exercise, self-reported feelings towards exercise, and self-reported exercise volume were generally unrelated to the number of fixations on the exercise (see Table 2) and on the non-exercise alternative (see Table 3). Only the number of gaze fixations on the non-exercise alternative was slightly associated with self-reported feelings towards exercise ($b = -0.27$, 95% CI [−0.53, −0.00], $p = 0.05$). Figure 3 illustrates that more positive reported feelings towards exercise were not associated with more exercise fixations (orange line), but more negative reported feelings were associated with more fixations on the non-exercise alternative (blue line). These findings indicate the number of fixations was statistically informative for the behavioral choices in the task, but it was not associated with what participants typically like (automatic valuation and self-reported feelings towards exercise) or their usual behavior (self-reported exercise volume).

4. Discussion

This study examined situated processes and interindividual differences in gaze behavior in a sample of healthy individuals when confronted with a choice between two behavioral alternatives: to exercise or not to exercise. We found that individuals' gaze behavior was associated with their in-the-moment choices, but not with their more general automatic affective valuation, their controlled evaluation of exercise, and not even with their self-reported exercise behavior. Findings suggest that individuals are more likely to focus on what they are about to choose in a single situation, but not what they usually like or do. Our results provide evidence that situated processes that arise from very specific stimulus configurations with behavioral alternatives can be independent of individuals' more general preferences.

These findings partially support theoretical perspectives from dual-process models such as the ART (Brand and Ekkekakis, 2018) and the TEMPA (Cheval and Boisgontier, 2021; or the Automatic Affective Evaluations of Physical Activity model, to name another; Conroy and Berry, 2017) that situated and probably conflicting processes between behavioral alternatives need to become a greater focus of research when analyzing behavioral choices. After having established the intention, for example, to start an exercise routine, the resulting behavior is often an in-the-moment choice between behavioral alternatives. Individuals may experience conflicts thereby, because choices involve the desired behavior (e.g., exercise) and an alternative behavior that may be a barrier for engaging in the desired behavior (e.g., lying on the couch). Therefore, not only should the processes that drive someone towards the desired behavior (e.g., beliefs, goals) be analyzed, but also the processes that occur in a particular situation (i.e., situated processes) that prevent someone from engaging in that desired behavior.

As expected, individuals who reported to generally like and do exercise were more likely to choose the exercise alternative (65%) than the non-exercise alternative in the behavioral alternatives task. This fits well with the self-reported exercise volume of the present study sample. We had a fairly active sample with the middle 50% of participants reporting to have between 180 and 450 min of exercise per week ($M = 358$, $SD = 283$). Thus, the sum of the individual choices in the behavioral alternatives task seems to reflect general exercise preferences.

TABLE 2 Predicting exercise fixations with automatic valuation of exercise (Model A), self-reported feelings towards exercise (Model B) and self-reported exercise behavior (Model C) when making exercise-related choices.

	Model A			Model B			Model C		
	b	95% CI	*p*	*b*	95% CI	*p*	*b*	95% CI	*p*
(IC)	3.80	3.43, 4.16	<0.001	3.79	3.43, 4.16	<0.001	3.78	3.27, 4.29	<0.001
Choice [ex]	0.37	0.11, 0.63	0.01	0.38	0.12, 0.64	<0.01	0.33	0.09, 0.57	0.01
Aut. ex valuation	−0.16	−0.46, 0.13	0.27						
SR ex feelings				−0.17	−0.46, 0.12	0.25			
SR ex volume								−0.00, 0.00	0.55

CI = Confidence Interval; b = unstandardized regression estimate; IC = intercept; ex = exercise; Aut. = automatic; SR = self-reported.

TABLE 3 Predicting non-exercise fixations with automatic valuation of exercise (Model D), self-reported feelings towards exercise (Model E) and self-reported exercise behavior (Model F) when making exercise-related choices.

	Model D			Model E			Model F		
	b	95% CI	*p*	*b*	95% CI	*p*	*b*	95% CI	*p*
(IC)	4.88	4.49, 5.26	<0.001	4.87	4.48, 5.26	<0.001	4.75	4.24, 5.25	<0.001
Choice [ex]	−1.54	−1.78, −1.31	<0.001	−1.53	−1.77, −1.29	<0.001	−1.56	−1.80, −1.32	<0.001
Aut. ex valuation	−0.16	−0.42, 0.10	0.27						
SR ex feelings				−0.27	−0.53, −0.00	0.05			
SR ex volume							0.00	−0.00, 0.00	0.79

CI = Confidence Interval; b = unstandardized regression estimate; IC = intercept; ex = exercise; Aut. = automatic; SR = self-reported.

There was no automatic bias in first gaze to either the exercise or the non-exercise alternative. This neither supports assumptions of ART nor TEMPA. Based on TEMPA, there would have been a general automatic bias towards the non-exercise alternative due to an inherent universal bias toward effort minimization. Alternatively, ART would suggest automatic responses are learned through experiences and triggered when confronted with an exercise-related stimulus. Based on ART, participants would initially direct their gaze in line with their automatic valuation of exercise. However, those who had a more positive automatic valuation of exercise had no automatic bias towards the exercise alternative. This result could also be biased by the relatively active sample (due to the limited variance in the exercise volume variable). Another possible explanation for these findings is that the AMP is just a proxy for measuring automatic valuations and may not adequately represent the construct of automatic affective valuation of exercise, despite robust findings in other fields (Payne and Lundberg, 2014). Only one study to date has shown a medium size effect ($d = 0.59$) between the AMP score and exercise behavior (Antoniewicz and Brand, 2014). In particular, these authors showed that frequent fitness center exercisers exhibited more positive affective valuation of fitness center exercising than exercisers who preferred other exercise settings. In the present study, the AMP score was significantly, but only slightly ($r = 0.20$, $p = 0.05$) correlated with choice behavior and unrelated to self-reported exercise volume ($r = 0.15$, $p = 0.12$). This does not necessarily mean that the AMP has no validity, but the results obtained with the AMP should be interpreted cautiously on a more nuanced level. The present findings (a higher, albeit small, correlation between the AMP and choice behavior than with exercise volume) support Antoniewicz and Brand's (2014) conclusion that automatic affective valuations may play a role in qualitative behavioral regulation (e.g., choice of exercise setting) rather than in quantitative behavioral regulation (i.e., exercise volume). Additionally, with the AMP, automatic valuations were not measured on a situational basis (i.e., for each choice situation). According to ART (Brand and Ekkekakis, 2018) automatic valuations of exercise arise and manifest themselves in situated decisions, meaning that automatic processes may vary depending on the situation at hand (e.g., the specific behavioral alternatives an individual faces). In the present study, however, affective valuation was measured only once with the AMP and thus may not be able to predict situated gaze behavior. This would require a tool that measures automatic valuations for each individual situation, which to our best knowledge does not yet exist.

As expected, first gaze was associated, albeit slightly, with the alternative chosen in that situation. This pattern of results is even more evident for fixations where participants directed their gaze on a specific location in the picture. These findings are in line with a large body of evidence on the gaze cascade effect, the tendency to look longer at stimuli that are eventually chosen (e.g., Onuma et al., 2017). Interestingly, similar to first gaze, the number of fixations were not associated with the assessed interindividual differences. For example, active individuals did not look longer at the exercise stimuli than inactive participants. These results seem to contradict previous findings from exercise psychology which have demonstrated an attentional bias towards exercise for active individuals (e.g., Berry et al., 2011; Cheval et al., 2020). However, in comparison to the study here, participants in previous studies were not forced to make a choice. There is research showing that attentional processes are more strongly influenced by the task itself (i.e., the goal of the decision: to choose what you want vs. what you do not want) than individual preferences (van der Laan et al., 2015). Our findings support this by showing that the task (to make a choice) and the specific alternatives presented in each situation (i.e., the presented behavioral alternatives) were associated with gaze behavior but not with individual preferences or behaviors. Hence, this lends support for the importance of situated processes emphasized in theoretical perspectives from dual-process framework (Brand and Cheval, 2019; Rhodes et al., 2019).

Although an individual may report liking exercise, certain features of an alternative behavior may drive the individual to choose the

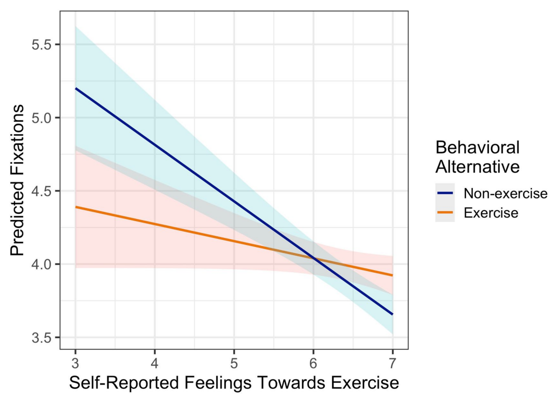

FIGURE 3
Predicting fixations on the exercise (orange) and non-exercise alternative (blue) with self-reported feelings towards exercise.

alternative over exercise. This is well in line with the idea of an inner conflict. Even if someone generally likes to exercise, but the couch seems more attractive in that very situation, an internal conflict arises. More attention may be on the non-exercise alternative, which increases the likelihood that the alternative behavior will be chosen. This suggests that in-the-moment individuals are confronted with the decision to exercise, additional situated processes may influence the decision. Thus, our results support the assumption that attentional processes may play an active role in constructing choice behavior above and beyond general preferences (Orquin and Mueller Loose, 2013).

Assuming that the present findings are robust and replicable, this could imply that neither an inherent nor a learned automatic bias toward exercise or a sedentary alternative can sufficiently explain behavioral choices. This challenges assumptions of TEMPA regarding a negative automatic bias towards exercise and some predictions of ART regarding a learned automatic association of exercise. On the other hand, a more fundamental assumption of dual process models can be supported. We found that processes that take place in-the-moment of choice play an active role in constructing the choice. This is consistent with the assumption of a continuous interaction between situated automatic-affective and reflective processes until a choice is reached (Brand and Ekkekakis, 2021). Further refinement would be needed with respect to assumptions about the interplay between psychological states and traits. The present study suggests that individuals bring some inherent general trait-like preferences (e.g., liking exercise) into a situation, but these general preferences may operate independently of state-like situated processes (e.g., the affective state).

In line with current perspectives of exercise behavior change (Rhodes et al., 2019), exercise interventions largely focused on interindividual preferences or differences may fail at long-term behavior change because they neglect the role of situated processes and competing behavioral tendencies (e.g., the appeal of a non-exercise behavioral alternative). Empirical studies focused on interindividual difference – such as perceived autonomy, competence, or relatedness – may explain behavior change, but intervention focused on these variables fail to result in sustained behavior change (Chevance et al., 2019; Compernolle et al., 2019; Ntoumanis et al., 2021). In order to improve exercise interventions, situational features such as attention to specific behavioral alternatives should be considered in addition to interindividual differences, e.g., in expectations and goals.

4.1. Limitations and future directions

While the study had several strengths (e.g., capturing processes in-the-moment of choice, using generalized mixed models), some limitations need to be considered. In the present study, hypothetical scenarios were used as a proxy for situated decision-making. Future studies should examine how the present results unfold in real life. One way to investigate situated processes in real life decisions could be the use of ecological momentary assessment (EMA), which can capture time-varying factors and intraindividual fluctuations (e.g., Dunton, 2017). EMA has been shown to be a feasible way to measure exercise behavior and motivation in real-time and naturalistic settings (Maher et al., 2018; Reichert et al., 2022). Studies using this technique already yielded reliable associations between momentary affective states and physical activity behavior (Liao et al., 2015). However, a randomized-controlled trial that investigated the effects of an intervention on controlled processes (goal setting) on daily physical activity levels failed to demonstrate a significant effect. Instead, these results revealed substantial individual variability, suggesting that other processes may play a role in promoting or hindering physical activity (Utesch et al., 2022). Automatic processes could be one of those variables. However, there is yet to be a tool that can capture automatic processes - such as those measured with the AMP - on a momentary basis. As an alternative, quick implicit measures such as the brief implicit association test (Sriram and Greenwald, 2009) or eye-tracking (Peng et al., 2021) could be modified for mobile devices.

Despite the use of a within-subject design, the present study is unable to conclude causal relationships. Future work is needed to understand whether exercise-related choice preferences can be influenced by experimentally manipulating attentional processes. Moreover, as the study sample consisted mostly of university students, generalizability is limited. It is possible that because many participants were enrolled in a physical activity focused program, this may have caused the bias toward the exercise alternative. The behavioral alternatives task appears to successfully assess a tendency of individuals to choose exercise, but it is important to note that the odds found in this study (preference for the exercise alternative) may not reflect the general population. This calls for replication studies with more heterogenous and larger sample sizes.

In addition, this task had relatively few trials compared to other eye-tracking or experimental studies (van der Laan et al., 2015). However, the focus of the present task was to examine processes within trials (choices) and not on an overall general score across all trials. Modeling both, participants and stimuli as random effects helped to increase the robustness of statistical analytics beyond the specific stimuli used (Westfall et al., 2014). However, if the focus of a study would be to examine a general preference across trials, more trials would certainly be needed.

The unique features of the computerized behavioral alternatives task – such as modeling single situated choices on different levels and the use of eye-tracking as a process-tracing method – open up possibilities to test hypotheses derived from exercise psychology theories. For example, it could be studied whether limited self-control alters the interplay of automatic and controlled processes or whether changing the affective experience during the behavior (e.g., Jones et al., 2020; Timme and Brand, 2020) influences exercise-related information processing. Furthermore, it would be interesting to investigate how stable these processes are and whether situational influences (such as exercising before the task) would render, for example, sedentary activities more attractive.

In terms of practical implications, our findings suggest that, for example, personal trainers should consider that situational factors (e.g., the specific behavioral alternatives) influence whether or not individuals follow an exercise program, probably quite independently of their more general beliefs and preferences.

5. Conclusion

Previous studies and interventions for exercise behavior change have largely focused on interindividual differences in automatic and controlled processes. This study provided partial support for dual-process theories in exercise psychology. We found that interindividual differences in general exercise preferences (i.e., automatic-affective valuation, controlled evaluation and exercise behavior) are related to the choice behavior among concrete behavioral alternatives (exercise vs. non-exercise). However, situated gaze behavior in these choice situations does not follow these interindividual preferences, but rather depends on the specific available behavioral alternatives. This implies that situated processes may augment interindividual differences in automatic and controlled (e)valuations of exercise when it comes to exercise-related choices. The importance of situated processes in behavior change has been neglected by most exercise psychology theories so far, and thus may be an important missing piece in understanding the processes underlying exercise motivation.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/ubrj7/.

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MR, RB, and ST developed the experimental design and carried out the data collection. ST performed the data analysis and wrote the first draft of the manuscript. MR and RB edited the manuscript. All authors contributed to the article and approved the submitted version.

Funding

During the analysis and manuscript preparation, ST was supported by the German Academic Scholarship Foundation. Open access costs were funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – project number 491466077. This funding body had no role in the study design, analysis, interpretation of findings, or writing of the manuscript.

Acknowledgments

We would like to thank Mathias Wegener for his help with data collection.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Antoniewicz, F., and Brand, R. (2014). Automatic evaluations and exercise setting preference in frequent exercisers. *J. Sport Exerc. Psychol.* 36, 631–636. doi: 10.1123/jsep.2014-0033

Antoniewicz, F., and Brand, R. (2016). Dropping out or keeping up? Early-dropouts, late-dropouts, and maintainers differ in their automatic evaluations of exercise already before a 14-week exercise course. *Front. Psychol.* 7:838. doi: 10.3389/fpsyg.2016.00838

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Berry, T. R., Spence, J. C., and Stolp, S. M. (2011). Attentional bias for exercise-related images. *Res. Q. Exerc. Sport* 82, 302–309. doi: 10.1080/02701367.2011.10599758

Bhatnagar, R., and Orquin, J. L. (2022). A meta-analysis on the effect of visual attention on choice. *J. Exp. Psychol. Gen.* 151:2265. doi: 10.1037/xge0001204

Bluemke, M., Brand, R., Schweizer, G., and Kahlert, D. (2010). Exercise might be good for me, but I don't feel good about it: do automatic associations predict exercise behavior? *J. Sport Exerc. Psychol.* 32, 137–153. doi: 10.1123/jsep.32.2.137

Brand, R., and Cheval, B. (2019). Theories to explain exercise motivation and physical inactivity: Ways of expanding our current theoretical perspective. *Frontiers in Psychology* 10:1147. doi: 10.3389/fpsyg.2019.01147

Brand, R., and Ekkekakis, P. (2018). Affective–reflective theory of physical inactivity and exercise. *German J. Exercise and Sport Res.* 48, 48–58. doi: 10.1007/s12662-017-0477-9

Brand, R., and Ekkekakis, P. (2021). "Exercise behavior change revisited: affective-reflective theory" in *Essentials of exercise and sport psychology: An open access textbook*. eds. Z. Zenko and L. Jones (Society for Transparency, Openness, and Replication in Kinesiology), 62–92. doi: 10.51224/B1004

Brand, R., and Schweizer, G. (2015). Going to the gym or to the movies?: situated decisions as a functional link connecting automatic and reflective evaluations of exercise with exercising behavior. *J. Sport Exerc. Psychol.* 37, 63–73. doi: 10.1123/jsep.2014-0018

Brito, H., Teixeira, D., and Araújo, D. (2022). Traducción y validez de constructo de la feeling scale y la felt arousal scale en ejercitadores recreativos portugueses. *Cuadernos de Psicología Del Deporte* 22:3. doi: 10.6018/cpd.514061

Cameron, C. D., Brown-Iannuzzi, J. L., and Payne, B. K. (2012). Sequential priming measures of implicit social cognition: a meta-analysis of associations with behavior and explicit attitudes. *Personal. Soc. Psychol. Rev.* 16, 330–350. doi: 10.1177/1088868312440047

Cavanagh, J. F., Wiecki, T. V., Kochar, A., and Frank, M. J. (2014). Eye tracking and pupillometry are indicators of dissociable latent decision processes. *J. Exp. Psychol. Gen.* 143, 1476–1488. doi: 10.1037/a0035813

Cheval, B., and Boisgontier, M. P. (2021). The theory of effort minimization in physical activity. *Exerc. Sport Sci. Rev.* 49, 168–178. doi: 10.1249/JES.0000000000000252

Cheval, B., Miller, M. W., Orsholits, D., Berry, T., Sander, D., and Boisgontier, M. P. (2020). Physically active individuals look for more: an eye-tracking study of attentional bias. *Psychophysiology* 57:e13582. doi: 10.1111/psyp.13582

Chevance, G., Bernard, P., Chamberland, P. E., and Rebar, A. (2019). The association between implicit attitudes toward physical activity and physical activity behaviour: a systematic review and correlational meta-analysis. *Health Psychol. Rev.* 13, 248–276. doi: 10.1080/17437199.2019.1618726

Chevance, G., Caudroit, J., Romain, A. J., and Boiché, J. (2017). The adoption of physical activity and eating behaviors among persons with obesity and in the general population: the role of implicit attitudes within the theory of planned behavior. *Psychol. Health Med.* 22, 319–324. doi: 10.1080/13548506.2016.1159705

Compernolle, S., DeSmet, A., Poppe, L., Crombez, G., De Bourdeaudhuij, I., Cardon, G., et al. (2019). Effectiveness of interventions using self-monitoring to reduce sedentary behavior in adults: a systematic review and meta-analysis. *Int. J. Behav. Nutr. Phys. Act.* 16:63. doi: 10.1186/s12966-019-0824-3

Conroy, D. E., and Berry, T. R. (2017). Automatic affective evaluations of physical activity. *Exerc. Sport Sci. Rev.* 45, 230–237. doi: 10.1249/JES.0000000000000120

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., et al. (2003). International physical activity questionnaire: 12-country reliability and validity. *Med. Sci. Sports Exerc.* 35, 1381–1395. doi: 10.1249/01.MSS.0000078924.61453.FB

Dierker, H., Schlaaf, E., and Raupach, K. (2018). *Sportstudie Berlin 2017: Untersuchung zum Sportverhalten*. Berlin: Berlin/Senatsverwaltung für Inneres und Sport.

Dunton, G. F. (2017). Ecological momentary assessment in physical activity research. *Exerc. Sport Sci. Rev.* 45, 48–54. doi: 10.1249/JES.0000000000000092

Ekkekakis, P., and Brand, R. (2021). "Exercise motivation from a post-cognitivist perspective: Affective-reflective theory" in *Motivation and Self-regulation in Sport and Exercise*. eds. C. Englert and I. M. Taylor (London: Routledge), (pp. 20–40).

Harris, S., and Bray, S. R. (2019). Effects of mental fatigue on exercise decision-making. *Psychol. Sport Exerc.* 44, 1–8. doi: 10.1016/j.psychsport.2019.04.005

Harris, S., and Bray, S. R. (2021). Mental fatigue, anticipated effort, and subjective valuations of exercising predict choice to exercise or not: a mixed-methods study. *Psychol. Sport Exerc.* 54:101924. doi: 10.1016/j.psychsport.2021.101924

Hofmann, W., and Baumert, A. (2010). Immediate affect as a basis for intuitive moral judgement: an adaptation of the affect misattribution procedure. *Cognit. Emot.* 24, 522–535. doi: 10.1080/02699930902847193

Hofmann, W., van Koningsbruggen, G. M., Stroebe, W., Ramanathan, S., and Aarts, H. (2010). As pleasure unfolds: hedonic responses to tempting food. *Psychol. Sci.* 21, 1863–1870. doi: 10.1177/0956797610389186

Jones, L., Stork, M. J., and Oliver, L. S. (2020). Affective responses to high-intensity interval training with continuous and respite music. *J. Sports Sci.* 38, 2803–2810. doi: 10.1080/02640414.2020.1801324

Karpen, S. C., Jia, L., and Rydell, R. J. (2012). Discrepancies between implicit and explicit attitude measures as an indicator of attitude strength. *Eur. J. Soc. Psychol.* 42, 24–29. doi: 10.1002/ejsp.849

Kiviniemi, M. T., Voss-Humke, A. M., and Seifert, A. L. (2007). How do I feel about the behavior? The interplay of affective associations with behaviors and cognitive beliefs as influences on physical activity behavior. *Health Psychol.* 26, 152–158. doi: 10.1037/0278-6133.26.2.152

Krajbich, I., Armel, C., and Rangel, A. (2010). Visual fixations and the computation and comparison of value in simple choice. *Nat. Neurosci.* 13, 1292–1298. doi: 10.1038/nn.2635

Liao, Y., Shonkoff, E. T., and Dunton, G. F. (2015). The acute relationships between affect, physical feeling states, and physical activity in caily life: a review of current evidence. *Front. Psychol.* 6:1975. doi: 10.3389/fpsyg.2015.01975

Maher, J. P., Rebar, A. L., and Dunton, G. F. (2018). Ecological momentary assessment is a feasible and valid methodological tool to measure older adults' physical activity and sedentary behavior. *Front. Psychol.* 9:1485. doi: 10.3389/fpsyg.2018.01485

Ntoumanis, N., Ng, J. Y. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., et al. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: effects on motivation, health behavior, physical, and psychological health. *Health Psychol. Rev.* 15, 214–244. doi: 10.1080/17437199.2020.1718529

Olsen, A. (2012). The Tobii I-VT Fixation Filter. *Tobii Technology* 21, 4–19. Available at: https://www.tobiipro.com/learn-and-support/learn/steps-in-an-eye-tracking-study/data/how-are-fixations-defined-when-analyzing-eye-tracking-data/

Onuma, T., Penwannakul, Y., Fuchimoto, J., and Sakai, N. (2017). The effect of order of dwells on the first dwell gaze bias for eventually chosen items. *PLoS One* 12:e0181641. doi: 10.1371/journal.pone.0181641

Orquin, J. L., and Mueller Loose, S. (2013). Attention and choice: a review on eye movements in decision making. *Acta Psychol.* 144, 190–206. doi: 10.1016/j.actpsy.2013.06.003

Payne, B. K., Cheng, C. M., Govorun, O., and Stewart, B. D. (2005). An inkblot for attitudes: affect misattribution as implicit measurement. *J. Pers. Soc. Psychol.* 89, 277–293. doi: 10.1037/0022-3514.89.3.277

Payne, B. K., Govorun, O., and Arbuckle, N. L. (2008). Automatic attitudes and alcohol: Does implicit liking predict drinking? *Cognition and Emotion* 22, 238–271. doi: 10.1080/02699930701357394

Payne, K., and Lundberg, K. (2014). The affect misattribution procedure: ten years of evidence on reliability, validity, and mechanisms. *Soc. Personal. Psychol. Compass* 8, 672–686. doi: 10.1111/spc3.12148

Peng, M., Browne, H., Cahayadi, J., and Cakmak, Y. (2021). Predicting food choices based on eye-tracking data: comparisons between real-life and virtual tasks. *Appetite* 166:105477. doi: 10.1016/j.appet.2021.105477

R Core Team (2021). "R: a language and environment for statistical computing" in *R Foundation for Statistical Computing* (Vienna: Austria).

Rebar, A. L., Dimmock, J. A., Jackson, B., Rhodes, R. E., Kates, A., Starling, J., et al. (2016). A systematic review of the effects of non-conscious regulatory processes in physical activity. *Health Psychol. Rev.* 10, 395–407. doi: 10.1080/17437199.2016.1183505

Reichert, M., Brüßler, S., Reinhard, I., Braun, U., Giurgiu, M., Hoell, A., et al. (2022). The association of stress and physical activity: mind the ecological fallacy. *German J. Exercise and Sport Res.* 52, 282–289. doi: 10.1007/s12662-022-00823-0

Rhodes, R. E. (2017). "The evolving understanding of physical activity behavior: a multi-process action control approach" in *Advances in Motivation Science*. ed. A. J. Elliot, *Vol. 4* (Netherlands: Elsevier), 171–205.

Rhodes, R. E. (2021). Multi-process action control in physical activity: a primer. *Front. Psychol.* 12:797484. doi: 10.3389/fpsyg.2021.797484

Rhodes, R. E., and de Bruijn, G.-J. (2013). How big is the physical activity intention-behaviour gap? A meta-analysis using the action control framework. *Br. J. Health Psychol.* 18, 296–309. doi: 10.1111/bjhp.12032

Rhodes, R. E., McEwan, D., and Rebar, A. L. (2019). Theories of physical activity behaviour change: a history and synthesis of approaches. *Psychol. Sport Exerc.* 42, 100–109. doi: 10.1016/j.psychsport.2018.11.010

Schinkoeth, M., and Antoniewicz, F. (2017). Automatic evaluations and exercising: systematic review and implications for future research. *Front. Psychol.* 8:2103. doi: 10.3389/fpsyg.2017.02103

Schinkoeth, M., and Brand, R. (2020). Automatic associations and the affective valuation of exercise: disentangling the type-1 process of the affective–reflective theory of physical inactivity and exercise. *German J. Exercise and Sport Res.* 50, 366–376. doi: 10.1007/s12662-020-00664-9

Schotter, E. R., Berry, R. W., McKenzie, C. R. M., and Rayner, K. (2010). Gaze bias: selective encoding and liking effects. *Vis. Cogn.* 18, 1113–1132. doi: 10.1080/13506281003668900

Sriram, N., and Greenwald, A. G. (2009). The brief implicit association test. *Exp. Psychol.* 56, 283–294. doi: 10.1027/1618-3169.56.4.283

Timme, S., and Brand, R. (2020). Affect and exertion during incremental physical exercise: examining changes using automated facial action analysis and experiential self-report. *PLoS One* 15:e0228739. doi: 10.1371/journal.pone.0228739

Utesch, T., Piesch, L., Busch, L., Strauss, B., and Geukes, K. (2022). Self-tracking of daily physical activity using a fitness tracker and the effect of the 10,000 steps goal. *German J. Exercise and Sport Res.* 52, 300–309. doi: 10.1007/s12662-022-00821-2

van der Laan, L. N., Hooge, I. T. C., de Ridder, D. T. D., Viergever, M. A., and Smeets, P. A. M. (2015). Do you like what you see? The role of first fixation and total fixation duration in consumer choice. *Food Qual. Prefer.* 39, 46–55. doi: 10.1016/j.foodqual.2014.06.015

Westfall, J., Kenny, D. A., and Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *J. Exp. Psychol. Gen.* 143, 2020–2045. doi: 10.1037/xge0000014

World Health Organization (2020). *WHO guidelines on physical activity and sedentary behavior: At a glance*. World Health Organization: Geneva, Switzerland.

Zenko, Z., and Ekkekakis, P. (2019). Internal consistency and validity of measures of automatic exercise associations. *Psychol. Sport Exerc.* 43, 4–15. doi: 10.1016/j.psychsport.2018.12.005

frontiers | Frontiers in Sports and Active Living

TYPE Original Research
PUBLISHED 21 March 2023
DOI 10.3389/fspor.2023.1033619

Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Sports and Active Living

RECEIVED 31 August 2022
ACCEPTED 07 February 2023
PUBLISHED 21 March 2023

CITATION
Stults-Kolehmainen MA, Gilson TA, SantaBarbara N, McKee PC, Sinha R, Bartholomew JB, Boullosa D, Budnick CJ, Bueno FA, Haughton A, Barker JL and Ash GI (2023) Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups.
Front. Sports Act. Living 5:1033619.
doi: 10.3389/fspor.2023.1033619

Motivation for physical activity and sedentary behaviors (e.g., desires, urges, wants, cravings) varies from moment to moment. According to the WANT model, these motivation states may be affectively-charged (e.g., felt as tension), particularly after periods of maximal exercise or extended rest. The purpose of this study was to examine postulates of the WANT model utilizing a mixed-methods approach. We hypothesized that: (1) qualitative evidence would emerge from interviews to support this model, and (2) motivation states would quantitatively change over the course of an interview period. Seventeen undergraduate students (mean age = 18.6y, 13 women) engaged in focus groups where 12 structured questions were presented. Participants completed the "right now" version of the CRAVE scale before and after interviews. Qualitative data were analyzed with content analysis. A total of 410 unique lower-order themes were classified and grouped into 43 higher order themes (HOTs). From HOTs, six super higher order themes (SHOTs) were designated: (1) wants and aversions, (2) change and stability, (3) autonomy and automaticity, (4) objectives and impulses, (5) restraining and propelling forces, and (6) stress and boredom. Participants stated that they experienced desires to move and rest, including during the interview, but these states changed rapidly and varied both randomly as well as systematically across periods of minutes to months. Some also described a total absence of desire or even aversion to move and rest. Of note, strong urges and cravings for movement, typically from conditions of deprivation (e.g., sudden withdrawal from exercise training) were associated with physical and mental manifestations, such as fidgeting and feeling restless. Urges were often consummated with behavior (e.g., exercise sessions, naps), which commonly resulted in satiation and subsequent drop in desire. Importantly, stress was frequently described as both an inhibitor and instigator of motivation states. CRAVE-Move increased pre-to-post interviews ($p < .01$). CRAVE-Rest demonstrated a trend to decline ($p = .057$). Overall, qualitative and quantitative data largely corroborated postulates of the WANT model, demonstrating that people experience wants and cravings to move and rest, and that these states appear to fluctuate significantly, especially in the context of stress, boredom, satiety, and deprivation.

KEYWORDS

motivation, motivation states, desires, physical activity, exercise, qualitative study, focus groups, stress

Introduction

Physical inactivity and sedentarism plague the United States and other developed countries. Sitting time, not including other sedentary behaviors like napping, has steadily increased among Americans to nearly 5.9 h/day (1), and only 24% of American adults meet the physical activity guidelines for combined aerobic and strength training (2). Structured exercise (e.g., a 30-minute run) is just one facet of energy expenditure (EE). Other sources of EE include non-exercise activity thermogenesis (NEAT). This includes lifestyle physical activity (PA; e.g., walking to a train station) and spontaneous physical activity (SPA; e.g., standing up, getting a glass of water, fidgeting, etc.) (3). Active and sedentary behaviors vary widely across the day and between days, are not necessarily synchronous and, in fact, they can be demonstrated simultaneously (4–7). Unfortunately, current models of health behavior are insufficient to explain and predict the complexity of human movement and EE as they focus on habitual activity and trait-like motives without consideration for variations in movement and motivation from moment to moment (8–11). There has also been criticism that decades of research focused on cognitive aspects of physical activity behavior have overshadowed constructs of emotion and motivation, despite the low predictability of such factors (12, 13). Improvements have recently been made in modelling physically active behaviors, as with the Affective-Reflective Theory (ART) of physical inactivity and exercise (14), the dual process model from Conroy and Berry (15), and the Affective Health Behavior Framework (AHBF) (16). These theories incorporate the influences of affect, cognitive deliberation, hedonic motivation, and the idea of a final action impulse—a motivational catalyst or endpoint that instigates both active and sedentary behaviors.

In addition, common to these and other models is the idea of subjective wanting or desiring to move and rest, also known as motivation states (17). For instance, there are times when people may want to get up and stretch their legs, exercise, or go for a walk. Likewise, they may desire to sit on the couch, take a nap, or lay down in bed. In this case, "desire" and "want" are used interchangeably, as has been done by other researchers (18), but they can also be used separately to denote influence from reflective or appetitive systems (12). These motivation states may be experienced as strong urges and cravings, conspicuously incorporating the idea of felt tension and may be experienced as positive or negative. Collectively, desires, wants, urges, and cravings are known as affectively-charged motivation states (ACMS) (19). These occur in both healthy individuals, where they may often go unnoticed, and also in clinical populations, where they can be quite bothersome and even disabling (20). The basis of these states could be a basic drive to move and be active (21), which initially Feige (22) and more recently others (17) recognized as the foundation of physical activity motivation. The recognition of ACMS could significantly enhance our theoretical models as they: (1) apply to any rewarding behavior, (2) can change from moment to moment, and (3) incorporate aspects of affective response (16, 23). Over the last few years, Stults-Kolehmainen and colleagues (17, 20, 21, 24–27) have developed the idea of motivation states for movement and rest in one of the first efforts to incorporate these ideas into behavioral models.

To understand how desires and urges for movement and sedentarism interact, Stults-Kolehmainen and colleagues (17) developed the WANT model (Wants and Aversions for Neuromuscular Tasks). This heuristic is a circumplex-type framework that incorporates three main factors (i.e., move and rest; want and lack of want; approach and withdrawal). A complete set of postulates of the WANT model include:

1. Humans have reflective and appetitive desires to move and rest.
2. Desires for movement and rest are characterized as two separate systems, and not opposite sides of the same axis.
3. There is both approach and avoidance motivation for movement and rest (e.g., one might be actively dis-wanting to move) (8, 23, 28).
4. These desires vary in strength or intensity (29) from very weak to nearly unavoidable/maximal, where they might be felt as an urge or craving.
5. Wants/desires are highly transitory psychological states.
6. They change in response to behavior (i.e., the provision, deprivation, or avoidance of certain physical stimuli, such as exercise).
7. They interact asynchronously (e.g., one may be high in both, low in both, or anywhere in-between).
8. There may also be a total lack of desire, as in meditative or sleeping states, or perhaps total apathy or indifference.
9. They differ from psychosomatic sensations, such as energy and fatigue.

10. They differ from emotions; however, the experience of desire for movement and rest might vary systematically with certain emotions (e.g., stress responses, fight, flight, fright, freeze), situations (e.g., sporting event, sudden terror) and conditions (e.g., illness) (23).

The WANT model is influenced by theories mentioned above, but perhaps most concordant with the concept of motivation control systems from Frijda and colleagues (30–32), who articulated ideas of motivation states, strength of urges, wanting vs. not wanting, approach vs. withdraw, a center point of no desire (e.g., apathy, disinterest, indifference), and how these relate to emotion. Also related is the Elaborated Process Model of self-regulation by Inzlicht and colleagues (33), who describe opposing motivational systems of "exploration, leisure & want-to" vs. "exploitation, labor & have-to." Some researchers, however, have presented data and models that are less supportive of our model. These have speculated that: (1) desires to move and be active have weak influences on physically active behaviors, (2) desire to move may be subservient to desires to rest and be sedentary, (3) avoidance motivation (e.g., dread of movement) rather than approach or want of movement, is most influential or (4) desires to be active may not exist at all (12, 16, 29, 34–37). Importantly, there appears to be a consistent logical fallacy from many of these sources and others—that low exercise behavior and large waist lines observed across the population are evidence that most people do not want to move (38, 39). Nevertheless, our recent work seems to dispute these assertions (24).

Our laboratory recently conducted a series of studies (24) to provide initial validation for the concept of affectively-charged motivation states (ACMS) for physical activity and sedentarism and the WANT model. With 846 participants, we developed a tool to measure ACMS, called the CRAVE (Cravings for Rest and Volitional Energy Expenditure), and subsequently conducted factor analyses to analyze both "right now" and "past week" versions. One hundred and twenty-seven people from New England were then tracked over a two-year period, where it was determined that ACMS have properties more similar to states than traits. In a later study, 21 undergraduate students from Texas completed the CRAVE before and after a maximal treadmill test, where it was found that motivation states to move declined precipitously (Cohen's $d_{av} = 1.05$) and to rest increased (Cohen's $d_{av} = 0.82$). In a separate study, 41 students from the American Midwest were measured 3 times across a lecture period, where it was found that desires to move increased 20% just before class dismissal, while desires to rest decreased 17%. In this last investigation, ACMS were moderately related to sensations of energy and fatigue. In line with expectations, these studies verified that motivation states are predicted by preceding behaviors. Overall, we can conclude that the concept of motivation states to be active and rest is valid and worthy of further exploration.

Despite the initial progress in developing and validating the concept of motivation states for physical activity and rest, many challenges need to be faced. First, there is still a dearth of evidence in the area, as noted by influential scientists in the area of exercise psychology (12). Second, the concept is still largely theoretical and lacks ecological validation—the voice of opinion from non-scientists. That is to say, in investigations up until this time, the concept has been largely limited to responses on an instrument in controlled settings, without greater naturalistic context. For instance, the way people describe motivation states in common language may not include the terms "desire", "want", "urge" or "craving". Similarly, the WANT model needs further development and ecological validation as it may be missing important postulates that could be identified qualitatively. Conversely, important suppositions in the model (e.g., two axes, magnitude, approach vs. withdrawal) may lack sufficient ecological validity. Further development is also needed as the WANT model is largely descriptive and explanatory without being predictive. In this regard, 1) there is little evidence to show a strong connection between ACMS and future behavior (26), and 2) there are currently no adequate predictive models that incorporate desires and wants to move and rest. Qualitative research can fill that gap, using insights from participants to identify mechanisms for theory and conceptual model development (40).

Consequently, to further develop and validate the concept of affectively-charged motivation states (ACMS) and the WANT model, there are five aims of the current investigation.

1. To extend the quantitative validation of: (a) the CRAVE scale, (b) the ACMS concept (i.e., that people do have wants and desires), and (c) the WANT model.
2. To further validate qualitatively the ACMS concept for movement and rest; to uncover if respondents recognize these states in their own personal experience and how they might be described in layman's terms.
3. To further validate qualitatively postulates of the WANT model.
4. To understand if ACMS relate to and spur physically active and sedentary behavior.
5. To generate information and themes to further develop the concept of motivation states and the WANT model and/or develop stronger predictor models of behavior.

Aims 2–4 will use a qualitative deductive approach and aim 5 will use a qualitative inductive approach.

Regarding the deductive analyses, we hypothesized that:

1) motivation states (assessment *via* the CRAVE scale) would change over the course of an interview period (pre to post),
2) qualitative evidence would emerge from interviews to support: (a) the ACMS concept and (b) postulates of the model,
3) qualitative evidence that ACMS are linked to future physically active and sedentary behavior.

Materials and methods

Experimental approach

To address the aims and hypotheses of this study, we chose a mixed methods approach combining qualitative and quantitative methods. Participants were interviewed in focus groups (described below) with quantitative measures collected before and after the interviews.

Participants

Participants were 17 college undergraduate students (mean ± SD: age = 18.6 ± 0.94y; BMI = 26.1 ± 6.5; 7 people of color; 12 first-year students) enrolled in the Honors Program at the university. We queried about gender and not biological sex. There were 13 women, 2 men, and 2 individuals identifying as non-binary. Participants were largely recruited in-person during classes by word of mouth with a script by one of the principal investigators (TG). Participants received a $30 gift card for participation.

Procedure

The interviews took place in-person, in a private setting on the university campus, in one of seven focus groups that incorporated one to four participants at a time. Before commencement of the interviews, participants were briefed on the study purpose—to better understand the determinants of movement behaviors in humans, such as the urge to be active. Procedures, potential risks, and requirements for participation were discussed with all participants. They completed a consent form indicating their willingness to participate and have the interview digitally recorded. Upon completion of the informed consent participants filled out a short demographic questionnaire and CRAVE questionnaires (Past Week and Right now versions). Following the completion of these questionnaires, participants engaged in a focus group interview that presented 12 structured questions (**Supplementary Data Sheet S1**). A researcher with extensive experience in qualitative research (TG) conducted the focus groups. Finally, participants ended by completing the CRAVE (Right now version) questionnaire one last time. Interviews were recorded by the interviewer and transcribed by a professional scribe.

Interview questions

Questions were structured to be balanced between move and rest (i.e., 4 specific to activity, 4 specific to rest, 4 for both move and rest). The first 4 questions regarded the validation of the concept and model. Questions 5–12 were created with the idea of conceptual and model development. Questions were always presented in the same order, with questions 1 and 2 intended to prime participants for later questions. The interview responses were free flowing in that the same person did not always respond first. Once the interviewer finished posing the question, the first person who wished to comment was allowed to do so; however, each person had a chance to respond to every question. Participants typically engaged in a discussion format regarding their feelings, perceptions and observations related to the topics at hand. When necessary, and to facilitate greater discussion, probes were used by the researcher to elicit more detailed responses.

Quantitative measure

CRAVE (Cravings for Rest and Volitional Energy Expenditure): The CRAVE is a 13-item questionnaire with two versions, "past week" and "right now", which has been validated across six studies (24, 26), demonstrating excellent psychometric properties. For this study, the past week version was used just at the beginning and the right now version was used both pre and post. Six scale items relate to physical activity (e.g., “move my body”), and 7 items are related to sedentary behaviors (e.g., “do nothing active”). In validation testing, an exploratory structural equation model (ESEM) revealed that 10 items should be retained, loading onto two factors (5 each for Move and Rest). Consequently, the remaining 3 items are unscored fillers. Move and Rest factors are correlated moderately and inversely ($r = -.71$ and $-.78$, in two different studies). Reliability of the scale in the same studies, as determined by McDonald’s ω, was very high (both .97). The CRAVE has good test-retest reliability and reliably measures state-like properties of motivation. Across-session interclass correlations (ICC) for Move (ICC = 0.72–0.95) and Rest (ICC = 0.69–0.88) are higher than those measured across 24-months (Move: ICC = 0.53; Rest: ICC = 0.49). The CRAVE is sensitive to changes with exercise testing, with Move decreasing with a maximal stress test (Cohen’s $d_{av} = 1.05$) and Rest increasing (Cohen’s $d_{av} = 0.82$). It has small to moderate associations with sensations of energy, fatigue, tiredness, and deactivation.

Data analysis

Quantitative data was analyzed with paired t-tests with the Jamovi statistical package (Version 2.2) (41). For qualitative data, researchers used content analysis as described by Hsieh & Shannon (42) and formerly utilized by one of the first authors (43) to analyze results. A deductive approach was used for theoretical validation—to identify support or disagreement with both: (A) the concept of ACMS for movement and rest and (B) the WANT Model. An inductive approach was used for concept development. These approaches were conducted simultaneously for efficiency. Two analysts, both experts in the content area (TG and MSK), started by identifying lower order themes, which were entered into Microsoft Excel. Associated data from interviewees was tagged to lower order themes (LOTs). For the inductive approach, analysts independently inspected LOTs to generate higher order themes (HOTs). Every LOT was tagged to a HOT. Later, HOTs were sorted into a reduced number of bins to create super-higher order themes (SHOTs). In creating SHOTs, additional theory was considered, such as the Elaborated Process Model of self-regulation (33), motivation control systems (30–32), Self-Determination Theory (44), the Incentive Sensitization Model (ISM) of rewarding behaviors (45, 46), and the Theory of Hedonic Motivation (12). In the case of disagreement in the creation of HOTs and SHOTs, a third author (NSB) provided the tiebreaker.

Results

Quantitative analysis

CRAVE-Move was rated higher than CRAVE-Rest for both pre- ($p = .022$, Cohen's d = 0.61) and post-interviews ($p < .001$, Cohen's d = 1.48). PW and RN versions of CRAVE-Move were moderately correlated ($r = .51$, $p < .05$). Respondents rated their CRAVE-Move as being higher "over the past week" (PW) than "right now" (RN) (33.7 ± 8.0 vs. 28.9 ± 9.8). PW and RN versions of CRAVE-Rest were also moderately associated ($r = .49$, $p < .05$). We could not reject the null hypothesis that there was no difference for rest "over the past week" vs. "right now" (16.5 ± 7.6 vs. 17.3 ± 10.9). See Table 1.

CRAVE-Move (right now) significantly increased across the interviews from 28.9 (SD = 9.8) to 35.3 (8.9) ($p = .006$, Cohen's d = 0.76). CRAVE-Rest demonstrated a trend to decline: 17.3 (SD = 10.9) to 11.9 (8.3) ($p = .057$, Cohen's d = 0.50). Variance decreased meaningfully, as seen in Table 2 and Figure 1.

Deductive qualitative analyses

Evidence for motivation states

Thematic findings from these qualitative interviews, specifically Questions 3, 4 and 12 (presented later), corroborated the concept of ACMS for movement and rest. In question 3 ("Do you want to move right now?"), 12 reported "Yes" and indicated some desire to move; five indicated "No". Of these, some respondents qualified their answer by noting they only wanted to move at a low intensity ($n = 2$), and one "No" was emphatic. In Question 4, 12 respondents reported that they did not want to rest; 4 responded they wanted to rest, and 1 did not know. Of these, 1 person noticed a conflict between wanting to move and rest. Two respondents noted they wanted to rest "a lot", and 1 respondent noted she/he did not want to rest "at all".

Throughout the focus group sessions, participants remarked frequently about their desires to move, be active, but also to rest, both over the past week (e.g., "I have been wanting to move around a lot") and right now (during the interview, e.g., "I want to get out and train"). Interviewees also provided evidence of aversions or avoidance of both movement and rest. While many of these statements were unambiguous, others were suggestive and less concrete, ["I am feeling like I wish we were doing a bit more (exercise)"]. Table 3 provides a compilation of statements supportive of the concept of affectively-charged motivation states.

There was also some doubt about the desire or want to move. For instance, one respondent said,

> "… When it comes to 'urge' and 'crave' it's a natural thing [where] you crave sleep because you can't really just stay up all the time—because you need to sleep. It's more primal, I guess. Because everyone has to sleep. You don't have to move. Well, I guess it depends. There are people who don't really move, but there are some people that do. But everyone sleeps, no matter how active you are." (9/15/21, Participant A).

TABLE 1 Correlation Matrix (Pearson's *r*) and descriptive statistics for "Past week" (PW) and "Right now" (RN) versions of the CRAVE Scale, measuring desires and wants to move and rest.

	RN MOVE PRE	RN REST PRE	RN MOVE POST	RN REST POST	PW MOVE PRE	PW REST PRE
RN MOVE PRE	—					
RN REST PRE	−.66**	—				
RN MOVE POST	.59*	−.08	—			
RN REST POST	−.45	.39	−.71**	—		
PW MOVE PRE	.51*	−.53*	.42	−.58*	—	
PW REST PRE	−.35	.49*	−.42	.67**	−.74***	—
Mean	28.9	17.3	35.3	11.9	33.7	16.5
SD	9.8	10.9	8.9	8.3	8.0	7.6

*$p < .05$, **$p < .01$, ***$p < .001$.

TABLE 2 Paired samples T-tests comparing pre- versus post-interview time points for both "Right now" (RN) and "Past week" (PW) versions of the CRAVE scale.

								95% Confidence Interval	
		t	df	*p*-value	Mean difference	SE difference	Effect Size (Cohen's d)	Lower	Upper
RN MOVE PRE	RN MOVE POST	−3.129	16	.0065	−6.412	2.049	−0.759	−1.292	−0.208
RN REST PRE	RN REST POST	2.054	16	.0567	5.412	2.635	0.498	−0.014	0.997
RN MOVE PRE	RN REST PRE	2.533	16	.0221	11.588	4.575	0.614	0.086	1.127
RN MOVE POST	RN REST POST	6.091	16	<.0001	23.412	3.843	1.477	0.771	2.162
PW MOVE PRE	RN MOVE PRE	2.234	16	.0401	4.824	2.160	0.542	0.024	1.045
PW REST PRE	RN REST PRE	−0.322	16	.7517	−0.765	2.376	−0.078	−0.553	0.399
PW MOVE PRE	PW REST PRE	4.874	16	.0002	17.176	3.524	1.182	0.546	1.797

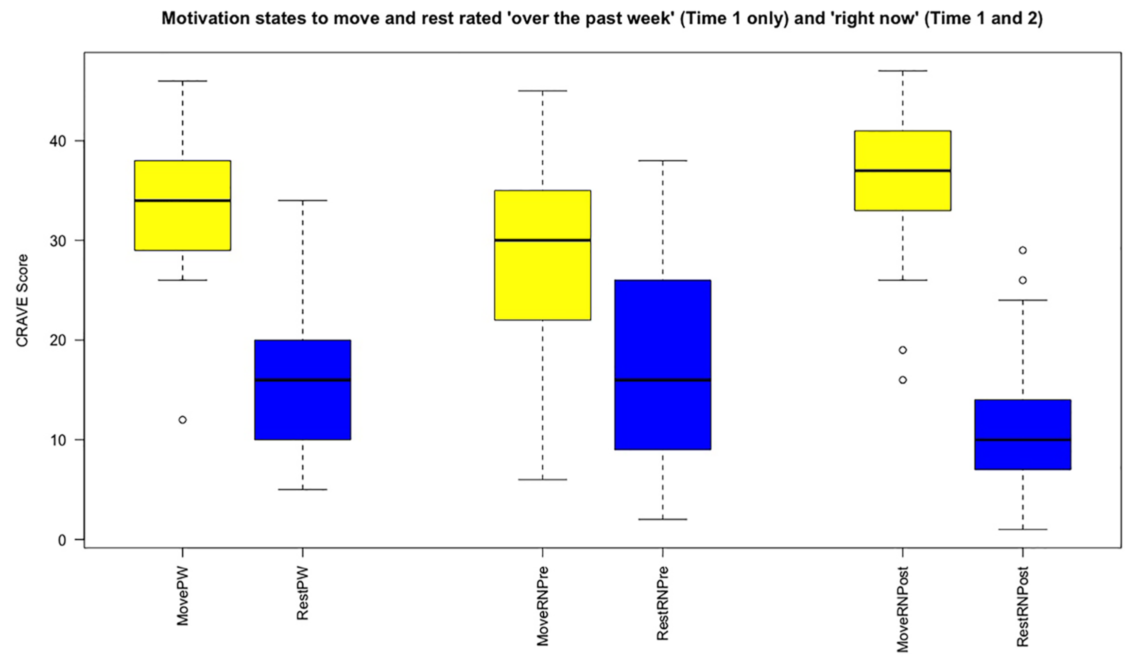

FIGURE 1
Motivation states to move and rest rated "over the past week" (PW, pre only) and "right now" (RN, pre and post).

There was even some doubt about the desire or urge to rest, "I don't see an urgency necessarily to rest, because I gotta reach that brink of exhaustion, to feel that I have earned the right to rest. … I don't feel an urgency to rest." (9/27, A). Also, "Do I want to rest physically? I don't know, but I am ok with being active because I feel like my brain needs a rest" (8/31, D).

Changes in motivation states from pre- to post-interview

Question 12 revealed that at the end of the interview, 12 participants declared a greater desire to move, and two had no perceived changes in desires to move. Of the three remaining, they reported increased awareness of affectively-charged desires for movement and rest behaviors, which was corroborated by two other participants. One participant noted how this awareness also related to behavior,

> "I think I get urges to move because I always have a twitch going on, and I'll move my legs a lot, like I am doing now. They are always moving, and if I notice it happening more, I feel like, 'Okay, I need to get up and walk around', even if it's just while I am listening to a class online. … I have to do something!" (9/21, C).

One of the participants who reported no change in movement desires contrasted that with a report of a decrease in rest. Another respondent reported, "Interestingly enough, I think I've actually woken up in the hour that I've been here …" (9/17, A).

Support for the WANT model

Respondents' comments provided supporting evidence for all postulates of the WANT model. One postulate, "Desires to move and rest interact asynchronously (e.g., one may be high in both or low in both or anywhere in-between)," had few supporting statements. However, in regard to this tenet, a respondent reflecting on a stressful situation noted,

> "I was a bit hungover, and I was stuck to my bed because I was a bit nauseous, but I [couldn't] fall asleep. [I thought] 'If you can't rest, you should be doing something', and it was very annoying because I wanted to begin cleaning my room. 'I'm awake, I should be moving', but I needed my eyes to be closed and a pillow over my head. I couldn't satisfy the urge to move and get stuff done, and that was very stressful." (9/27, A).

There was some evidence against specific postulates of the WANT model. For instance, concerning the supposition that "Desires vary in strength from very weak to nearly unavoidable/maximal," an interviewee remarked,

> "I would say that want, desire, and urge—the whole set—feels the same to me. I don't think that they are super different." (8/31, B).

See Table 4.

TABLE 3 Qualitative evidence for ACMS for movement/physical activity/exercise as well as rest/sedentary behaviors.[a]

		MOVE	REST
WANT	Recently	"My desire has been pretty high to move and be active." (9/17, Participant A) "I have been wanting to move around a lot." (9/17, B) "I am trying to get [my desire] back up so I can actually work out." (9/21, A) "Over the past week I wanted to move a little bit more." (9/21, A) "In the past few days I've wanted to move around a little bit more." (9/21, A) "I think I am still on a 'move thing' right now. I went hiking on Saturday, and afterwards I went out [to socialize]. Even though I am tired I don't really want to stop." (9/21, C) "I really wanted to move over the past week—more than I have consistently over the first few weeks of the semester." (9/10, B) "I get random bursts of energy, and it makes me really motivated, and it makes me want to get more done, and it makes me wanna go on runs, go on walks, get more homework done, or get the next week's homework done." (9/13, A) "… Over spring break our coach tells us … 'You shouldn't be training … You shouldn't be pushing yourself to any degree that's beyond something casual' … By the time you get back from spring break you're dying to get a hard workout in [and] get that sweat going … You miss it, and … you're reinvigorated [and] wanting to train and push yourself. It's a craving." (9/17, A) "The workload is not too heavy—so I wish we were doing a bit more [exercise]." (9/17, A)	"Over the past week, I have wanted to rest a lot." (9/10, A) "I [have] just wanted to sit down." (8/31, A) "I [have] just wanted to go to sleep." (9/17, A)
	Now	"I have had a jam-packed day full of stuff, and I am going to be going until 11pm—so it's a bit more like jolty, anxiety movement. I want to kick my foot around a little, or shake a bit, just to get rid of that nervous energy, in terms of moving, in terms of exercise or working out". (9/27, A) "… I want to work out." (8/31, C) "I wanna get out and train". (9/17, A) "I'd say yeah, I wanna move right now, but not like I'm itching to get out of my seat and go run." (9/17, A) " … I feel urged to move and get stuff done …" (9/27, A) "I want to [move] but I guess I don't really want to heavily exert myself …" (8/31, D)	"I definitely crave rest a lot. I crave just sitting! Sitting is nice. It is very good. Sitting here during the interview is very good. It's nice." (9/27, A) "I would really love to be laying down right now in a fetal position with my teddy bear. That would be ideal because I don't get enough sleep, and it would be nice to just take a nap right now." (9/27, A)
DON'T WANT	Recently	"I have NOT wanted to move more than the necessary amount." (9/21, A) "A time where I really wanted to just slow down and do nothing or just rest … was, not really rest, in itself, but just not move." (9/10, B) "… We'll finish a game". [Maybe] the next day we have off. I'm like, "Oh, I wanna go to the gym". He's like, "I'm wiped out from yesterday. I don't wanna go to the gym". (9/17, A)	"Last night I felt like I couldn't fall asleep. I was just awake and had this jitteriness—almost where it was hard for me to fall asleep. I didn't want to rest." (9/17, A) "I have not been willing to get any rest, [and] because of that, it has been impacting my sleep." (9/21, B)
	Now	"I don't want to move at all." (9/10, B)	"I just do NOT want to get any rest." (9/21, B)

[a]Note that some participants made slightly conflicting statements from one part of the interview to another, or more simply, their motivation state changed over time.

Impact of affectively-charged motivation states (ACMS) on subsequent behavior

We found qualitative evidence that motivation states were related to aspects of subsequent movement and sedentary behavior—in type, quantity and in quality of motor behaviors. The effect on behavior was often related to the strength of the ACMS. One participant stated, "If I really want to exercise, I will make time for it." (9/10, B). Respondents also reported that motivation states did not result in behavior enactment/consummation. For instance,

> "'Want' is more knowing I should, but it doesn't incite me to actually do it. Want is just, 'I should probably do this, because I know it's good for me', but I don't actually do it." (8/31, D).

See Table 5.

Qualitative inductive analyses

Lower-Order theme (LOT) identification

Investigators found 435 lower-order themes (e.g., "move for sport", "rest and be lazy"), only 25 of which were identical between raters, resulting in 410 unique lower order themes. LOTs generated per interview question ranged from 16 for Question 12 to 65 for Question 7 (mean = 36.3, SD = 12.4). There was a total of 753 counts (e.g., instances or tags) across all LOTs. Counts (e.g., instances or tags) per LOT identified were 1.7 (range 1.1 to 3.0). In the first eight questions, move queries resulted in 180 LOTs, and rest resulted in 145, but total counts from move queries were 285 and from rest were 264. Overall, these data demonstrate that many lower order themes were identified (for both move and rest factors). LOTS were tagged to participants' comments.

TABLE 4 Qualitative evidence for the WANT model.

#	Postulate of the WANT model	Qualitative evidence (for)	Qualitative evidence (against)
1	Humans have desires to move and rest.	See Table 3 above.	
2	Desires for movement and rest are two separate systems.	"If I just don't want to go to practice [for sports]—I want to rest that day. That's completely different from craving and needing to rest." (8/31, Participant A)	
3	These desires have both approach and avoidance motivation.	See Table 3 above.	
4	Desires vary in strength from very weak to nearly unavoidable/maximal, where they might be felt as an urge or craving.	"… 'want/desire' are a little lower compared to 'urge' and 'crave'. Those are more towards the need to do something. When you want to do it, you don't necessarily do it, but if you have the urge, or if you really crave to do it, then you are going to do it …" (8/31, A) "In terms of wanting to move … desires are where it would be nice if I moved—it would be nice if I worked out, but it's never going to happen." (9/27, A) "I think that cravings or urges to rest are BOTH physical [sensations] and mental [thoughts]. However, when I want to rest—I feel that 'want' is usually either physical or mental, but not both. For 'want', it's like, 'Oh, I'm kinda tired; I want to rest', but I still have the [physical] energy in me to keep doing something. I feel that 'crave' [to rest] is when everything in me is just like, 'I can't do this anymore; I just need to stop.' (8/31, D)	"I would say that the want, desire, and urge—the whole set—feels the same to me. I don't think that they are super different." (8/31, B)
5	Wants/desires are highly transitory—representing a psychological state.	"I'd say a 'want' to rest is maybe more of a short-term feeling for me. I just finished a game, you know, my body's tired. I just want to chill out for a second, rehydrate, eat something. Whereas 'desire' or 'urge' to rest, I feel is more created by a longer-term circumstance, whether it's that we've been in pre-season now, and you're training twice a day, every day, and you're just thinking, 'All I want is to just relax and rest and catch up on sleep', or whatever it may be." (9/17, A) "I think that 'want' and 'desire' is more like a superficial thing. It's not going to last. It's short term, but then 'urge' or 'crave' is almost like you physically need to." (9/17, C) "I only crave rest right after I wake up, because I feel that as soon as I get going in the day, its fine. If I actually get myself up, the craving for rest goes away. So, I will wake up and it's, 'Oh my god —its 7am. All I want is to go back to the bed.' And then as soon as I go brush my teeth or something, I'm thinking, 'What was I tired for?', and it's fine. I woke up that way essentially, and the craving goes away, and I am fine for the rest of the day." (9/21, C)	
6	ACMS change based on previous behaviors (i.e., the provision or avoidance of certain physical stimuli, such as exercise).	"'Craving' is more when I am doing something [highly] repetitive because I am bored of the same activity, so I want to do something else, if that's resting, being on my phone, or just laying down, or watching TV. While 'want' and 'desire' is when I am doing something in the moment—let's say I am working out, and I think, 'Oh, I want to stop'". (8/31, B) "… Over spring break our coach tells us, 'You shouldn't be training … You shouldn't be pushing yourself to any degree that's beyond something casual' … By the time you get back from spring break, you're dying to get a hard workout in that gets the sweat going … You miss it, and … You're reinvigorated [and] wanting to train and push yourself. It's a craving." (9/17, A) "I think I have the urge when something is going on in my life where I just need to get out, and I need to run if I have been sitting for a long time. I need to just run on vacations. We would always stop at a rest area for a road trip, and I would literally just get out[!]—because when I was little I'd just run to the playground. I needed to run because I craved moving, because I was in the car for about 10 h." (8/31, D) "… after a long time of movement you want to rest, but [after] a long time of resting, you DON'T want to get up and, you know, run two miles." (9/8, A)	
7	Desires to move and rest interact asynchronously.	"I was a bit hungover, and I was stuck to my bed because I was a bit nauseous, but I [couldn't] fall asleep. [I thought] 'If you can't rest, you should be doing something', and it was very annoying because I wanted to begin cleaning my room. 'I'm awake, I should be moving', but I needed my eyes to be closed and a pillow over my head. I couldn't satisfy the urge to move and get stuff done, and that was very stressful." (9/27, A)	
8	A total lack of desire is possible	"I don't want to do anything right now." (9/21, D)	

(*continued*)

TABLE 4 Continued

#	Postulate of the WANT model	Qualitative evidence (for)	Qualitative evidence (against)
9	ACMS differ from psychosomatic sensations, such as energy and fatigue.	"I get random bursts of energy, and it makes me really motivated, and it makes me want to get more done, and it makes me wanna go on runs, go on walks, get more homework done, or get the next week's homework done." (9/13, A) "The desire to rest is more motivated by my body and how my body is feeling, and the desire to move is more like a mental thing." (9/17, A) "I am just too tired. I have wanted to be active, but I just don't always have that energy." (9/10, A)	
10	They differ from emotions but might vary systematically with certain emotions and situations.	"What makes me want to move is just the joy I get from playing sports. I enjoy exercising [and] definitely feel motivated …" (9/17, A) "When I get overwhelmed, I prefer to rest and just be alone resting." (9/10, C)	

TABLE 5 Qualitative evidence that affectively-charged motivation states (ACMS) have influence on movement and sedentary behaviors.

	Qualitative evidence (for)	Qualitative evidence (against)
Movement/physical activity/exercise	"If I really want to exercise, I will make time for it." (9/10, Participant B) "The 'want' and 'desire' are feeling motivated, but not really motivated, and then ['urges' and 'cravings'] are, "Oh, I'm going to do this. I'm going to get up. I'm going to move. You want to get out. You want to do the exercise or whatever the movement is." (8/31, C) "I remember all of last summer, every morning, I craved to work out, and I craved to practice even though I couldn't go. In my own time in my backyard I would work out and mimic a practice by myself because I craved it." (8/31, B)	"'Want' is more knowing I should, but it doesn't incite me to actually do it. 'Want' is just, 'I should probably do this, because I know it's good for me,' but I don't actually do it." (8/31, D) "I sometimes actually move when I have a 'want' to move, but it takes a lot more willpower to do it." (8/31, D) "I have a lot of friends on social media who will post gym selfies, and when I see those I'm feeling like, 'Ah, look at them. I should probably do that!' That's an outside factor that potentially pushes me to want to move or do what they are doing. It never really happens, but definitely I mentally get that, but not physically." (9/27, A)
Rest/sedentary behaviors	"… When I desire rest, it's much more appealing [than movement]. And I very much try my very best to make it happen. And if I desire to take a nap, I feel you will be able to tell it more. I'll be kinda drooping a bit. I'll be a bit more tired- not as talkative. Versus if I want to move, I don't know if you'd necessarily see that in a physical appearance." (9/27, A) "I feel that 'crave' [to rest] is when everything in me is just like, 'I can't do this anymore; I just need to stop.'" (8/31, D) "… It's a natural thing [where] you crave sleep, because you can't really just stay up all the time, because you need to sleep. It's more primal, I guess. Because everyone has to sleep." (9/15, A)	None observed

Higher-Order theme (HOT) identification

The two analysts generated the same (or highly similar) higher-order themes only 22.4% of the time. Discordant HOTs were sent to analyst 3, who chose analyst 1's HOT in 33.6% of instances. In 1.3% of instances, the analyst was unable to make a determination, resulting in the items being discussed until consensus. In the end, 43 higher order themes were agreed upon.

The 10 most common HOTs (based on frequency of LOTs in ach HOT) were: (1) "sensations/stimulation" ($n = 62$ LOTs), (2) "demands" ($n = 52$), (3) "facilitators of movement" ($n = 40$), (4) (tie) theoretical support ($n = 37$), (4) (tie) "physical sensations" ($n = 37$), (6) "cycles/variation" ($n = 35$), (7) (tie) "stress" ($n = 32$), (7) (tie) "exhaustion threshold" ($n = 32$), (7) (tie) "deprivation/satiation" ($n = 32$), and (10) "barriers for movement" ($n = 31$).

Super higher-order theme (SHOT) identification

From the 43 HOTs, super higher order themes (SHOTs) were created. Analyst 1 sorted the 43 themes in 10 clusters, which included: (1) Stable change / biorhythms, (2) Factors affecting change in motivation states, (3) Processes of control, (4) Impulse control/Impulsivity, (5) Objective-oriented, (6) Moderators, (7) Sensations, (8) Strength of motivation states, (9) Theoretical postulations, and (10) Stress factors. Analyst 2 sorted the HOTs into three SHOTs: (1) Theoretical support, (2) Behavioral processes, and (3) Stress. Through a process of consensus, six were designated: (1) "People experience movement urges", (2) "Change", (3) "Autonomy", (4) "Objective-orientation", (5) "Moderators", and (6) "Stress effects". These were then presented collectively at an international conference (see Acknowledgements), and feedback was garnered.

We then decided to present the themes as dualities based on the contrasting ideas of: (1) "propelling vs. restraining" forces, (2) "automaticity vs. deliberation" in the Affective-Reflective Theory of Physical Inactivity (14), and (3) "reflective vs. appetitive" desires (12, 18). However, to be consistent with the WANT Model (17, 20, 24), we decided to present these dualities as additive ("and") and not necessarily as a conflicting binary ("vs."). This was also done to emphasize the potential for an adaptive and flexible behavioral repertoire (47), as with the WANT Model (i.e., which includes move and rest, and not move vs. rest), where combinations of desires can lead to more diverse behavioral outcomes (47). The final SHOTs were: (1) Want—and do not want (diswants), (2) Change and stability, (3) Autonomy and automaticity, (4) Objectives and impulses, (5) Restraining and propelling forces, and (6) Stress and boredom. Each SHOT is explained in detail below. See Figure 2.

SHOT 1—Wants and diswants (aversions)

All of the higher order themes in this SHOT related to affectively-charged motivation states and their characteristics. Thus, the SHOT was called "Wants and diswants". This SHOT encompassed six higher order themes: (1) sensations/stimulation (i.e., people subjectively feel wants to move and rest), (2) theoretical support for ACMS and the WANT model, (3) tension strength of motivation states, (4) aversions/dread for movement and rest, (5) intrinsic motivation, and (6) thresholds differentiating ACMS. Supplementary Table S1 contains the HOTs, exemplar LOTs, and quotes for the "Wants and diswants" super higher order theme.

SHOT 2—Change and stability

The higher order themes in this SHOT all related to factors changing or remaining stable over time, which invokes concepts of biorhythms and regulated change, and perhaps similar to homeostasis and allostasis (48). This SHOT had seven higher order themes: (1) cycles and variation, (2) homeostasis, (3) inertia and momentum, (4) balance of movement and rest, (5) habits and routine, (6) traits and (7) aging and the life course. Supplementary Table S2 contains the HOTs, exemplar LOTs, and quotes for the "Change and stability" super higher order theme.

SHOT 3—Autonomy and automaticity

With close inspection of the HOTs, it was determined to call this SHOT "Autonomy and automaticity", in respect to processes of control and higher-order cognitive processes, such as decision-making. Both HOTs and LOTs in this theme appear to point to many user-generated decisions—or at the very least—the

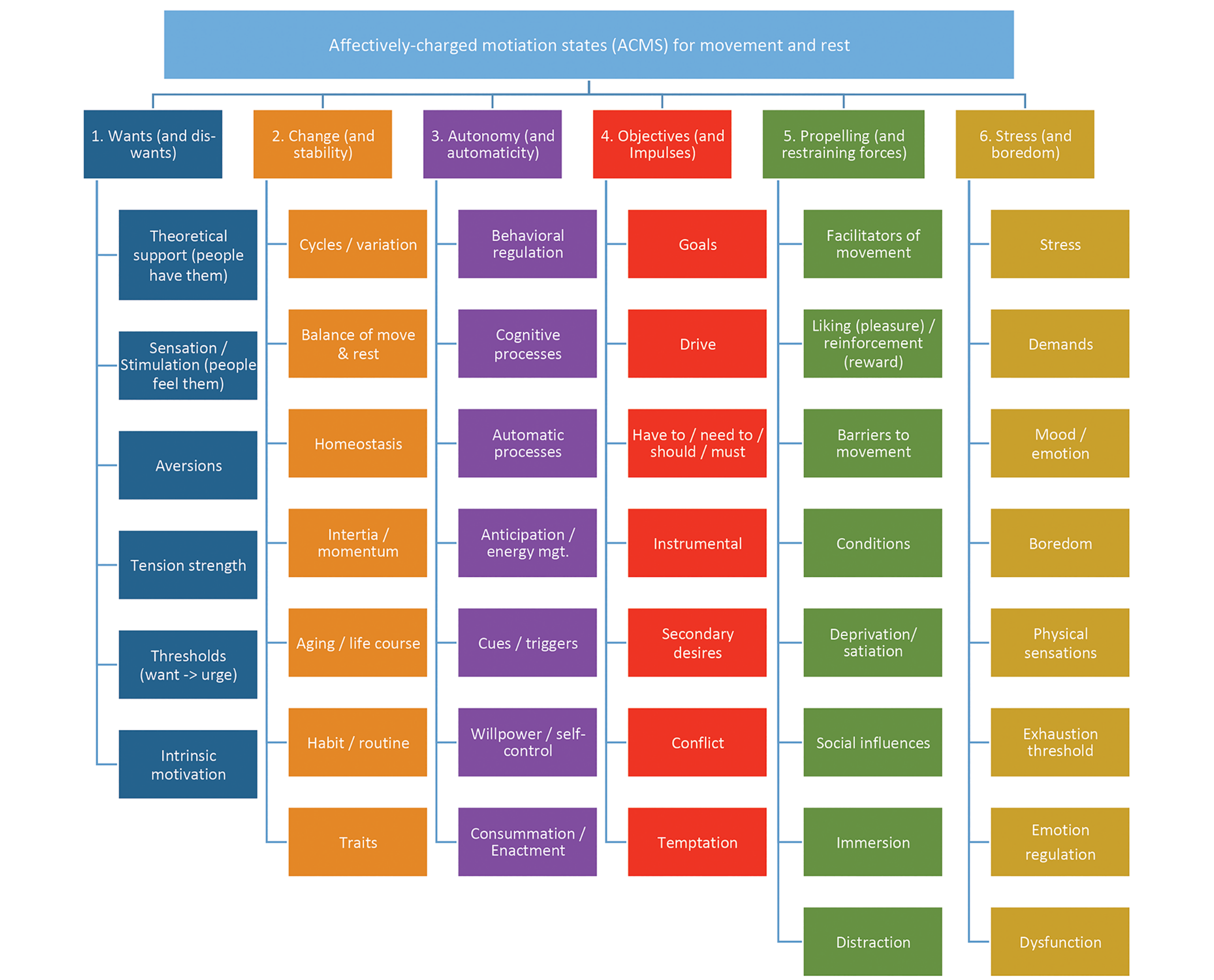

FIGURE 2
Final model of the 43 higher order themes (HOTs) categorized into six super higher order themes (SHOTs).

inability to make decisions (49). In other words, some processes have a locus of control generated consciously by the self, while others are generated more unconsciously. Considering the framework of Self-Determination Theory (44, 50), the notion of autonomy is a feeling that one has choice and is willingly endorsing one's own behavior (49). Autonomy here makes sense as individuals might think about actions (e.g., cognitive processes), regulate behavior (e.g., energy management), and must overcome urges in order to produce a desired behavior (e.g., temptation vs. will power). When looking through this lens, autonomy appears as the concept that encompasses all of these lower order themes. In regard to those decisions that appear to be not consciously generated, the idea of automaticity applies from Affective-Reflective Theory (14). Recent work suggests that automaticity and autonomy interact to produce stronger physical activity behaviors (51). This SHOT had seven higher order themes: (1) automatic processes, (2) cognitive processes, (3) behavioral regulation, (4) anticipation/energy management, (5) cues/triggers/feedback, (6) willpower/self-control, and (7) consummation/behavioral enactment. **Supplementary Table S3** contains the HOTs, exemplar LOTs, and quotes for the "Autonomy and automaticity" super higher order theme.

SHOT 4—Objectives and impulses

This SHOT was named "objectives and impulses" to reflect that some desires are rational while others are appetitive, which is in line with the theory of desires from Davis (12, 18). Examining the lower and higher order themes of this SHOT, and the quotes associated with them, it was apparent that the respondents were trying to reconcile commitments against impulses to accomplish competing objectives. This would entail setting and working toward goals, in concert or in conflict with thinking about what one has to do, needs to do, should do, or must do based on the desired end result. Taken together, this reads as an objective-oriented mindset contrasting against an impulsive mindset, where one is actively working towards a desired outcome. This SHOT had seven higher order themes: (1) goals, (2) drive, (3) have to/need to/should/must, (4) instrumental demands, (5) conflict, (6) secondary desires, and (7) temptation. **Supplementary Table S4** contains the HOTs, exemplar LOTs, and quotes for the "Objectives and impulses" super higher order theme.

SHOT 5—Propelling and restraining forces

Respondents indicated that there were several factors that modified or moderated their experience of motivation states to affect activity and sedentary behaviors. Thus, it was decided to name this "Propelling and restraining forces", in alignment with Affective-Reflective Theory (ART) of physical inactivity and exercise (14). This SHOT had eight higher order themes: (1) facilitators of movement, (2) deprivation / satiation, (3) barriers for movement, (4) social influences, (5) conditions, (6) liking (pleasure) / reinforcement (reward), (7) immersion, and (8) distraction. **Supplementary Table S5** contains the HOTs, exemplar LOTs, and quotes for the "Propelling and restraining forces" super higher order theme.

SHOT 6—Stress and boredom

Respondents frequently noted that desires to move and rest were instigated by states of over- and under-stimulation—strain and monotony. This makes sense, as psychological stress states can have a strong effect on physically activity and sedentarism (52), both inhibiting and activating behavior, perhaps by affecting psychosomatic sensations (53). This SHOT encompassed eight higher order themes: (1) impinging life demands, (2) physical sensations, such as energy and fatigue, (3) stress, (4) exhaustion threshold, (5) monotony and boredom, (6) emotional regulation, (7) mood and emotion, and (8) dysfunction and dysregulation. **Supplementary Table S6** contains the HOTs, exemplar LOTs, and quotes for the "Stress and boredom" super higher order theme.

Discussion

This is the first mixed-methods (qualitative and quantitative) study to provide evidence that individuals experience appetitive and reflective wants (or desires) to move and rest; that these states change rapidly, and are highly influenced by a number of ever-changing factors, such as the daily experience of stress (52). Interviews with 17 college honors students revealed that they subjectively felt affectively-charged motivation states (ACMS) to move and rest both in recent weeks and in the present moment. They also provided evidence for other postulates of the WANT model, such as not wanting to move or rest at all, or rather, *actively avoiding* certain behaviors. In a few cases, respondents provided contrasting perspectives that contradicted expectations. For instance, some respondents expressed some doubt that they had any desire to move, or that there were any differences between various motivation states, such as the desire to move vs. an urge to move. Importantly, some evidence, though not extensive, supported the idea that motivation states to move and rest spur actual activity behaviors in a time frame proximal to the experience of the subjective desire. To understand how motivation states might impact behavior, we conducted an inductive content analysis of the interviews. Forty-three higher order themes were found, which we separated into six super-higher order themes, such as "Objectives and impulses", "Propelling and restraining forces" and "Stress and boredom". The study also provided further validation of the CRAVE scale, which was recently developed to measure motivation states (24, 26). As measured with this instrument, there were changes in ACMS from pre- to post-interview with moderate effect sizes (0.76 and 0.50, for move and rest, respectively). Overall, there was an abundance of support, but also some minor conflicting evidence, for the concept of affectively-charged motivation states for physical activity and sedentarism and their influence on subsequent behaviors.

Evidence of affectively-charged motivation states—quantitative and qualitative deductive analyses

The major priority of this study was to determine if a group of respondents would qualitatively support or negate the idea of feeling motivated, in the present moment, to move, be active and exercise. This has come into focus given a preponderance of opinion, and some empirical data, that humans prefer to be sedentary, or may not have any experience of desiring or wanting movement (35, 36). While there is a strong rationale that humans do want to move (17) and initial quantitative data exists to support it (24), we were interested in opinions from interviewees and their expressions of desire (or lack thereof) in their own words. As it happened, participants largely corroborated the concept of motivation states, but they also presented unique perspectives. Participants stated that they did subjectively experience desires to move and rest, including at the time of the interview, which sometimes differed from desires experienced over the past week. Moreover, these states were volatile, rapidly dissipating or succumbing to other desires. They also described a total absence of desire, often during flow states, or even aversion to movement and rest; in other words, actively avoiding these behaviors. Desires were sometimes described as being consummatory (e.g., as in feeling an urge to exercise that instigates actions to go work out at the gym), which in turn often resulted in satiation—a fulfillment of desire leading to a drop in the motivation state and subsequent cessation of activity. Of note, strong urges and cravings for movement, typically from conditions of deprivation (e.g., sudden, abnormal, and/or prolonged decreases in exercise) were associated with physical and mental manifestations, such as leg stiffening, fidgeting, and feelings of being antsy, jittery, and restless. Urges for rest and sleep featured prominently as well, and some respondents even expressed having extreme cravings for rest.

While qualitative data addressed the experience of motivation states, quantitative data mainly demonstrated variance in those states. As hypothesized, motivation states, as assessed with the CRAVE scale, changed significantly over the course of the focus groups. We observed that the desire to move increased pre- to post-interview, and the desire to rest decreased, which agrees with data previously collected from a study that saw similar trends over three time points throughout an educational seminar (24). Some participants described the experience of motivation states as something novel and unimaginable beforehand, but now that it was in their conscious awareness, it had some concreteness and veracity. The notion that we may or not be aware of our desires and impulses has been discussed extensively (30, 31), and the idea of arousing awareness for movement impulses was famously demonstrated by Benjamin Libet (54) in his studies on free will. Having satisfactorily analyzed the interviews for deductive evidence of motivation states, we turned to analyze the data from an inductive perspective, creating hierarchical themes to understand how motivation states operate within a larger regulatory scheme. The first super higher-order theme, "wants and diswants (aversions)" was mostly constituted from the deductive information generated above.

Qualitative inductive analysis

Do motivation states matter in the control of behavior, and if so, how? Desires and urges for movement and rest are ostensibly antecedents to and consequences of behavior, but how they operate within behavioral systems is unknown. Super higher-order themes two through five commonly related to ideas of behavior regulation, comprising the categories of: SHOT 2) Change and stability, SHOT 3) Autonomy and automaticity, SHOT 4) Objectives and impulses, and SHOT 5) Restraining and propelling forces. In regard to the SHOT on change and stability, participants widely reported diurnal, weekly, and seasonal variation in desires for movement and rest. A plethora of data exists in the area of circadian rhythms (26), supporting the notion that pertinent hormones (e.g., cortisol) (55), neural peptides (e.g., hypocretin-1 / orexin A) (56), psychological factors (e.g., perceptions of energy and fatigue), and other attributes vary cyclically over the course of a day, month, year, or longer (23). Another theme emerging from this SHOT was that of behavioral and motivational momentum and inertia (e.g., being "in a rut" or "stuck") (15), perhaps similar to the ideas of affective inertia or *stickiness* (57), which are associated with symptoms of depression and/or attention disorders (58). This is intriguing as one might speculate that motivational inertia serves as another indicator of psychological dysfunction. On the other hand, the feeling of inertia may be a key difference between types of ACMS, with cravings and urges having more motivational pull against inertia. Clearly though, sometimes inertia is less pernicious and simply due to forces of habit and environmental demands. Participants indicated that habit drove their behavior without awareness of a desire for movement, attesting to the power of habits (59, 60). Another force (perhaps equally strong to habit) indicated by respondents was provided by movement's instrumental or utilitarian value. In short, despite technological advances, people still have some tasks that can only be accomplished through bodily movement, and motivation states match those situational demands through a process Brehm and Self (29) call *motivational arousal.*

These concepts segue easily into SHOT 3 (Autonomy and automaticity), and of these two contrasting perspectives, perhaps automatic processes of regulation were most frequently described by participants; they did represent the greatest number of lower-order themes in this SHOT. Central to automatic processes are the related ideas of randomness and spontaneity, which recently have been highlighted in motivation research but are rarely accounted for in analyses (61); "Motivation arrives as opposed to being planned" (61), suggesting a non-linear path of motivation. Participants were clear that a variety of external variables, such as cues, were antecedents of movement and rest, perhaps accounting for some of this variability (15). Finally, the theme of automaticity is also consistent with terminology used in the social psychology work on conscious vs. nonconscious processing and decision-making. Hallmark research from Bargh (62) resulted in the adoption of *automaticity* vs. *control* to refer to non-conscious and conscious processes. In the current case, autonomy and control are parallel in that they refer to conscious, volitional processes.

In line with the Affective—Reflective Theory of Physical Inactivity and Exercise (14), participants also described, though less frequently, deliberative processes, such as decision making, planning, energy management, and prioritization of rest and exercise. Motivation states are key mediators in adaptive planning (47). As seen in SHOT 4, participants described desire changing in the context of conflict, which existed between competing desires as well as between desires and goals. Participants expressed these as contrasts between "want to", "have to", "should", "need to", and their converses ("don't want to", "shouldn't", etc.), many or most of which interacted with goals, intentions, and other cognitive factors to spur change (17, 63–65). Saunders and colleagues (66) found that, on average, 60% of participants' desires conflicted with at least one goal. The interplay between these forces was often influenced by willpower (resistance), self-control, or harmonization of desires—to result in behavioral enactment or avoidance. Greater resistance or willpower applied immediately in the moment of temptation results in less enactment of unproductive desires (66, 67). While a lack of willpower might be the key factor in some situations, in others it might more simply be a lack of opportunity (e.g., situational constraints) to move or be sedentary in the moment of experiencing desire. Sometimes respondents indicated that desires were managed, manipulated, or ignored, but frequently urges and cravings were strong enough to hijack attention and thoughts, consuming physical and mental resources to the point of not being able to overcome them—ostensibly resulting in rapid behavior (63, 68). On the other hand, as laid out in SHOT 5, there were a variety of barriers blocking consummation of the desire to move, such as injury, exhaustion, and responsibilities. There were also a variety of conditions (e.g., having free time for leisure, being in proximity to a gym or nature) and social factors facilitating desires—leading to opportunities to act on the impulse (11, 49, 69). Taken together, motivation states appear to play a prominent role in behavioral processes. More specifically, they seem to relate clearly to the concept of self-regulation, which is defined as "any effort to actively control behavior by inhibiting dominant and automatic behaviors, urges, emotions, or desires, and replacing those with goal-directed responses" (70, 71).

Stress and boredom

Psychological stress, both subjective and objective, emerged as a major theme, and participants frequently cited facets of stress as abating and/or instigating motivation states to move (e.g., "Stress makes me want to move.") and rest (e.g., "My desire to rest is normally about stress."). Stressful emotions (e.g., "freaking out", being overwhelmed), life stressors (e.g., transition to college, COVID-19, family death), demands (e.g., schoolwork, sports training), daily hassles, and work/rest imbalance were all regarded as influential in either activating or inhibiting motivation and related behavior. Several participants stated that they utilized exercise as a method to cope and regulate emotions, which may explain why some people move more in the face of stress. All of these observations fall in line with a classic systematic review that found that psychological stress was associated with inhibited physically active behaviors in 86% of higher-quality studies, but 18% of prospective studies found that it was associated with activated movement as well (52). Investigations including sophisticated analyses have demonstrated that the effects of negative affect on physical activity are stronger than the opposite direction (72, 73). Stults-Kolehmainen, Blacutt & Filgueiras (74) found that individuals reporting very high levels of stress reported either no exercise at all, or alternatively, very high levels of exercise (e.g., working out 6 days a week). Despite facing extraordinary stressors, some athletes are able to self-regulate to maintain effortful behaviors by focusing on goals, the so-called "self-regulatory efficacy" (75), resulting in a null effect of stress.

Back to the current data, excitement and eustress typically were related to an increased drive to move (21), but so was a lack of stress and under-stimulation—feelings of boredom and monotony. Interestingly, stress also resulted in feelings of numbness or being frozen, in other words, not wanting to move or rest at all, which is in accordance with postulates of the WANT model (17). One unique observation was that not being able to satisfy or consummate an urge or craving to move or rest sometimes resulted in the experience of stress, frustration, and agitation, indicating possible bidirectional effects (e.g., "I couldn't satisfy the urge to move and get stuff done, and that was very stressful"). Overall, it appears that stress and emotion interact with motivation states (e.g., desire, urge, craving) to move and rest in a highly complicated manner to influence behavior (76). Unfortunately, at the current time there is a lack of a clear model to explain stress and motivation interactions—whether motivation mediates and/or moderates the effects of stress on physical activity.

Aside from psychological stress, other mental health and psychological considerations had sway over motivation states. For instance, psychosomatic sensations, such as tiredness, pain, and soreness all had a clear impact on desires to move and rest, with aversive sensations typically extinguishing the desire to move and propelling desires to be sedentary. Both good and poor moods were commonly cited as influencing desires to move, be productive, and rest. Although unprompted, some respondents openly commented that they had various mental health conditions, such as anxiety, ADHD, bipolar disorder, and body image problems. These respondents spoke about episodes of impaired activity—being "in a rut", feeling "stuck" or, conversely, being hyperactive and feeling manic (77). However, no participant discussed depression and trauma. Those with PTSD, for instance, sometimes complain of being "frozen" and unable to move and be productive (78), while those with panic attack and agoraphobia suffer from "fear responses to acute threat with the urge for active avoidance/escape" (79). Stults-Kolehmainen and colleagues have discussed aspects of motivation states as they appear in psychological disorders, including: anorexia nervosa, muscle dysmorphia, akathisia, restless legs syndrome, and others (20). Until recently, these sensations appeared to be obscure and idiopathic symptoms, but recently NIMH has classified these in the *sensorimotor domain* under the construct "motor actions" (sub-construct: "sensorimotor dynamics") (80), which seems to validate the notion that ACMS might have a place in mental health and pathology. Unfortunately, this study included a sample that was too small to explore any of these ideas, and we did not include any physical or mental health measures in this study.

Limitations

The results of the current investigation must be interpreted with some caution due to several limiting factors. First, the number of participants was small and homogeneous; the group was composed mostly of young, female, undergraduate honors students. Previous studies have found no differences between genders for motivation states (24), so lack of variability in gender may not be an issue, but we have observed differences by age (24). Older individuals have a much wider range of life experiences and are subject to the effects of both primary and secondary physical aging (81). Consequently, it seems likely that older adults will experience motivation states for movement differently and will probably have a greater desire for rest. Comments from our respondents could also reflect a specific motivational climate, culture, and education around movement and rest that might be tied to this population of high achieving college students (49, 69, 82). Indeed, our previous work also demonstrates that adults of different age groups have different motives for exercise (10). Motivation states also vary by exercise stage-of-change, a proxy for physical activity behavior (24). The fitness and physical activity levels of the sample were not measured, but based on their extensive comments, it is certain that this group was a healthy, active, and high functioning sample. This is important, as for some people, there are likely trait manifestations of wanting to move and rest.

Regardless of these influential factors, the interviews generated over 400 lower-ordered themes, indicating that even though the participant number was low, the interviews were very productive. Also, despite the low n, we observed changes in CRAVE scores across the focus groups, indicating increased desires to move. There was no control group, therefore, we don't know if changes in CRAVE ("right now") were due to: (1) increased awareness of normally unconscious desires, resulting from talking about physical activity and rest behaviors (54), (2) the effects of behavioral priming, which Bargh demonstrated clearly impacts physical activity (62), because participants felt "cooped up" during the interview, (3) anticipation of leaving the venue for their next daily task, (4) demands effects, (5) reactivity to the CRAVE scale, or (6) some other unknown factor. The first point might be discounted as we did not observe concomitant increases in the desire to rest ("right now"), even though it was also widely discussed. On the contrary, it was diminished. Furthermore, we found similar results in Study 4 from Stults-Kolehmainen et al. (24), which observed a lecture period when the topics of physical activity and rest were not specifically discussed. Future studies will need to untangle these effects with better experimentation.

Future research

Future research could attempt to make the necessary methodological advances noted above, or it could go in alternative directions to address other issues, which are roughly divided into four research questions.

Are people naturally lazy?

While the current study provided both quantitative and qualitative evidence that desires to move and rest are subjectively felt in conscious awareness, and most aspects of the WANT model were supported, we were not able to adequately address the idea of which desire (physical activity or sedentarism) is predominant in this group of respondents, nor in the larger scope of human behavior. However, our quantitative data found that the desire to move was greater than the desire to rest at every time point. This is consistent with our previous investigations, where desire to move was consistently rated higher than desire to rest in quantitative analysis (24). It is also congruent with the idea that, "The human body is built for physical activity, not rest" (83), implying that humans have both a natural need and inherent drive to move [discussed extensively by Stults-Kolehmainen et al. (17, 21)]. However, we did not specifically ask our interviewees questions to directly compare desires, such as, "Which desire do you feel more often?" or "Which desire is stronger for you typically and right now?" Various researchers have suggested that humans are naturally inclined to rest and thus conserve energy; therefore, they likely have greater desire to be sedentary, are typically lazy, and only move when necessary (12, 29, 35–37, 84). The ideas of laziness and productivity did feature among respondents in these focus groups, with laziness generally being viewed as the opposite of productivity, and desires to rest and move associated with those tendencies (e.g., "I feel urged to move and get stuff done."). Future research should address whether the feeling of laziness is simply: 1) a lack of a desire to move (regardless of the desire to rest), 2) a combination of low desire to move and high desire to rest, or 3) a low desire to move and a high desire to rest but felt in the shroud of "should" move.

How do "shoulds" and "want to's" interact?

Following from above, a person may feel and/or think that they "should" be moving, and they "should" be productive, but they do not have the subjective and appetitive feeling of wanting to move and be productive. Future studies should address the ideas of "should" and "have to" in relation to reflective and appetitive "want to"—developing better instruments and theories to connect these related constructs. More practically, future studies might investigate how to create exercise routines that are more enjoyable, less compelled by "shoulds", or help people to move more mindfully—paying attention to desires and/or embracing desires to move and rest in balance, as with mindful walking or martial arts (85, 86). These might be conducted as part of just-in-time adaptive interventions (JITAI) (87), which attempt to gauge and take advantage of motivation states (i.e., "CRAVE moments"), but at this time no studies have sufficiently incorporated this idea (88)—as none have used a valid measure, such as the single-item CRAVE scale (24, 27).

How can the WANT model be improved?

Future research should also focus on updating and revising the WANT model (17), which was created because of apparent theoretical deficits and the inability of existing theories to adequately explain the motivation states phenomena we have observed, but still falls sort of its intended goal. In short, the WANT model is a heuristic to understand how desires might vary in strength, approach, and how they interact with each other. This effort is concordant with the NIMH Research Domain Initiative Criteria, which seeks to understand elements of psychological phenomena, such as urges and motor sensations (80). The current data provide evidence that facets of the WANT model (e.g., that desires may be oriented to approach or avoidance, are impacted by previous behaviors, etc.) are valid. However, the model as a whole lacks extensive quantitative validation, mainly because there are no measurement tools available to assess aversions (i.e., diswants) to move and rest. Until this measure exists, adequate validation of the dual-axis structure of desires for movement and rest (and thus four quadrants) is not feasible. The WANT model could be further explicated by considering how ACMS to move and rest fluctuate in tandem with other internal and external states (e.g., stress, satiety, deprivation, hunger, and fatigue), emotion, and other influences that vary by the situation and context. For example, a revised WANT model might incorporate exogenous stimuli known to influence desires to move, such as music, light, and other environmental factors identified by participants in these focus groups. Insights generated from qualitative data, as in the current study, is pertinent for the advancement of model, theory, and intervention development in the areas of physical activity and sedentary behavior, as has been delineated by Bonell (40).

What other theories offer insight into motivation states for movement and sedentarism?

The WANT model is not a predictive model; therefore, frameworks predictive of physical activity and sedentarism, such as dual-process theories (14, 15), or models of affective response (16) may be better suited to explain these phenomena. Alternatively, new research frameworks may be needed. Dissimilar from theories mentioned above, the Elaborated Process Model of self-regulation (33) focuses on the idea of depletion and how it moderates motivation. It asserts that people switch from move to rest (and from "have-to" to "want-to") systems and back again as they become depleted in each system. Importantly, depletion is associated with fatigue, boredom, and negative emotions, which propels the individual to avoid exploitation types of tasks (i.e., work) and approach exploration types of tasks (e.g., watching video clips or television) or vice versa. While the switch is ostensibly prompted by fatigue, it may also be triggered by a (perhaps unconscious) cost/benefit analysis, stoking desires for rewarding stimuli and causing changes in attention, salience, and emotion. From an evolutionary aspect, such fatigue-induced switching is highly utilitarian and adaptive as it: (A) prevents excessive focus on any one single desire, for instance, in the dysfunctional cases of *punding* (89), and (B) it also protects the human organism from overexertion and collapse (90, 91). However, the theory also postulates that to promote the continuation of valued behaviors, fatigue can be better tolerated and made less aversive with the provision of extra reward, distractions, affirming values, prayer, or other strategies (33), all of which may be relevant in the promotion of physically active behaviors. Other models of depletion and satiation, such as the exercise satiation model (92), should be studied for ideas to expand and/or modify existing frameworks—together with Self-determination Theory (44, 50) and the Theory of Effort Minimization in Physical Activity (36).

Finally, future research should investigate whether people act on their desires to move and rest when these are experienced in the moment of tension. This may be studied in a naturalistic setting (93) or in a laboratory environment where such desires are instigated.

Conclusion

Both quantitative and qualitative data support the notion that humans experience subjective feelings of wanting or desiring to move their bodies, be physically active and/or exercise, which we call affectively-charged motivation states (ACMS). Sometimes, these actionable feelings were described as strong, engrossing or even irresistible, as in an urge or craving to get up and walk around or engage in a workout or training session. Respondents clearly indicated having experiences of desire or craving to rest, sleep, and engage in sedentary behaviors, and frequently these collided with ambitions to move or be productive. How interviewees described their subjective states largely fell in line with postulates of the WANT model (17), which describes how desires, wants, urges, and cravings to move, be active and rest operate loosely and asynchronously. Motivation states to move and be sedentary varied by numerous factors, which we divided into six super higher-order themes. Perhaps the most prominent of these was the theme centered on stress. Indeed, the experience of stress frequently stymied desires to move and be active, though sometimes it had the opposite effect. Stress also stoked desires to rest and be sedentary, though again, sometimes it also diminished those. Quantitative data revealed that, across focus groups, desires to move increased, and desires to rest trended to decrease, which participants corroborated when specifically asked about perceived changes in motivation states. The overarching picture that emerged from this investigation is that motivation states (e.g., desires, wants, urges, and cravings) likely play a prominent role in behavioral processes, interacting with other factors (e.g., stress, habit) to drive movement and sedentary activities. Such information may lead to better theories and, down the road, adaptive interventions to promote physical activity.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Northern Illinois University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MSK and TAG conceptualized the project and designed the study. Data collection was conducted by TAG. MSK and TAG conducted the qualitative analyses, with support from NSB and FAB. PM and MSK conducted the quantitative analyses. The manuscript was written primarily by MSK and TAG, in that order. The manuscript was evaluated and refined by RS, JBB, DB, CB, GA, FAB, AH and JLB, in that order. All authors provided critical feedback, reviewed, and approved the final manuscript. All authors contributed to the article and approved the submitted version.

Funding

GA was supported by a fellowship from the Office of Academic Affiliations at the United States Veterans Health Administration, a Robert E. Leet and Clara Guthrie Patterson Trust Mentored Research Award, Bank of America, N.A., Trustee, and American Heart Association Grant #852679 (GA, 2021–2024). DB was supported by Grant RYC2021-031098-I funded by MCIN/AEI/10.13039/501100011033, by "European Union NextGenerationEU/PRTR", and by a productivity research grant (PQ1D) from CNPq (Brazil).

Acknowledgments

These data were presented at the NASPSPA (North American Society for the Psychology of Sport and Physical Activity) annual conference in Kona, HI, United States, where many attendees, in particular Ralf Brand (University of Potsdam, Germany), provided thoughtful comments that significantly improved this manuscript. Miguel Blacutt (University of Notre Dame, IN, United States) provided some assistance with data interpretation. The authors also wish to thank Philip R. Stanforth (The University of Texas at Austin, United States), Alberto Filgueiras (Rio de Janiero State University, Brazil), and Cyrus Dadina (Dobbs Ferry High School, NY, United States) for miscellaneous research support. SciPod created a podcast to explain the concepts of affective-charged motivation states for physical activity and sedentarism in the context of the WANT model (25). This study has a preprint in SportRχiv, which was posted on August 29, 2022 (DOI: https://doi.org/10.51224/SRXIV.189).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2023.1033619/full#supplementary-material.

References

1. Ussery EN, Whitfield GP, Fulton JE, Galuska DA, Matthews CE, Katzmarzyk PT, et al. Trends in self-reported sitting time by physical activity levels among US adults, NHANES 2007/2008–2017/2018. *J Phys Act Health*. (2021) 18(S1):S74–S83. doi: 10.1123/jpah.2021-0221

2. Hyde ET, Whitfield GP, Omura JD, Fulton JE, Carlson SA. Trends in meeting the physical activity guidelines: muscle-strengthening alone and combined with aerobic activity, United States, 1998–2018. *J Phys Act Health*. (2021) 18(S1):S37–S44. doi: 10.1123/jpah.2021-0077

3. Levine JA, Schleusner SJ, Jensen MD. Energy expenditure of nonexercise activity. *Am J Clin Nutr*. (2000) 72(6):1451–4. doi: 10.1093/ajcn/72.6.1451

4. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science*. (1999) 283(5399):212–4. doi: 10.1126/science.283.5399.212

5. Thompson D, Batterham AM. Towards integrated physical activity profiling. *PLoS ONE*. (2013) 8(2):9. doi: 10.1371/journal.pone.0056427

6. Rosenberger ME, Fulton JE, Buman MP, Troiano RP, Grandner MA, Buchner DM, et al. The 24-hour activity cycle: a new paradigm for physical activity. *Med Sci Sports Exerc*. (2019) 51(3):454–64. doi: 10.1249/mss.0000000000001811

7. Raichlen DA, Pontzer H, Zderic TW, Harris JA, Mabulla AZ, Hamilton MT, et al. Sitting, squatting, and the evolutionary biology of human inactivity. *Proc Natl Acad Sci USA*. (2020) 117(13):7115–21. doi: 10.1073/pnas.1911868117

8. Lochbaum M, Jean-Noel J, Pinar C, Gilson T. A meta-analytic review of Elliot's (1999) hierarchical model of approach and avoidance motivation in the sport, physical activity, and physical education literature. *J Sport Health Sci*. (2017) 6(1):68–80. doi: 10.1016/j.jshs.2015.07.008

9. Rhodes RE, McEwan D, Rebar AL. Theories of physical activity behaviour change: a history and synthesis of approaches. *Psychol Sport Exerc*. (2019) 42:100–9. doi: 10.1016/j.psychsport.2018.11.010

10. Stults-Kolehmainen MA, Ciccolo JT, Bartholomew JB, Seifert J, Portman RS. Age and gender-related changes in exercise motivation among highly active individuals. *Athletic Insight*. (2013) 5(1):45–63.

11. Stults-Kolehmainen MA, Gilson TA, Abolt CJ. Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. *J Sport Behav*. (2013) 36(3):306–27.

12. Williams DM, Bohlen LC. Motivation for exercise: reflective desire versus hedonic dread. In: MH Anshel, SJ Petruzzello, EE Labbé, editors. *APA Handbook of sport and exercise psychology, volume 2: Exercise psychology. APA handbooks in psychology series*. Washington, DC, United States: American Psychological Association (2019). 363–85.

13. Rhodes RE, Dickau L. Experimental evidence for the intention–behavior relationship in the physical activity domain: a meta-analysis. *Health Psychol*. (2012) 31(6):724–7. doi: 10.1037/a0027290

14. Brand R, Ekkekakis P. Affective–reflective theory of physical inactivity and exercise. *German J Exerc Sport Res*. (2018) 48(1):48–58. doi: 10.1007/s12662-017-0477-9

15. Conroy DE, Berry TR. Automatic affective evaluations of physical activity. *Exerc Sport Sci Rev*. (2017) 45(4):230–7. doi: 10.1249/jes.0000000000000120

16. Williams DM, Rhodes RE, Conner MT. Conceptualizing and intervening on affective determinants of health behaviour. *Psychol Health*. (2019) 34(11):1267–81. doi: 10.1080/08870446.2019.1675659

17. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Gilson TA, Ash GI, McKee PC, et al. Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front Psychol*. (2020) 11(3076):1–7. doi: 10.3389/fpsyg.2020.568390

18. Davis WA. The two senses of desire. *Philos Stud*. (1984) 45(2):181–95. doi: 10.1007/BF00372477

19. Kavanagh DJ, Andrade J, May J. Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol Rev*. (2005) 112(2):446–67. doi: 10.1037/0033-295x.112.2.446

20. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Boullosa D, Janata P, Koo BB, et al. Urges to move and other motivation states for physical activity in clinical and healthy populations: a scoping review protocol. *Front Psychol*. (2022) 13:1–7. doi: 10.3389/fpsyg.2022.901272

21. Stults-Kolehmainen MA. Humans have a basic physical and psychological need to move the body: physical activity as a primary drive. *SportRxiv*. (2022):1–25. doi: 10.51224/SRXIV.236

22. Feige K. Wesen und Problematik der Sportmotivation. *Sportunterricht*. (1976) 5:4–7.

23. Schiller D, Yu ANC, Alia-Klein N, Becker S, Cromwell HC, Dolcos F, et al. The human affectome. *HAL*. (2022):1–47. doi: 10.31234/osf.io/9nu32

24. Stults-Kolehmainen MA, Blacutt M, Fogelman N, Gilson TA, Stanforth PR, Divin AL, et al. Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front Psychol*. (2021) 12:1–23. doi: 10.3389/fpsyg.2021.568286

25. Stults-Kolehmainen MA. SciPod. London: SciPod. (2022) [cited August 28, 2022]. Podcast. Available from: https://www.scipod.global/dr-matthew-stults-kolehmainen-measuring-our-motivation-for-physical-activity-and-sedentary-behaviour/.

26. Budnick CJ, Stults-Kolehmainen MA, Dadina C, Bartholomew JB, Boullosa D, Ash GI, et al. Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal. *SportRxiv*. (2022):1–20. doi: 10.51224/SRXIV.217

27. Filgueiras A, Stults-Kolehmainen MA, Boullosa D, Sinha R, Bartholomew JB, McKee P, et al. The CRAVE and ARGE Scales for motivation states for physical activity and sedentarism: Brazilian Portuguese translation and single-item versions. *SportRxiv*. (2022):1–36. doi: 10.51224/SRXIV.224

28. Glaviano NR, Baellow A, Saliba S. Elevated fear avoidance affects lower extremity strength and squatting kinematics in women with patellofemoral pain. *Athl Train & Sports Health Care*. (2019) 11(4):192–200. doi: 10.3928/19425864-20181029-01

29. Brehm JW, Self EA. The intensity of motivation. *Annu Rev Psychol*. (1989) 40 (1):109–31. doi: 10.1146/annurev.ps.40.020189.000545

30. Frijda NH. Emotion, cognitive structure, and action tendency. *Cogn Emotion*. (1987) 1(2):115–43. doi: 10.1080/02699938708408043

31. Frijda NH, Kuipers P, ter Schure E. Relations among emotion, appraisal, and emotional action readiness. *J Pers Soc Psychol*. (1989) 57(2):212–28. doi: 10.1037//0022-3514.57.2.212

32. Frijda NH, Ridderinkhof KR, Rietveld E. Impulsive action: emotional impulses and their control. *Front Psychol*. (2014) 5:1–9. doi: 10.3389/fpsyg.2014.00518

33. Inzlicht M, Schmeichel BJ, Macrae CN. Why self-control seems (but may not be) limited. *Trends Cogn Sci (Regul Ed)*. (2014) 18(3):127–33. doi: https://doi.org/10.1016/j.tics.2013.12.009

34. Williams DM, Evans DR. Current emotion research in health behavior science. *Emot Rev*. (2014) 6(3):277–87. doi: 10.1177/1754073914523052

35. Lieberman D. *Exercised: why something we never evolved to do is healthy and rewarding*. New York: Knopf Doubleday Publishing Group (2020).

36. Cheval B, Boisgontier M. The theory of effort minimization in physical activity (TEMPA). *Exerc Sport Sci Rev*. (2021) 49(3):168–78. doi: 10.1249/JES.0000000000000252

37. Speakman JR. An evolutionary perspective on sedentary behavior. *BioEssays*. (2020) 42(1):1900156. doi: 10.1002/bies.201900156

38. Puhl R, Brownell KD. Bias, discrimination, and obesity. *Obes Res*. (2001) 9 (12):788–805:1–5. doi: 10.1038/oby.2001.108

39. Braun V, Clarke V, Weate P. Using thematic analysis in sport and exercise research. In: B Smith, AC Sparkes, editors. *Routledge handbook of qualitative research in sport and exercise*. London: Routledge; 2016. p. 191–205.

40. Bonell C, Warren E, Melendez-Torres G. Methodological reflections on using qualitative research to explore the causal mechanisms of complex health interventions. *Evaluation*. (2022) 28(2):166–81. doi: 10.1177/13563890221086309

41. R Core Team. R. A Language and environment for statistical computing. Version 4.0 ed. Computer software (2021).

42. Hsieh H-F, Shannon SE. Three approaches to qualitative content analysis. *Qual Health Res*. (2005) 15(9):1277–88. doi: 10.1177/1049732305276687

43. Gilson TA, Latimer M, Lochbaum M. Post-LDAC reflections of ROTC cadets: relationship to leadership and performance. *J Appl Sport Psychol*. (2015) 27 (2):235–48. doi: 10.1080/10413200.2014.982306

44. Ryan RM, Deci EL. Active human nature: self-determination theory and the promotion and maintenance of sport, exercise and health. In: MS Haggar, NLD Chatzisarantis, editors. *Intrinsic motivation and self-determination in exercise and sport.*. Champaign, IL: Human Kinetics (2007). p. 1–20.

45. Robinson TE, Berridge KC. The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Res Rev*. (1993) 18(3):247–91. doi: 10.1016/0165-0173(93)90013-p

46. Berridge KC, Robinson TE. What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Res Rev*. (1998) 28(3):309–69. doi: 10.1016/s0165-0173(98)00019-8

47. Koechlin E. Prefrontal executive function and adaptive behavior in complex environments. *Curr Opin Neurobiol*. (2016) 37:1–6. doi: 10.1016/j.conb.2015.11.004

48. Antle MC, Silver R. Circadian insights into motivated behavior. In: E Simpson, P Balsam, editors. *Behavioral Neuroscience of Motivation. Current Topics in Behavioral Neurosciences*, Springer, Cham. 2015, 117. doi: 10.1007/7854_2015_384

49. Hassandra M, Goudas M, Chroni S. Examining factors associated with intrinsic motivation in physical education: a qualitative approach. *Psychol Sport Exerc*. (2003) 4 (3):211–23. doi: https://doi.org/10.1016/S1469-0292(02)00006-7

50. Deci EL, Ryan RM. The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychol Inq*. (2000) 11(4):227–68. doi: 10.1207/s15327965pli1104_01

51. Maltagliati S, Sarrazin P, Isoard-Gautheur G, Pelletier L, Rocchi M, Cheval B. Action planning makes physical activity more automatic. Only If it is autonomously regulated: a moderated mediation analysis. *SportRxiv*. (2022) 1–33. doi: https://doi.org/10.51224/SRXIV.152

52. Stults-Kolehmainen MA, Sinha R. The effects of stress on physical activity and exercise. *Sports Med*. (2014) 44(1):81–121. doi: 10.1007/s40279-013-0090-5

53. Stults-Kolehmainen MA, Lu T, Ciccolo JT, Bartholomew JB, Brotnow L, Sinha R. Higher chronic psychological stress is associated with blunted affective responses to strenuous resistance exercise: RPE, pleasure, pain. *Psychol Sport Exerc*. (2016) 22:27–36. doi: 10.1016/j.psychsport.2015.05.004

54. Libet B, Gleason C, Wright E, Pearl D. Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). *Brain*. (1983) 106 (3):623–42. doi: 10.1093/brain/106.3.623

55. Scheer FAJL, Hu K, Evoniuk H, Kelly EE, Malhotra A, Hilton MF, et al. Impact of the human circadian system, exercise, and their interaction on cardiovascular function. *Proc Natl Acad Sci USA*. (2010) 107(47):20541–6. doi: 10.1073/pnas.1006749107

56. España RA, Plahn S, Berridge CW. Circadian-dependent and circadian-independent behavioral actions of hypocretin/orexin. *Brain Res*. (2002) 943 (2):224–36. doi: 10.1016/S0006-8993(02)02653-7

57. Wen X, An Y, Li W, Du J, Xu W. How could physical activities and sleep influence affect inertia and affect variability? Evidence based on ecological momentary assessment. *Curr Psychol*. (2022) 41(5):3055–61. doi: 10.1007/s12144-020-00803-3

58. Koval P, Kuppens P, Allen NB, Sheeber L. Getting stuck in depression: the roles of rumination and emotional inertia. *Cogn Emotion*. (2012) 26(8):1412–27. doi: 10.1080/02699931.2012.667392

59. Rhodes RE, Rebar AL. Physical activity habit: complexities and controversies. In: B Verplanken, editor. *The psychology of habit: theory, mechanisms, change, and contexts*. Cham: Springer International Publishing (2018). p. 91–109.

60. Rebar AL, Gardner B, Rhodes RE, Verplanken B. The measurement of habit. In: B Verplanken, editor. *The psychology of habit: Theory, mechanisms, change, and contexts*. Cham: Springer International Publishing (2018). p. 31–49.

61. Resnicow K, Page SE. Embracing chaos and complexity: a quantum change for public health. *Am J Public Health*. (2008) 98(8):1382–9. doi: 10.2105/AJPH.2007.129460

62. Bargh JA, Chen M, Burrows L. Automaticity of social behavior: direct effects of trait construct and stereotype activation on action. *J Pers Soc Psychol*. (1996) 71 (2):230–44. doi: 10.1037/0022-3514.71.2.230

63. Hofmann W, Kotabe H.P, Vohs K.D., Baumeister R.F. Desire and desire regulation. In: W Hofmann, LF Nordgren, editors. *The psychology of desire*. New York: Guilford Publications (2015). p. 61–81.

64. deRidder DT, de Witt HJC, Evers C. License to sin: reasoning processes in desire. In: W Hofmann, LF Nordgren, editors. *The psychology of desire*. NY, NY: Guilford Publications (2015), p. 199–224.

65. Bitterly TB, Mislavsky R, Dai H, Milkman KL. Want-should conflict: a synthesis of past research. In: W Hofmann, LF Nordgren, editors. *The psychology of desire*. New York: Guilford (2015). p. 244–64.

66. Saunders B, Milyavskaya M, Inzlicht M. Longitudinal evidence that event related potential measures of self-regulation do not predict everyday goal pursuit. *Nat Commun*. (2022) 13(1):1–14. doi: 10.1038/s41467-022-30786-7

67. Hofmann W, Baumeister RF, Forster G, Vohs KD. Everyday temptations: an experience sampling study of desire, conflict, and self-control. *J Pers Soc Psychol*. (2012) 102(6):1318–35. doi: 10.1037/a0026545

68. Hofmann W, Van Dillen L. Desire: the new hot spot in self-control research. *Curr Dir Psychol Sci*. (2012) 21(5):317–22. doi: 10.1177/0963721412453587

69. González-Cutre D, Sicilia Á, Moreno JA, Fernández-Balboa JM. Dispositional flow in physical education: relationships with motivational climate, social goals, and perceived competence. *J Teach Phys Educ*. (2009) 28(4):422–40. doi: 10.1123/jtpe.28.4.422

70. Baumeister RF, Heatherton T, Tice DM. *Losing control: How and why people fail at self-regulation*. San Diego, CA: Academic Press (1994).

71. Kwasnicka D, Dombrowski SU, White M, Sniehotta F. Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health Psychol Rev*. (2016) 10(3):277–96. doi: 10.1080/17437199.2016.1151372

72. Ruissen GR, Beauchamp MR, Puterman E, Zumbo BD, Rhodes RE, Hives BA, et al. Continuous-Time modeling of the bidirectional relationship between incidental affect and physical activity. *Ann Behav Med*. (2022) 56(12):1284–99. doi: 10.1093/abm/kaac024

73. Lutz RS, Lochbaum MR, Lanning B, Stinson LG, Brewer R. Cross-lagged relationships among leisure-time exercise and perceived stress in blue-collar workers. *J Sport Exerc Psychol*. (2007) 29(6):687–705. doi: 10.1123/jsep.29.6.687

74. Stults-Kolehmainen M, Filgueiras A, Blacutt M. Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. *medRxiv*. (2021):1–19. doi: 10.1101/2020.05.12.20099374

75. Gilson TA, Heller EA, Stults-Kolehmainen MA. The relationship between an effort goal and self-regulatory efficacy beliefs for division I football players. *J Strength Cond Res*. (2013) 27(10):2806–15. doi: 10.1519/JSC.0b013e31828151ca

76. Fredrickson BL. What good are positive emotions? *Rev Gen Psychol*. (1998) 2 (3):300–19. doi: 10.1037/1089-2680.2.3.300

77. Cheniaux E, Filgueiras A, Silva Rde A, Silveira LA, Nunes AL, Landeira-Fernandez J. Increased energy/activity, not mood changes, is the core feature of mania. *J Affect Disord*. (2014) 152–154:256–61. doi: 10.1016/j.jad.2013.09.021

78. Lu W, Bates FM, Waynor WR, Bazan C, Gao CE, Yanos PT. I feel frozen: client perceptions of how posttraumatic stress disorder impacts employment. *Psychiatr Rehabil J*. (2022) 45(2):136–43. doi: 10.1037/prj0000477

79. Hamm AO, Richter J, Pané-Farré C, Westphal D, Wittchen H-U, Vossbeck-Elsebusch AN, et al. Panic disorder with agoraphobia from a behavioral neuroscience perspective: applying the research principles formulated by the research domain criteria (RDoC) initiative. *Psychophysiology*. (2016) 53(3):312–22. doi: 10.1111/psyp.12553

80. National Institute of Mental Health. Sensorimotor Dynamics (RDoc Constructs): National Institutes of Health (2022). Available from: https://www.nimh.nih.gov/research/research-funded-by-nimh/rdoc/constructs/sensorimotor-dynamics

81. Booth FW, Laye MJ, Roberts MD. Lifetime sedentary living accelerates some aspects of secondary aging. *J Appl Physiol*. (2011) 111(5):1497–504. doi: 10.1152/japplphysiol.00420.2011

82. Kilpatrick M, Hebert E, Bartholomew J. College Students' motivation for physical activity: differentiating men's and women's motives for sport participation and exercise. *J Am Coll Health*. (2005) 54:87–94. doi: 10.3200/JACH.54.2.87-94

83. Peterson L, Renstrom PAFH. *Sports injuries: prevention, treatment and rehabilitation*. 4th ed. London: Routledge (2016).

84. Chakravarthy MV, Booth FW. Eating, exercise, and "thrifty" genotypes: connecting the dots toward an evolutionary understanding of modern chronic diseases. *J Appl Physiol (1985)*. (2004) 96(1):3–10. doi: 10.1152/japplphysiol.00757.2003

85. Naves-Bittencourt W, Mendonça-de-Sousa A, Stults-Kolehmainen M, Fontes E, Córdova C, Demarzo M, et al. Martial arts: mindful exercise to combat stress. *Eur J Hum Move*. (2015) 34:34–51.

86. Stults-Kolehmainen M, Malcolm LR, DiLoreto J, Gunnet-Shoval K, Rathbun EI. Psychological interventions for weight management: a primer for the allied health professional. *ACSMS Health Fit J*. (2015) 19(5):16–22. doi: 10.1249/FIT.0000000000000150

87. Hardeman W, Houghton J, Lane K, Jones A, Naughton F. A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity. *Int J Behav Nutr Phys Act*. (2019) 16(1):31. doi: 10.1186/s12966-019-0792-7

88. King AC, Hekler EB, Grieco LA, Winter SJ, Sheats JL, Buman MP, et al. Effects of three motivationally targeted Mobile device applications on initial physical activity and sedentary behavior change in midlife and older adults: a randomized trial. *PLoS One*. (2016) 11(6):e0156370. doi: 10.1371/journal.pone.0156370

89. Evans AH, Katzenschlager R, Paviour D, O'Sullivan JD, Appel S, Lawrence AD, et al. Punding in Parkinson's disease: its relation to the dopamine dysregulation syndrome. *Mov Disord*. (2004) 19(4):397–405. doi: 10.1002/mds.20045

90. Marcora SM, Staiano W. The limit to exercise tolerance in humans: mind over muscle? *Eur J Appl Physiol*. (2010) 109(4):763–70. doi: 10.1007/s00421-010-1418-6

91. Boullosa DA, Nakamura FY. The evolutionary significance of fatigue. *Front Physiol*. (2013) 4(309):1–2. doi: 10.3389/fphys.2013.00309

92. Barker JL, Kolar D, Lazzer AS-D, Keel PK. Exercise satiation: a novel theoretical conceptualization for problematic exercise observed in eating disorders. *Int J Eating Disord*. (2022) 55(2):176–9. doi: 10.1002/eat.23635

93. Ponnada A, Wang S, Chu D, Do B, Dunton G, Intille S. Intensive longitudinal data collection using microinteraction ecological momentary assessment: pilot and preliminary results. *JMIR Form Res*. (2022) 6(2):e32772. doi: 10.2196/32772

frontiers | Frontiers in Psychology

TYPE Hypothesis and Theory
PUBLISHED 31 March 2023
DOI 10.3389/fpsyg.2023.1130654

OPEN ACCESS

EDITED BY
Garrett Ash,
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SPECIALTY SECTION
This article was submitted to
Movement Science and Sport Psychology,
a section of the journal
Frontiers in Psychology

RECEIVED 23 December 2022
ACCEPTED 13 March 2023
PUBLISHED 31 March 2023

CITATION
Zhao YS, Ma QS, Li XY, Guo KL and
Chao L (2023) The relationship between
exercise motivation and exercise behavior in
college students: The chain-mediated role of
exercise climate and exercise self-efficacy.
Front. Psychol. 14:1130654.
doi: 10.3389/fpsyg.2023.1130654

The relationship between exercise motivation and exercise behavior in college students: The chain-mediated role of exercise climate and exercise self-efficacy

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Objective: This study explored the relationship between college students' physical activity motivation and exercise behavior and constructed a chain mediation model through the mediating roles of exercise climate and exercise self-efficacy.

Methods: By random sampling, 1,032 college students were investigated using the *Exercise Motivation Scale, Physical Exercise Rating Scale, Exercise Climate Scale, and Exercise Self-Efficacy Scale.*

Results: (1) There was a huge positive correlation between exercise motivation and exercise behavior (r=0.240, p<0.01), and the immediate ways of linking exercise motivation to exercise behavior were critical (β=0.068, t=0.040, p<0.01). (2) Exercise motivation could positively predict exercise climate (β=0.373, t=0.061, p<0.01) and exercise self-efficacy (β=0.174, t=0.039, p<0.01), and exercise climate could emphatically foresee exercise behavior (β=0.302, t=0.051, p<0.01). Exercise self-efficacy could foresee exercise behavior decidedly (β=0.190, t=0.048, p<0.01). (3) Exercise climate and exercise self-efficacy play a critical intervening role between exercise motivation and exercise behavior. The intercession impact is explicitly made out of aberrant impacts created in three ways: exercise motivation → exercise climate → exercise behavior (mediating effect value: 0.113); exercise motivation → exercise self-efficacy → exercise behavior (mediating effect value: 0.033); exercise motivation → exercise climate → exercise self-efficacy → exercise behavior (mediating effect value: 0.027).

Conclusion: (1) Exercise climate, exercise self-efficacy, and exercise behavior can all be significantly predicted by exercise motivation, suggesting that exercise motivation may help to enhance these variables. (2) In addition to having a direct impact on exercise behavior, exercise motivation can also have an indirect impact through the separate mediating effects of exercise climate and exercise self-efficacy as well as the chain mediating effect of exercise climate and exercise self-efficacy, which is crucial for encouraging college students to engage in physical activity.

KEYWORDS

exercise motivation, exercise behavior, exercise atmosphere, exercise self-efficacy, college students

Introduction

A national strategy to advance the creation of a healthy China and enhance population health is outlined in the Healthy China 2030 Plan. It is a major measure to protect people's health. College students will be the main force in building China in the coming decades, and their health will be widely concerned by the outside world. The eighth national survey on students' physical health was conducted, and the results were published by the Ministry of Education in September 2021: from 2014 to 2019, the physical health of all college, middle school, and primary school students has significantly improved. Among them, the excellent and very good rate of junior high school students increased significantly by 5.1%, that of high school students by 1.8%, and that of college students by only 0.2 percentage points, indicating virtually no growth (Department of Physical Health and Arts Education Ministry of Education, 2021). A large number of studies have found that it has become an indisputable fact that the physical fitness of contemporary college students has been declining year by year. The most direct reason for the physical fitness decline of college students is the general lack of physical exercise (Yu et al., 2021). Exercise behavior refers to physical activities with a certain intensity, frequency, and duration that are carried out in leisure time with the main purpose of promoting individual health (Yan et al., 2020). Studies have found that moderate physical exercise plays a positive role in promoting human health development, such as reducing the risk of chronic diseases and improving individual mood (Jiang et al., 2017; Meng and Shen, 2018). However, college students participate in physical exercise activities with stages and instability; exercise behavior will increase when there is a physical fitness test task and stop when there is no physical fitness test task. During the period of heavy learning tasks and final exams, exercise will be stopped. After this period, exercise behavior will increase again (Tian et al., 2018). A study of university postgraduates found that their health condition was worse than that of undergraduates. The reason was that postgraduates did not participate in physical exercise seriously enough, with fewer times, shorter times, and less intensity (Liu, 2020b). The physical health of college students has continued to deteriorate.

Exercise motivation and exercise behavior

The term "motivation" refers to the psychological or emotional force that propels a person to engage in certain behaviors, while exercise motivation is the internal driving force and psychological motivation that drives an individual to engage in physical exercise, which determines the purpose, intensity, frequency, and effect of an individual's participation in physical exercise and is the direct cause of exercise behavior (Xu, 2020). Self-Determination Theory (SDT) holds that individual behavior can be divided into self-determined behavior and non-self-determined behavior, and the two behaviors are driven by three modes of motivation. Self-determined behaviors are driven by internal motivations, while non-self-determined behaviors are driven by external and unmotivated motivations (Jacobs, 2000). This theory holds that when individual exercise behavior is driven by internal motivation, it is conducive to the formation of good exercise habits. Liu (2010) found that college students' exercise motivation was related to exercise time, exercise intensity, and exercise behavior to some extent. In this manner, there was a huge relationship between exercise motivation and exercise behavior. Wei et al. (2020) discovered in a review of the elderly that the fulfillment of basic mental necessities could well predict the exercise behavior of the elderly *via* the intermediary factor of self-assurance and inspiration. Besides, investigations have discovered that exercise motivation straightforwardly advances and decidedly predicts exercise behavior (Yang et al., 2015). In light of this, hypothesis 1 is advanced: exercise motivation can definitely predict exercise behavior.

The mediating role of exercise climate

According to SDT and the hierarchy of motivation theory, the process of internalizing individual motivation is influenced by external environmental factors, so climate may play an important role in exercise motivation and exercise behavior. The achievement goal theory suggests that an individual's motivation is derived from goal orientation or task orientation, so scholar Ames has introduced the concept of "motivational climate" as an antecedent variable for internalizing motivation based on the achievement goal theory. There is also a common climate called "exercise climate," and the concept of exercise climate refers to the exercise environment created by the surrounding people and the exercise information available to the exercise participants. Both motivational and exercise climates are different kinds of climates, and exercise climates, as typical representatives of external environmental factors, have an important impact on university students' physical activity (Wang, 2017). Studies have proven that the exercise environment is one of the most important factors in encouraging college students to actively and independently engage in physical exercise activities (Hu et al., 2020). A good exercise climate is of great significance for improving college students' exercise behaviors. A natural atmosphere, such as a good field and first-class equipment during exercise, can attract college students to frequent physical exercise, stimulate their interest and enthusiasm to participate in physical exercise, and gradually guide and increase their exercise behavior (Yang, 2016). Therefore, exercise climate may play an important role in predicting college students' exercise behavior.

According to research, physical exercise motivation has an effect on the exercise environment, which may have a predictive effect (Hu and Wei, 2005). Li and Yang (2016) investigated square dancing groups and found that both motivation and exercise climate had an impact on exercise persistence. At the same time, physical exercise motivation influences the exercise environment. Therefore, exercise motivation may play an important role in predicting the exercise climate. In conclusion, exercise motivation may be closely related to exercise climate, and exercise behavior can be further predicted by exercise climate. As a result, it is suggested that exercise climate acts as a mediator between exercise motivation and exercise behavior in this study's second hypothesis.

The mediating role of exercise self-efficacy

Exercise self-efficacy may likewise assume a significant role in the connection between exercise motivation and exercise behavior. As indicated by the Environmental Model of Active Work (EMAW), mental variables are viewed as another significant component influencing exercise behavior. Exercise self-efficacy is the mental element variable most firmly connected with exercise behavior (Sallis et al., 1992). Exercise self-efficacy alludes to the mental capacity of a person to accept that they can finish the laid-out objectives and errands of physical exercise. It is an important concept in the cognitive theory of exercise and can directly affect the level of exercise behavior. Exercise self-efficacy can regulate personal emotions in physical exercise so that individuals can reasonably control negative emotions and deal with problems with a positive attitude when faced with difficulties in exercise (Dong et al., 2018). Investigations have discovered that the more grounded the exercise self-efficacy of people, the more effectively they are taking part in practice ways of behaving, and the recurrence, force, and season of activity will expand (Guo et al., 2010). Likewise, a review demonstrates the way that dynamic cooperation in actual activity can precisely predict the self-efficacy of center school understudies and cause them to keep a hopeful and bright mind-set, producing drive in exercise behavior (Yuan and Zhang, 2015). Subsequently, exercise self-efficacy might assume a significant role in predicting the exercise behavior of undergraduates.

The exploration observed that there is a critical positive connection between exercise motivation and self-efficacy, and exercise motivation can definitely influence the certainty of undergrads who take part in working out (Cheng and Xu, 2016). Dong et al. (2020) found that exercise self-efficacy meaningfully affected teenagers' cooperation in exercising. Generally speaking, individuals with high exercise motivation will have a better sense of exercise self-efficacy and thus form more active exercise behaviors. The reason is that people with strong exercise motivation often dare to face difficulties and setbacks in physical exercise and show a strong sense of self-efficacy. Those who are less motivated to exercise will avoid challenges. Therefore, exercise motivation may be an important predictor of exercise self-efficacy. In conclusion, exercise motivation may be closely related to exercise self-efficacy, and exercise self-efficacy can further predict exercise behavior. Based on this, hypothesis 3 of this study is proposed: exercise self-efficacy plays a mediating role between exercise motivation and exercise behavior.

The chain mediated role of exercise climate and exercise self-efficacy

The behavioral ecological model of exercise puts forward the theory that environmental factors, physiological factors, and psychological factors will interact with each other and jointly affect individual exercise behavior (Yang et al., 2014). As an external factor of the environment, the exercise climate provides a decision-making basis and driving effect for individuals to decide whether to do physical exercise. Exercise self-efficacy, as an internal factor of psychological factors, provides support for whether individuals choose physical exercise or whether they can persist when encountering difficulties in physical exercise. Dong et al. (2022) found that the interpersonal circle of individuals who share the same interest in exercise will gradually form a good exercise climate, making individuals feel the pleasure brought by exercise and thus improving the self-efficacy of exercise. Different examinations have found that the exercise climate meaningfully affects understudies' exercise self-efficacy, and the relational association, normal association, and data obtained in the exercise climate all assume a significant part in understudies' exercise self-efficacy. Undergrads practice in a decent exercise climate; they practice together, empower, progress, and become together; continuously, actual activity will create serious areas of strength for a person to work out, extraordinarily preparing the excitement of understudies to partake in actual activity. Exercise will likewise build your identity's viability. Hence, hypothesis 4 of this study is proposed: exercise climate and exercise self-efficacy play an intervening role between exercise motivation and exercise behavior.

To summarize, to examine the interior component between exercise motivation and exercise behavior, this study means to fabricate a chain intervention model (as displayed in Figure 1) and check the accompanying perspectives: (1) exercise motivation fundamentally and emphatically predicts exercise behavior of understudies; (2) exercise climate plays a free interceding job between exercise motivation and exercise behavior of understudies; (3) exercise self-efficacy plays an autonomous intervening job between exercise motivation and exercise behavior of understudies; and (4) exercise climate and exercise self-efficacy play a chain interceding job between exercise motivation and exercise behavior of understudies.

Materials and methods

Procedure and participants

A random sampling method was adopted to conduct a questionnaire survey among students from six colleges and universities in Anhui Province. Due to the impact of the epidemic, this survey used the platform of the Juanxing Network to issue electronic questionnaires. The purpose of the research is explained to the respondents in the questionnaire guidance, and they promise to keep the content they fill in strictly confidential. The questionnaire includes five parts: basic information filling, an exercise motivation scale, an exercise grade scale, an exercise climate scale, and an exercise self-efficacy scale. A total of 1,088 questionnaires were collected; 56 were excluded from regular answers and invalid questionnaires, and 1,032 were valid, with a recovery rate of 94.85%. Among them, 530 were boys and 502 were girls.

Measures and instruments

Exercise motivation

College students' exercise motivation was measured using the *Exercise Motivation Scale* (MAM-R) simplified version, which Chen et al. (2013) amended. Research has shown that the scale is appropriate for assessing Chinese college students' exercise motivation (Li and Li, 2020). The scale has 15 elements altogether and is broken down into five categories: fun motivation, ability motivation, appearance motivation, health motivation, and social motivation (e.g., "I want to have a strong body"). The Likert scale employs five points, from "strongly disagree" to "strongly agree," for each response. The individuals were more inclined to exercise if their ratings were higher. The three exercise motivation scale items in this study converge on one factor with a KMO value of 0.93 and a Chi-square worth of 5654.78 ($p < 0.01$), representing 64.39% of the all-out difference (Table 1). The fitting file of the corroborative element examination was $\chi^2/df = 4.082$, $CFI = 0.965$, $NFI = 0.954$, $GFI = 0.939$, $TLI = 0.942$, *and*

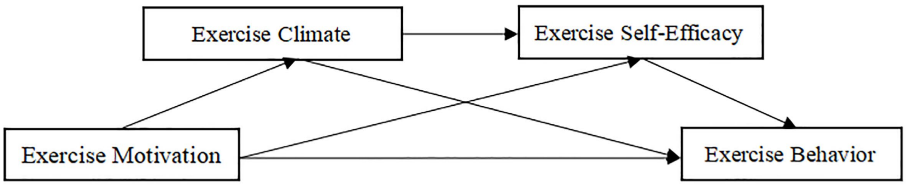

FIGURE 1
Hypothetical model.

TABLE 1 Exploratory factor analysis and internal consistency test results.

Factor naming	KMO	Bartlett chi square value (p-value)	Cumulative variance interpretation rate	Cronbach' coefficient
EM	0.93	5654.78 ($p<0.01$)	64.39%	0.95
EC	0.86	6105.34 ($p<0.01$)	77.21%	0.76
ESE	0.93	4051.30 ($p<0.01$)	58.79%	0.94
EB	0.68	411.17 ($p<0.01$)	68.44%	0.77

EM, exercise motivation; EC, exercise climate; ESE, exercise self-efficacy; EB, exercise behavior.

TABLE 2 Confirmatory factor analysis results.

Factor naming	χ^2/df	CFI	NFI	GFI	TLI	RMESA
EM	4.082	0.965	0.954	0.939	0.942	0.077
EC	4.167	0.965	0.955	0.940	0.929	0.078
ESE	3.748	0.972	0.962	0.954	0.955	0.073
EB	3.792	0.932	0.911	0.917	0.925	0.093

EM, exercise motivation; EC, exercise climate; ESE, exercise self-efficacy; EB, exercise behavior.

RMESA = 0.077, and the decency of fit was fundamentally better, demonstrating that the scale had great primary legitimacy (Table 2). In this review, *Cronbach's α* was 0.95, showing great interior consistency of the scale.

Exercise climate

The Exercise Climate Scale was adapted from the Liu et al. (2011) outdoor exercise climate scale for teenagers, which has five components and 17 items in total. The scale uses Likert 5 points, from "not at all" to "extremely strong," on a scale from 0 to 1. The workout atmosphere is felt more strongly the higher the score. Physical activity is substituted for key terms like "sports" and "outdoor sports" (e.g., "During the process of taking part in physical exercise, my friendship with my partners has been deepened"). Research has shown that this scale is appropriate for assessing how Chinese college students perceive the exercise climate (Dong et al., 2022). The 17 components on the exercise climate scale in this study well converged to one factor, whose KMO esteem was 0.86, and the Chi-square worth of the Bartlett round test was 6105.34 ($p<0.01$), representing 77.21% of the absolute difference (Table 1). The fitting file of the corroborative component examination was $\chi^2/df=4.167$, $CFI=0.965$, $NFI=0.955$, $GFI=0.940$, $TLI=0.929$, *and* $RMESA=0.078$, and the decency of fit was fundamentally better, showing that the scale had great underlying legitimacy (Table 2). In this review, *Cronbach's α* was 0.76, showing great inside consistency of the scale.

Exercise self-efficacy

The Exercise Self-Efficacy Scale developed by Wu et al. (2002) is designed to assess people's propensity for attitude following exercise-contradicting circumstances. There are 12 items on the scale (e.g., "I will keep exercising even if I feel tired") to "I'm sure I can do it" from "I cannot do it." The level of exercising self-efficacy increases with score. A prior study demonstrated that Chinese college students can effectively use this measure (Dong et al., 2022). The 12 items on the exercise self-efficacy measure in this study converge nicely to one factor, accounting for 58.79% of the total variance with a KMO value of 0.93 and a Chi-square value of 4051.30 ($p<0.01$) representing 58.79% of the complete difference (Table 1). The fitting list of the corroborative component examination was $\chi^2/df=3.748$, $CFI=0.972$, $NFI=0.962$, $GFI=0.954$, $TLI=0.955$, *and* $RMESA=0.073$. The decency of fit was altogether better, showing that the scale had great underlying legitimacy (Table 2). In this review, *Cronbach's α* was 0.94, demonstrating the great internal consistency of the scale.

Exercise behavior

To assess the quantity of physical activity from three perspectives—intensity, time, and frequency—the *Physical Activity Rating Scale* (PARS-3) developed by Liang (1994) was used. Physical activity scores range from 0 to 100, with 100 being the highest possible score. The more points you receive, the more exercise you receive. For low exercise, the total score is 19 or less; for moderate exercise, it ranges from 20 to 42; and for vigorous exercise, it ranges from 43. This study divided the quantity of light

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physical activity into two categories: no physical activity and light exercise. No physical activity is equal to or less than 4 points, and a small workout ranges from 5 to 19. As a result, there were four categories of physical activity in this study, ranging from "no physical activity" to "a great deal of physical activity." A prior study demonstrated that Chinese college students can effectively use this measure (Liu, 2020a). With a KMO value of 0.68 and a Chi-square value of 411.17 ($p < 0.01$), the three physical activity rating scale items in this study converge nicely to one factor, accounting for 68.44% of the total variance (Table 1). The scale exhibited strong structural validity, as evidenced by the confirmatory factor analysis's fitting index, which was $\chi^2/df = 3.792$, $CFI = 0.932$, $NFI = 0.911$, $GFI = 0.917$, $TLI = 0.925$, *and* $RMESA = 0.093$ (Table 2). *Cronbach's* α in this study was 0.77, indicating that the scale had acceptable internal consistency.

Processing of data

In this review, IBM SPSS 26.0 and AMOS 21.0 factual programming were utilized for all information examination. After the poll was gathered, all information was handled as follows: (1) Exploratory variable investigation was led for all scales utilizing SPSS 26.0; (2) Corroborative component examination was performed for all scales utilizing AMOS 21.0; (3) SPSS 26.0 was utilized to test the inner consistency of all scales; (4) "Harman single element strategy" was utilized for the normal technique deviation test; and (5) Pearson connection investigation with SPSS 26.0 was utilized to compute the connection between exercise motivation, exercise climate, exercise self-efficacy, and exercise behavior. The mean (M) and standard deviation (SD) of persistent factors with a typical dissemination were utilized. (6) The SPSS full-scale program ordered by Hayes in SPSS 26.0 was utilized to confirm the intervening job of exercise climate and exercise self-efficacy in the connection between exercise motivation and exercise behavior and the chain intervening job of exercise climate and exercise self-efficacy in the connection between exercise motivation and exercise behavior; (7) Model 6 in the SPSS full-scale program aggregated by Hayes was utilized for the chain intervention test. In this review, the significance level was set at $p < 0.05$.

Results

Common method bias test

The term "normal technique bias" refers to the erroneous covariation among indicator and rule factors caused by a similar information source or rater, a similar estimation climate, the venture setting, and the characteristics of the actual project. This fake correlation, which truly confounds the consequences of the review and possibly deceives the determinations, is a deliberate blunder. Since the information in this study was all gathered from surveys completed by subjects with emotional goals, there were a few strategic blunders. To stay away from such predispositions, the Harman single component examination was utilized to confirm whether the survey had explicit, normal systemic inclinations. An exploratory element investigation was performed on each of the 47 estimated scale questions. The outcomes showed that among the 8 elements with an eigenvalue more prominent than 1, the difference in translation pace of the primary variable was 29.68%, which was lower than the basic record of 40%. Subsequently, there was no normal technique predisposition in this study's information.

TABLE 3 Means, standard deviations, and correlations among variables.

Variable	*M*	*SD*	1	2	3	4
1. EM	4.53	0.55	1			
2. EC	3.72	0.52	0.373**	1		
3. ESE	2.11	0.54	0.316**	0.444**	1	
4. EB	33.18	27.55	0.240**	0.412**	0.336**	1

N = 1,032. EM, exercise motivation; EC, exercise climate; ESE, exercise self-efficacy; EB, exercise behavior, ***p* < 0.01.

Descriptive statistics and correlation analysis of variables

Table 3 presents the mean value, standard deviation, and correlation coefficient of variables in detail. It can be seen from the data in Table 3 that exercise motivation ($r = 0.240$, $p < 0.01$), exercise climate ($r = 0.412$, $p < 0.01$), and exercise self-efficacy ($r = 0.336$, $p < 0.01$) are significantly positively correlated with exercise behavior. Exercise motivation ($r = 0.316$, $p < 0.01$) and exercise climate ($r = 0.444$, $p < 0.01$) were positively correlated with exercise self-efficacy. Exercise motivation ($r = 0.373$, $p < 0.01$) was found to be positively related to exercise environment. The correlation analysis results provide preliminary support for the subsequent hypothesis testing.

The mediation effect test between exercise climate and exercise self-efficacy

As per Wen Zhonglin and Ye Baojuan's idea on the intervention impact test, the chain intercession impact model is tested (Wen and Ye, 2014), and the experimental outcomes are displayed in Table 4. As per the information in Table 4, exercise motivation can fundamentally and emphatically predict the exercise behavior of understudies, with a complete impact of 0.240 ($p < 0.01$) and an immediate impact of 0.068 ($p < 0.01$). In this manner, hypothesis 1 is substantial. At the point when exercise climate and exercise self-efficacy were remembered for the relapse condition, exercise motivation decidedly anticipated exercise climate ($\beta = 0.373$, $p < 0.01$) and exercise motivation ($\beta = 0.174$, $p < 0.01$). Exercise climate anticipated exercise self-efficacy ($\beta = 0.380$, $p < 0.01$) and exercise behavior ($\beta = 0.302$, $p < 0.01$). Exercise self-efficacy anticipated exercise behavior emphatically ($\beta = 0.190$, $p < 0.01$). Simultaneously, exercise motivation might in any case anticipate exercise behavior emphatically ($\beta = 0.068$, $p < 0.01$). It very well may be presumed that exercise climate and exercise self-efficacy play incompletely interfering roles between exercise motivation and exercise behavior, separately. Hypothesis 2 and 3 are upheld and confirmed by information.

The Bootstrap intercession test technique (Cole et al., 2008) was utilized to further test the intercession impact, and the Cycle module was utilized to fabricate an underlying condition model. Model 6 was chosen from the Cycle module to test the chain intervention impact of exercise

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TABLE 4 Analysis of regression relationship among variables.

Effect	Item	Effect	SE	*t*	*p*	LLCI	ULCI
Direct effect	EM⇒EB	0.068	0.040	1.705	<0.01	0.010	0.145
Indirect effect	EM⇒EC	0.373	0.061	6.128	<0.01	0.253	0.492
	EM⇒ESE	0.174	0.039	4.524	<0.01	0.099	0.250
	EC⇒ESE	0.380	0.037	10.352	<0.01	0.308	0.452
	EC⇒EB	0.302	0.051	5.958	<0.01	0.203	0.402
	ESE⇒EB	0.190	0.048	3.995	<0.01	0.097	0.284
Total effect	EM⇒EB	0.240	0.048	5.047	<0.01	0.147	0.334

EM, exercise motivation; EC, exercise climate; ESE, exercise self-efficacy; EB, exercise behavior.

climate and exercise self-efficacy. The experimental outcomes are displayed in Table 5. The certainty timespan trial of the intervening impact between exercise climate, exercise motivation, and exercise behavior is (0.069, 0.173), barring 0, and the interceding impact is tried. Hypothesis 2 is substantial, and its intervening impact represents 47.08% of the absolute impact. The certainty time period intervening in the impact trial of exercise self-efficacy between exercise motivation and exercise behavior is (0.017, 0.057), barring 0. The intervening impact has been tried. Hypothesis 3 is legitimate, and its intervening impact represents 13.75% of the complete impact, is not exactly the intervening impact of the exercise climate. The certainty timespan chain intervening impact way between exercise climate and exercise self-efficacy does exclude the number 0 (0.013, 0.044), and the chain intervening impact way exists, representing 11.25%. Hypothesis 4 is valid. The intervening impact of exercise climate and exercise self-efficacy on exercise motivation and exercise behavior is displayed in Figure 2.

TABLE 5 Mediating effect and effect size.

Path	Effect	Boot SE	Boot LLCI	Boot ULCI
EM⇒EC⇒EB	0.113	0.027	0.069	0.173
EM⇒ESE⇒EB	0.033	0.010	0.017	0.057
EM⇒EC⇒ESE⇒EB	0.027	0.008	0.013	0.044

EM, exercise motivation; EC, exercise climate; ESE, exercise self-efficacy; EB, exercise behavior.

Discussion

In this study, a chain mediation effect model was constructed to comprehensively explore the influence of exercise motivation, exercise climate, and exercise self-efficacy on exercise behavior and mainly explore the influence mechanisms of exercise climate and exercise self-efficacy on exercise motivation and exercise behavior, which is helpful to fully reveal the influence mechanism of exercise behavior. The results of this study have certain theoretical and practical significations for encouraging college students to develop good physical exercise habits and enhance their physical fitness.

Exercise motivation and exercise behavior

According to the findings of earlier pertinent studies, there is a considerable positive link between exercise habits and motivation for exercise (Xu, 2021) and verifies hypothesis 1. Xu (2021) believes that exercise motivation will promote exercise behavior, which further confirms that people with high exercise motivation will have more psychological needs for physical exercise and thus increase exercise behavior. The motivation for physical exercise has five dimensions, which are fun motivation, ability motivation, appearance motivation, health motivation, and social motivation. The fun motivation is to experience the pleasure brought by sports in physical exercise, which will make them physically and mentally happy. Competency motivation is the desire to learn new motor skills or improve the original motor skills through physical exercise. The appearance motivation is the need to get fit through physical exercise; the health motivation is to strengthen the body through physical exercise so that they have a healthy physique; and the social motivation is social motivation. I want to make friends and expand my circle of friends through physical exercise. According to the actual research results of various scholars, exercise motivation is often different in different genders and ages, and the motivation to participate in exercise behavior is diverse (Huang and Qiu, 2019). Studies have shown that most students take physical and mental health promotion as their main motivation (Zhang and Zhao, 2009). Girls' motivation for physical exercise is mainly physical appearance, while boys pay more attention to ability motivation and social motivation (Kilpatrick et al., 2005). According to Zhu (2019), college students' motivation and exercise activity are correlated, although there is a gender difference, with boys often showing higher levels of motivation. It was also mentioned that college students' exercise behavior increased when they had a considerable amount of motivation to exercise. Wei (2010) found in his research that freshmen have a strong motivation for physical exercise. The reason is that freshmen have just entered the school and are full of curiosity and desire for the new environment. Therefore, they set many goals and are determined to complete them, which enhances their exercise motivation. Sophomores and juniors have been living on campus for a while, and students have gradually found their interests on campus. Physical exercise may be a small part of them, so the motivation for physical exercise will decrease. Senior students gradually realize the importance of physical exercise. Therefore, the exercise motivation will improve, but due to the pressure of an internship, writing papers, and so on, the time and frequency of actual exercise will be limited. Others are motivated by the occurrence of specific events. For example, in the study of Yuan and You (2021), it was found that,

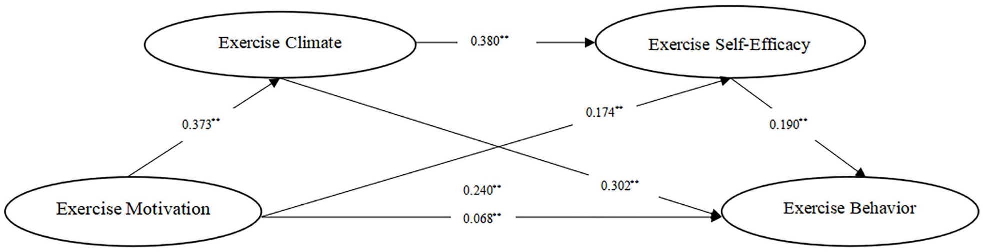

FIGURE 2
Chain mediation model. ***p*<0.01.

against the background of the COVID-19 epidemic, the motivation of college students to exercise and fight against the epidemic was also one of the reasons for them to do physical exercise. In general, exercise motivation is the primary factor that determines individual exercise behavior.

The independent mediating effect of exercise climate

In this study, it was found that exercise climate played a mediating role between exercise motivation and exercise behavior, and hypothesis 2 was verified. This is consistent with previous research evidence, namely, that exercise motivation significantly positively predicts exercise climate (Hu and Wei, 2005), and exercise climate significantly positively predicts exercise behavior (Jiang et al., 2004). In this study, the three variables were investigated at the same time, revealing that exercise motivation is an important factor to improve the exercise climate and improve exercise behavior.

The Ecological Model of Physical Activity (EMPA) suggests that the formation and change of physical activity behavior must be examined in relation to external environmental factors (John and Rebecca, 2003). Exercise climate often plays an important role as an external environmental factor that enhances individual exercise behavior. One side, exercise motivation has a positive predictive effect on the exercise climate. Exercise motivation has a unique influence on the exercise climate, and both motivation and atmosphere are factors that influence individuals' adherence to physical exercise (Liu et al., 2005). College campuses provide good sports venues and sports equipment for college students, attract more and more students to do physical exercise, and gradually form a positive exercise climate. A decent exercise climate can invigorate the excitement of undergrads to partake in actual activity and increment their time, power, and recurrence of actual activity. The expansion in actual activity is helpful for the advancement of the physical and psychological wellness of undergrads and the improvement of coordinated movements and social capacity.

Then again, the exercise climate emphatically anticipated exercise behavior. The exercise climate essentially affects whether contemporary understudies participate in actual activity; it straightforwardly decides the understudies' sports awareness and ideas and fills in as an exogenous power to urge understudies to participate in actual activity. A decent exercise climate can straightforwardly direct undergraduates to partake in sports exercises and act as an illustration in the sport activity. But the poor exercise climate will hinder the pace of physical exercise by college students, reduce their enthusiasm to participate in sports, restrain their desire to exercise, and even make them interrupt or quit physical exercise. In addition, according to the theory of "three factors of emotion" proposed by Wendell, emotion is produced by the interaction of external stimuli, physiological changes in the body, and cognitive processes. When the exercise environment around the individual is stronger, the cognition level of physical exercise rises, and the individual gradually produces an exercise mood, which encourages college students to adhere to physical exercise more closely. Therefore, on the premise of providing exercise places for students, colleges and universities should often organize sports events, create a good exercise climate, guide college students to participate in physical activity, enhance their exercise motivation, and stimulate their interest in physical exercise to increase the frequency, intensity, and time of exercise behavior.

The independent mediating effect of exercise self-efficacy

This investigation discovered that exercise self-efficacy played an intervening role between exercise motivation and exercise behavior, which affirmed theory 3. This is consistent with past examination proof, specifically that exercise motivation essentially emphatically predicts exercise self-efficacy (Dong et al., 2020) and exercise self-efficacy fundamentally decides exercise behavior (Dong et al., 2022). In this review, the three factors were researched simultaneously, uncovering that exercise motivation is a significant element to work on the feeling of exercise self-efficacy as well as a significant variable to increase exercise behavior.

According to the health behavior process model, high self-efficacy is an influential factor between exercise motivation and exercise behavior. Exercise motivation can positively predict exercise self-efficacy. College students with strong exercise motivation dare to face and overcome the difficulties and setbacks of participating in physical exercise, showing a strong sense of exercise self-efficacy. However, college students with weak exercise motivation will also have a low sense of self-efficacy in exercise. When they encounter difficulties, they will choose to avoid them rather than try to solve them, which will lead to the interruption or even termination of their exercise behavior.

Meanwhile, exercise self-efficacy can also affect exercise behavior. Exercise self-efficacy is the level of confidence that people have in their athletic ability. The easier it is to enjoy physical activity, increase the durability of exercise behavior, firmly exercise all the time, and form a lifelong habit of sports, the higher the exercise self-efficacy. Therefore, college students should gradually form the concept of regular physical exercise. Nowadays, it is very important to have a healthy body, and physical exercise is the best prescription. Physical activity can improve self-efficacy, improve mood, and have a positive impact on lifelong development.

The chain mediated effect of exercise climate and exercise self-efficacy

In view of the prior, a chain intercession model was created to research the cycle and system of exercise motivation that advances exercise behavior. Exercise climate and exercise self-efficacy play various intervening roles between exercise motivation and exercise behavior. Great exercise motivation, specifically, can further develop the activity climate around people, and exercise climate is a significant factor working on the improvement of exercise self-efficacy in people, and exercise self-efficacy will additionally influence people's exercise behavior. This affirms speculation 4 of this review. A few investigations have discovered that exercise climate and exercise self-efficacy play an intervening role between exercise motivation and exercise behavior (Dong et al., 2022). It is brought up that the exercise climate meaningfully affects undergrads' self-efficacy in working out. The stronger the exercise climate around college students is, the deeper their perception of physical exercise will be, which is conducive to forming positive emotions and promoting the improvement of college students' self-efficacy in exercise. Therefore, a good exercise climate can improve individual self-efficacy in exercise, stimulate college students' motivation to exercise, and increase exercise behavior.

Subsequently, the chain intercession of exercise climate and exercise self-efficacy in this study is doable, and it can have an impact on the interceding impact of exercise motivation on exercise behavior. In this way, involving exercise climate and exercise self-efficacy as the "third factor" to overcome any barrier between exercise motivation and exercise behavior is useful to make sense of and anticipate the perplexing component of the change from motivation to behavior and has a specific directing incentive for advancing exercise behavior in undergraduates.

Practical significance

This study looks at the impact of exercise motivation on exercise behavior, advances pertinent examination in the field of exercise motivation and exercise behavior, and has specific reasonable importance for further developing the exercise behavior of understudies. Firstly, exercise motivation is an important predictor of exercise behavior. The physical fitness of college students is declining year by year, and they lack serious physical exercise, which should be given full attention. Exercise behavior is related to exercise environment and exercise self-efficacy. Exercise motivation can not only positively predict exercise climate and exercise self-efficacy but also play an important role in predicting the exercise behavior of college students. Therefore, improving the motivation of college students' physical exercise should become an important part of a college education. According to the characteristics of the physical and mental development of students, physical education teachers should create conditions for students to do good physical education and extracurricular physical exercise, which can provide direct help to stimulate the exercise motivation of college students. Secondly, exercise climate and exercise self-efficacy are important factors affecting college students' exercise behavior. The chained impact of exercise climate and exercise self-efficacy suggests that sports instructors should focus on the exercise behavior of understudies because of exercise climate and exercise self-efficacy. Carry out the difference in understudies from "propelled" to "activity," advance the exercise behavior of undergrads, upgrade the exercise motivation simultaneously, and focus on upgrading the exercise climate around undergrads and working the fair and square of exercise self-efficacy to expand the exercise behavior of undergrads.

Limitations and prospects

Most importantly, this paper takes on an emotional detailing strategy to quantify understudies' exercise behavior, which is heavily impacted by individual subjectivity, so the causal connection between factors cannot be surmised. Later on, longitudinal following or an exploratory mediation configuration can be utilized to make even more sense of the impact of exercise motivation on the exercise behavior of understudies. Thirdly, the choice of subjects from a similar region is helpful for working on the interior legitimacy of the review, but it restricts the outside legitimacy of the review. Future examinations can zero in on various kinds of colleges in various territories for examination and exploration. At last, this concentration just considers the interceding impact of exercise climate and exercise self-efficacy on exercise motivation and exercise behavior of understudies, yet actually, there might be other intervening factors, for example, peer support, social help, and instructors' ability to instruct, that need further exploration.

Conclusion

This paper investigates the huge intervening impact of exercise climate and exercise self-efficacy on exercise motivation and behavior. What's more, there are three explicit interceding ways: (1) the single intervening impact of exercise climate; (2) the sole intervening impact of exercise self-efficacy; and (3) the chain interceding impact of exercise climate and exercise self-efficacy. Through the inside and outside investigation of the survey information of undergrads, the outcomes show that exercise motivation, exercise climate, exercise self-efficacy, and exercise behavior are altogether associated, and exercise motivation can essentially predict exercise behavior. It very well may be found in this paper that undergrads' exercise behavior is impacted by the encompassing exercise climate and the degree of exercise self-efficacy. Subsequently, during the time spent further developing understudies' exercise behaviors, more consideration ought to be paid to the exercise climate around understudies as well as individual self-efficacy of exercise.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/ participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YZ and KG designed the study, collected and analyzed the data, and wrote the manuscript. QM, XL, and LC revised the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Chen, S. P., Wang, Y. B., Rong, J. Z., Pan, X. G., and Bao, J. (2013). Construction and reliability and validity analysis of exercise motivation scale (MPAM-R). *J. Beijing Univ. Sport.* 36, 66–70+78. doi: 10.19582/j.cnki.11-3785/g8.2013.02.013

Cheng, F., and Xu, Z. H. (2016). The relationship between exercise motivation, self-efficacy and physical health of college students. *J Nanjing Univ Phys Educ.* 15, 57–61. doi: 10.15877/j.cnki.nsin.2016.03.011

Cole, M. S., Walter, F., and Bruch, H. (2008). Affective mechanisms linking dysfunctional behavior to performance in work teams: A moderated mediation study. *J. Appl. Psychol.* 93, 945–958. doi: 10.1037/0021-9010.93.5.945

Department of Physical Health and Arts Education Ministry of Education (2021). Release report of the eight national survey on student physical fitness and health. *Chin. Sch. Health.* 42, 1281–1282. doi: 10.16835/j.cnki.1000-9817.2021.09.001

Dong, Y. Q., Ge, Y. Y., Ding, F., Zhong, J. W., and Li, X. C. (2022). Effects of cumulative ecological risk on physical exercise in college students: Mediating effects of sports atmosphere and exercise self-efficacy. *Chin. J. Health Psychol.* 30, 1244–1249. doi: 10.13342/j.cnki.cjhp.2022.08.025

Dong, Y. Q., Guo, T. L., Li, W., Ren, B., and Zhong, J. W. (2020). Study on the relationship between exercise motivation, physical self-efficacy and sports participation in junior middle school only children. *Sichuan Sports Sci.* 39, 69–72. doi: 10.13932/j.cnki.sctykx.2020.05.15

Dong, B. L., Zhang, H., Zhu, L., and Cheng, Y. F. (2018). Effects of health belief, self-efficacy and social support on leisure exercise in adolescents. *J. Shandong Univ. Phys. Educ.* 34, 106–112. doi: 10.14104/j.cnki.1006-2076.2018.05.018

Guo, W., Huang, Y. Z., and Zhu, Y. (2010). The influence of self-efficacy of physical exercise and self-congruence of goal on participation in physical exercise of college students with serious physical health problems. *J. Phys. Educ.* 17, 68–73. doi: 10.16237/j.cnki.cn44-1404/g8.2010.11.008

Hu, W. Y., and Wei, Y. Y. (2005). The influence of goal orientation and motivation on college students' physical exercise. *Zhejiang Sports Sci.* 27, 41–45. doi: 10.3969/j.issn.1004-3624.2005.04.012

Hu, D. G., Zong, B. B., Wang, B. S., and Zhang, W. L. (2020). Study on home physical exercise behavior and promotion of college students during COVID-19 epidemic. *J. Wuhan Univ. Sport.* 54, 80–86. doi: 10.15930/j.cnki.wtxb.2020.06.012

Huang, T., and Qiu, F. (2019). The promotion mechanism of psychological need satisfaction on college students' exercise behavior. *Fujian Sports Sci. Technol.* 38, 38–42.

Jacobs, J. A. (2000). Commentaries on "the 'What' and 'Why' of goal pursuits: Human needs and the self-determination of behavior". *Psychol. Inq.* 11, 269–318. doi: 10.1207/S15327965PLI1104_02

Jiang, X. Z., Bai, W. F., and Xu, L. (2004). Investigation on external factors influencing the formation of physical exercise habits of students in compulsory education. *J. Inner Mongolia Normal Univ.* 33, 341–344. doi: 10.3969/j.issn.1001-8735.2004.03.029

Jiang, Q., Qu, D. L., and Wang, E. J. (2017). The relationship among physical exercise, self-efficacy, and mental health of college students. *Chin. J. Health Psychol.* 25, 763–766. doi: 10.13342/j.cnki.cjhp.2017.05.033

John, C. S., and Rebecca, E. L. (2003). Toward a comprehensive model of physical activity. *Psychol. Sport Exerc.* 4, 7–24. doi: 10.1016/S1469-0292(02)00014-6

Kilpatrick, M., Hebert, E., and Bartholomew, J. (2005). College students' motivation for physical activity: Differentiating men's and women's motives for sport participation and exercise. *J. Am. Coll. Heal.* 54, 87–94. doi: 10.3200/JACH.54.2.87-94

Li, C. L., and Li, L. (2020). The effect of exercise motivation on exercise behavior of college students: The mediating role of exercise engagement. *Hubei Sports Sci. Technol.* 39, 415–419. doi: 10.3969/j.issn.1003-983X.2020.05.010

Li, G. Y., and Yang, W. B. (2016). The influence of physical exercise motivation on exercise persistence: The mediating effect of exercise climate: A case study of square dancing participants. *Chin. Sch. Phys. Educ.* 3, 82–87.

Liang, D. Q. (1994). The relationship between stress level and physical exercise in college students. *Chin. J. Ment. Health.* 8, 5–6.

Liu, G. F. (2010). Study on the relationship between physical exercise motivation and exercise behavior of college students. *J. Adult Phys. Educ.* 26, 44–45+70. doi: 10.16419/j.cnki.42-1684/g8.2010.04.018

Liu, C. H. (2020a). Effects of physical exercise on negative emotions in college students: Mediating and moderating effects of self-efficacy and psychological resilience. *J. Phys. Educ.* 27, 102–108. doi: 10.16237/j.cnki.cn44-1404/g8.2020.05.014

Liu, M. (2020b). Research on postgraduate students' physical exercise behavior. *Sports Sci. Technol. Lit. Bull.* 34, 80–85. doi: 10.13720/j.cnki.22-1286.2018.01.014

Liu, D. J., Ma, J. G., and Ma, Y. F. (2005). Investigation and research on sports consciousness and behavior of postgraduates in Shanghai universities. *Sports Sci. Res.* 9, 74–77. doi: 10.3969/j.issn.1007-7413.2005.04.019

Liu, W. N., Zhou, C. L., and Sun, J. (2011). The influence of outdoor sports motivation on sports persistence in adolescents: The mediating role of sports atmosphere. *Sports Sci.* 31, 41–47. doi: 10.16469/j.css.2011.10.006

Meng, S. X., and Shen, C. (2018). Effect and associated factors of physical exercise on the physical and mental health among college students. *Chin. Sch. Health.* 39, 1026–1029. doi: 10.16835/j.cnki.1000-9817.2018.07.019

Sallis, J. F., Hovell, M. F., and Hofstetter, C. R. (1992). Predictors of adoption and maintenance of vigorous physical activity in men and women. *Prev. Med.* 21, 237–251. doi: 10.1016/0091-7435(92)90022-A

Tian, H. M., Li, X., Lu, S. X., Ge, J. J., and Li, A. Q. (2018). The relationship between attitude towards physical exercise and exercise behavior in college students: The moderating effect of exercise partners. *J. Jilin Inst. Physi. Educ.* 34, 80–85. doi: 10.13720/j.cnki.22-1286.2018.01.014

Wang, L. (2017). The influence of adolescent outdoor sport motivation on sport persistence: The mediating role of sporting climate. *Youth Sports* 6, 49–50. doi: 10.3969/j.issn.2095-4581.2017.08.020

Wei, J. M. (2010). Investigation and analysis of motivation intensity and exercise behavior of college students. *Zhejiang Sports Sci.* 32, 108–110. doi: 10.3969/j.issn.1004-3624.2010.06.033

Wei, J. J., Xie, H., Wang, C. C., and Liu, C. X. (2020). The relationship between basic psychological needs satisfaction, self-determination motivation and physical exercise behavior of elderly people in community. *J. Nurs. Res.* 34, 3791–3795. doi: 10.12102/j.issn.1009-6493.2020.21.009

Wen, Z. L., and Ye, B. J. (2014). Mediating effect analysis: Method and model development. *Adv. Psychol. Sci.* 22, 731–745.

Wu, T. Y., Ronis, D. L., and Pender, N. (2002). Development of questionnaires to measure physical activity cognitions among Taiwanese adolescents. *Prev. Med.* 35, 54–64. doi: 10.1006/pmed.2002.1049

Xu, W. (2020). A summary of the relationship between exercise motivation and exercise behavior of teenagers at home and abroad. *Zhejiang Sports Sci.* 42, 77–81+106. doi: 10.3969/j.issn.1004-3624.2020.06.015

Xu, N. Y. (2021). The relationship between physical exercise motivation and physical exercise behavior of college students. *Modern Commun.* 35, 183–185.

Yan, J., Tao, B. L., Shi, L., Lou, H., Li, H. Y., and Liu, M. (2020). The relationship between extracurricular physical exercise and school adaptation of adolescents: A chain mediating model and gender difference. *China Sports Sci. Technol.* 56, 11–18. doi: 10.16470/j.csst.2020161

Yang, S. J. (2016). The relationship between social support, self-efficacy and adolescents' satisfaction with physical exercise. *J. Wuhan Univ. Phys. Educ.* 50, 90–94. doi: 10.15930/j.cnki.wtxb.2016.02.015

Yang, J., Qiu, Q., and Ji, L. (2014). Behavioral ecology model of exercise and its application in the field of physical education. *J. Wuhan Univ. Physi. Educ.* 48, 75–81. doi: 10.15930/j.cnki.wtxb.2014.10.032

Yang, J. P., Xiang, C. Y., and Xu, J. (2015). The path of promoting adolescent aerobic fitness and physical exercise behavior: The perspective of motivation theory. *Phys. Educ. Sci.* 36, 115–120. doi: 10.13598/j.issn1004-4590.2015.04.019

Yu, K. H., Lu, Y. J., and Wu, Y. Z. (2021). An analysis of the structural equation model with the factors affecting exercise behavior for university students. *J. Phys. Educ.* 28, 103–110. doi: 10.16237/j.cnki.cn44-1404/g8.2021.02.017

Yuan, S. J., and You, M. L. (2021). Social support measures of sports participation and exercise behavior of college students during the epidemic: The mediating role of exercise motivation. *J. Shandong Inst. Phys. Educ.* 37, 53–60. doi: 10.14104/j.cnki.1006-2076.2021.04.007

Yuan, G. Y., and Zhang, M. L. (2015). The effect of physical exercise on self-efficacy, self-esteem and subjective well-being of middle school students. *Chin. J. School Health* 36, 442–443. doi: 10.16835/j.cnki.1000-9817.2015.03.044

Zhang, Y. H., and Zhao, J. (2009). Current situation analysis and countermeasures of college students' physical exercise. *J. Weifang Univ.* 9, 123–127.

Zhu, X. Q. (2019). Mediating effect of procrastination and exercise motivation of college students. *J. Guangzhou Univ. Phys. Educ.* 39, 81–85+120. doi: 10.13830/j.cnki.cn44-1129/g8.2019.04.022

frontiers | Frontiers in Psychology

TYPE Hypothesis and Theory
PUBLISHED 11 April 2023
DOI 10.3389/fpsyg.2023.1134049

OPEN ACCESS

EDITED BY
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SPECIALTY SECTION
This article was submitted to
Movement Science and Sport Psychology,
a section of the journal
Frontiers in Psychology

RECEIVED 29 December 2022
ACCEPTED 13 March 2023
PUBLISHED 11 April 2023

CITATION
Stults-Kolehmainen MA (2023) Humans have a basic physical and psychological need to move the body: Physical activity as a primary drive. *Front. Psychol.* 14:1134049.
doi: 10.3389/fpsyg.2023.1134049

Humans have a basic physical and psychological need to move the body: Physical activity as a primary drive

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Physical activity, while less necessary for survival in modern times, is still essential for thriving in life, and low levels of movement are related to numerous physical and mental health problems. However, we poorly understand why people move on a day-to-day basis and how to promote greater energy expenditure. Recently, there has been a turn to understand automatic processes with close examination of older theories of behavior. This has co-occurred with new developments in the study of non-exercise activity thermogenesis (NEAT). In this narrative review, it is hypothesized that psycho-physiological drive is important to understand movement in general and NEAT, specifically. Drive, in short, is a motivation state, characterized by arousal and felt tension, energizing the organism to acquire a basic need. Movement is a biological necessity, like food, water, and sleep, but varies across the lifespan and having the greatest impact before adolescence. Movement meets various criteria for a primary drive: (a) deprivation of it produces feelings of tension, such as an urge or craving, known as affectively-charged motivation states, and particularly the feelings of being antsy, restless, hyper or cooped up, (b) provision of the need quickly reduces tension - one can be satiated, and may even over-consume, (c) it can be provoked by qualities of the environment, (d) it is under homeostatic control, (e) there is an appetite (i.e., appetence) for movement but also aversion, and (f) it has a developmental time course. Evidence for drive has mainly come from children and populations with hyperkinetic disorders, such as those with anorexia nervosa, restless legs syndrome, and akathisia. It is also stimulated in conditions of deprivation, such as bed rest, quarantine, long flights, and physical restraint. It seems to be lacking in the hypokinetic disorders, such as depression and Parkinson's. Thus, drive is associated with displeasure and negative reinforcement, subsuming it within the theory of hedonic drive, but it may fit better within new paradigms, such as the WANT model (Wants and Aversions for Neuromuscular Tasks). Recently developed measurement tools, such as the CRAVE scale, may permit the earnest investigation of movement drive, satiation, and motivation states in humans.

KEYWORDS

drive, motivation, affectively charged motivation states, satiation, exercise, physical activity, non-exercise activity thermogenesis

Introduction

Movement is important for both physical and mental health, thriving in life and until recently, even survival. While exercise is widely recognized as improving physical fitness and cardiovascular health (Garber et al., 2011; Usdhhs, 2018; Bull et al., 2020), less recognized is the importance of bodily movement in general, which is necessary for proper circulation, tissue perfusion (i.e., oxygenation of tissues), metabolism, and many other functions (Greenleaf and Kozlowski, 1982; DeRoshia and Greenleaf, 1993). Those who move more frequently have less occurrence of blood clots (i.e., pulmonary embolisms, deep vein thromboses), frozen joints, cartilage degeneration, impaired digestion, metabolic disease and even skin problems (Lee et al., 2012; Musumeci et al., 2013; Crane et al., 2015; Pedersen and Saltin, 2015; Khmaladze et al., 2020). Under conditions of movement, weight is maintained in the face of increased or decreased calories (Levine et al., 1999, 2005; Donnelly et al., 2009). Movement is needed for proper growth, maturation and development of immune function (Vicente-Rodríguez, 2006). Mental health and even basic perception and psychological attention is facilitated with movement and degrades with lack of it (Zubek, 1964; Greenleaf and Kozlowski, 1982; Winget and Deroshia, 1986; Kim et al., 2012; Chekroud et al., 2018; de Sousa et al., 2018a,b; Parker et al., 2020; Pearce et al., 2022). Even when sleeping, a healthy body continues to move regularly, with about 135 total movements per session of sleep, of which 15.1 are major postural adjustments (Wilde-Frenz and Schulz, 1983). If indisposed, the body must still be moved frequently (e.g., by a nurse) to prevent pressure injuries (i.e., skin ulcers), additionally highlighting the importance of movement (Walton-Geer, 2009). Sudden declines in movement (i.e., outside of normal sleep and rest) are associated with precipitous worsening of health and accelerated aging (Greenleaf and Kozlowski, 1982; Winget and Deroshia, 1986). Engagement in a new and regular exercise routine results in immense health benefits that is dose-dependent, leading some to call it a "polypill" (Fiuza-Luces et al., 2013). Consequently, one might imagine that movement is as vital as food, water, air, sleep, shelter, and sexual activity – in other words, a basic or genuine need.

Movement falls on a spectrum of energy expenditure and movement intensity, ranging from sleep to vigorous activity (Rosenberger et al., 2019; Biddle, 2022). Furthermore, movement varies cyclically over a 24-h activity cycle (Rosenberger et al., 2019), typically higher when one is awake and peaking in the afternoon (McDonnell et al., 2022). Energy expenditure, *per se*, is largely not under volitional control, with the majority of energy being expended automatically through the resting metabolic rate (RMR) and the thermic effect of food (TEF; King et al., 2007). Substantial energy expenditure, however, is under volitional control, such as lifestyle and occupational physical activity and structured exercise. All physical activity not accounted for by exercise, RMR or TEF is deemed non-exercise activity thermogenesis (NEAT), which cannot be directly measured (Levine et al., 1999, 2005). Within NEAT falls incidental or spontaneous physical activity (SPA), such as fidgeting, pacing, and postural adjustments, which may also result in substantial energy expenditure (Garland et al., 2011). Some sedentary behavior common for our ancestors and in hunter gatherers of today, such as "static squatting," results in enough muscular activity that it could be construed as a form of physical activity. This signifies the complexity of separating physically active and sedentary behaviors, the latter of which typically includes sitting (Raichlen et al., 2020; Higgins et al., 2022). For this hypothesis and theory paper, it is important to note that some volitional activity could also be characterized as "obligatory" (Garland et al., 2011) and instrumental (Stults-Kolehmainen et al., 2020a; see below).

Unfortunately, with modern times, physical activity and exercise have declined, and sedentarism has become dominant (Hyde et al., 2021; Ussery et al., 2021). Likewise, calories are abundant along with expanding waistlines and central adiposity (Fryar et al., 2021; Wong et al., 2022). The putative mechanism is that calories (e.g., particularly from highly palatable food) are highly reinforcing, while movement is less attractive. Reinforcement, however, has two forms, both positive (i.e., providing a pleasurable stimulus) and negative (i.e., taking away a negative stimulus). Movement as a positive reinforcer has been considered extensively (Cheval et al., 2018). Atypically has movement been considered as a negative reinforcer, such as taking away displeasure (Stults-Kolehmainen et al., 2020a). Drive theory contends that humans are motivated to extinguish the negative sensations that are usually produced through the deprivation of basic needs (Hull, 1943, 1952). Bodily movement has periodically been considered as a basic need (Bridges, 1936; Seward and Seward, 1937; Rowland, 2016). However, while instances of low movement are abundant, it's uncommon in parlance to think of oneself as being *deprived* of movement. In fact, many may prefer it that way. Nevertheless, for some, there may be an obvious need to move, and a sense of deprivation when it is lacking. Furthermore, modern innovations have also produced situations where humans, who are otherwise active, become constrained, sometimes for long periods (e.g., academic lectures, flights, space travel, laboratory tasks, quarantine, various forms of confinement and sensory deprivation; Galton, 1885; Zubek, 1964; Zuckerman et al., 1968; Reardon et al., 2008; Shalev, 2008; Morgan et al., 2013; Seli et al., 2014; Bouwens et al., 2018; Blacutt et al., 2021; Stults-Kolehmainen et al., 2021a; Filgueiras and Stults-Kolehmainen, 2022). If movement is a basic need, there should be a sense of deprivation in these instances. Given these observations, it seems worthwhile to consider whether human movement has drive-like qualities, if it might even be considered a primary drive, and if so, what might be implicated for theories of physical activity behavior. The goal of this hypothesis and theory paper is to explore these issues in both a historical and modern context, drawing on a wide variety of literature. The goal is not to conduct a systematic review, particularly given the difficulties of searching for the term "drive," and because there is no research question, *per se*.

Discussion

Theories of physical activity behavior

Human movement as a behavior remains an enigma. Dominant theories of exercise and physical activity behavior have largely failed to explain human movement in its totality, largely leaving the concept of daily energy expenditure to the physiologist (Garland et al., 2011). Theories of motivation have typically focused on motives and self-determination, as well other cognitive-oriented constructs (Biddle, 1995; Ryan and Deci, 2007; Stults-Kolehmainen et al., 2013a,b; Ekkekakis and Brand, 2021). There has been a recent resurgence of interest in older psychological theories in the construction of dual process theories of motivation (Conroy and Berry, 2017; Brand and

Ekkekakis, 2018), which posit both automatic and deliberative components to motivation. For instance, ART theory has resurrected Lewin's ideas of driving and restraining forces (Marrow, 1977; Brand and Ekkekakis, 2018), yet, attempts to reconcile these inputs on behavior are not unique. Butt (1976) commented that, "motivation may be seen as evolving from two major sources: a biologically-based fund of energy, and all secondary or environmental influences, each with positive and negative pulls." Alderman (1974), took a more comprehensive view, stating, "motivated behavior is the sum total of instincts and needs, motives and drives, conscious and unconscious forces, and a function of what one expects to gain from participation in sport," which Feige (1976) categorized hierarchically to explain physical activity motivation. The ideas of action impulse and urge have also reemerged, though they remain very poorly defined across the literature (Gardner, 2015; Brand and Ekkekakis, 2018; Rebar et al., 2018; Stults-Kolehmainen et al., 2020a, 2022a; Ekkekakis and Brand, 2021; Williams, 2023).

With attention now placed on older theories and constructs and rectifying them with newer ones, it begs the question of the relevance of some of the oldest theories of motivation, Drive Theory and the related Drive Reduction Theory (Hull, 1943, 1952). Drive theory posits that humans are motivated primarily to reduce tension and arousal, typically occurring from the deprivation of basic needs (Allen et al., 2017). With the dawning of behaviorism and cognitivism, this idea has been largely ignored, relegated or simply forgotten (Skinner and Morse, 1958). Early sport and exercise psychologists were disappointed with the ability of Drive Theory to predict the effects of arousal, and in particular anxiety, on performance of complex motor tasks, and they recommended the abandonment of the concept (Martens, 1971, 1974; Landers, 1980; Tenenbaum and Bar-Eli, 1995). These researchers had little interest in applying the concept to general movement and physical activity behavior. Those that were interested in exercise behavior were turned off by the idea of "people as machines" (Biddle, 1995).

However, the idea has persisted in the work of exercise physiologists within the notion of *biological control* (Rowland, 1998, 1999, 2016). In the current exercise psychology literature, "drive" is usually used in the context of basic psychological needs, as defined by Self-Determination Theory (Rhodes et al., 2019), nervous system activity (i.e., sympathetic and parasympathetic drive; Greenwood and Fleshner, 2019), as well as use in expressions of being "driven" (Frijda, 2016; Lichtenstein and Jensen, 2016). In fields outside of exercise science, there has been an earnest re-examination of the concept (Allen et al., 2017) because, while drive has been roundly criticized by some scholars, no meaningful substitutes have been found (Conrad, 2021). Recently, the WANT model of physical activity and sedentarism posited that the desire for movement behaviors is attributed to a combination of attempts to reduce tension (e.g., from drive and stress) and maximize pleasure and enjoyment (i.e., hedonic motivation; Seward, 1956; Stults-Kolehmainen et al., 2020a, 2022a). This idea deserves further delineation, but my basic postulate is that humans have a primary drive to move.

Drive and drive theory

Drive theory is an early theory of motivation. The idea of drive is a "frontier" concept that straddles the physiology and psychology literatures (Conrad, 2021) and varies widely by field of inquiry (Katsafanas, 2018). It is traced back to the work of German physician Johann Friedrich Blumenbach (1752–1840) who used the term *trieb*, meaning force or impulse (Conrad, 2021). Notably, for this review, that term derives from an older word, *trieben*, meaning "to herd animals." Nonetheless, the term is frequently associated with the works of Nietzsche and Freud (1964), who were primarily concerned with the drives of sex and aggression. Since this time, however, the concept of drive has been applied more expansively - making a concise definition difficult to find (Bridges, 1936). Some notable definitions follow here:

1. Clark Hull, who is most closely associated with Drive Theory, described drive as "motivation that arises due to a psychological or physiological need" (Hull, 1952).
2. Baumeister and Vohs (2007) describe it as "increased arousal and internal motivation to reach a particular goal."
3. The American Psychological Association (2022) defines it essentially as a motivation state (Stults-Kolehmainen et al., 2020a), saying drive is "a generalized state of readiness precipitating or motivating an activity or course of action." They add, "Drive is … usually created by deprivation of a needed substance (e.g., food), the presence of negative stimuli (e.g., pain, cold), or the occurrence of negative events."
4. Seward and Seward (1937) defined drive as "an activity of the total organism resulting from a persistent disequilibrium."
5. Seward described drive as an "excitatory state produced by a homeostatic disturbance" (Seward, 1956).
6. Conrad (2021) notes that "A drive is fundamentally a force, a pressure impelling the organism endogenously." Speaking from a psychoanalytic viewpoint, Conrad also describes drive as, "bedrock psychical forces that attach to ideational content and are realized in dispositional states that induce affective, and so evaluative, orientations."
7. Other perspectives come from: (a) Carver and White (1994) in their studies of behavioral activation, which consider drive as more similar to a trait, and label it as "persistent pursuit of desired goals," (b) Lewin considered drive within his notion of "tension systems" (Marrow, 1977).

Consequently, the idea of drive is multifarious and difficult to operationalize. The most common elements from the definitions above are motivation, psychological states, goals, and homeostasis. A similar problem exists with the concept of stress, which conflates the ideas of stressors (i.e., impinging forces) with strain (i.e., the reaction to stress; Bartholomew et al., 2008; Lutz et al., 2010; Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2014, 2016; Stults-Kolehmainen and Sinha, 2014). In this case, drive has been blended, sometimes indiscriminately, with the ideas of: (a) needs, (b) deprivation of the need (i.e., a stressor), (c) felt tension and affective strain (i.e., a response), (d) a process of motivation, and (e) a motivation state. Given that the difficulties of stress have been met head on, I suggest that the concept of drive may also be pursued more rigorously. Here I define drive as, "a *motivation state* triggered by deprivation of a need or relevant environmental factors and associated with a subjective feeling of tension, functioning to help the organism maintain homeostasis." [Note that, below, drive is often referred to as (a) a tendency to experience motivation states, which energize the organism to action through processes of deprivation, tension, consumption, and satiation or (b) as the *totality of these processes*.]

Given this lack of clarity, I find it best to start with the concept of needs and, specifically, primary needs. For Hull (1952), a need is a *biological requirement of the organism*, though Taormina and Gao (2013) more broadly assert that it is "characterized by, and defined as, a lack of something that is essential to an organism's (a person's) existence or well-being." These researchers, who follow the paradigm from Maslow (1943, 1987), specifically note that "physiological needs can be operationally defined as the lack of chemicals, nutrients, or internal (e.g., exercise/health) or environmental (e.g., temperatures) conditions necessary for the body to survive, such that the extended absence of these things could lead to psychological stress or physical death" (Taormina and Gao, 2013). The generally accepted primary needs are food, water, oxygen, warmth, shelter, sleep, and sex (Taormina and Gao, 2013). Seward and Seward (1937) also include: activity, exploration (Butler, 1953), attack and self-assertion, escape, and submission. Clearly, there is no universal agreement on the numeration of the primary drives, and later Maslow (1987) urged ending the deliberation over the matter.

Needs are frequently categorized by the type of stimuli that are needed (e.g., water, food, movement). To help avoid circularity, "need" might be viewed as the lack of the necessary stimulus (Taormina and Gao, 2013). Lack of a necessity results in a state of *deprivation* or deficiency – a threat to homeostasis, and thus a stressor. There is an internal stimulus, a signal, as well as arousal associated with the deprivation. For instance, the condition of hunger is a motivation state produced by the deprivation of needed energy. It stimulates the sensation of being hungry, which is a signal to acquire food. Likewise, thirst is a motivation state, a condition, resulting from deficient water intake, associated with the feeling of being thirsty (see Table 1; Allen et al., 2017). Sensations produced by drive, like being hungry and thirsty, are almost always unpleasant and are considered sources of tension. Drive, however, is not simply the experience of tension. In Hull's system, drive is the energy or motivational force that powers behavior (Hull, 1943, 1952). For Lewin (Marrow, 1977), drive was characterized as a "tension system." It is an uncomfortable motivation state and resulting arousal, both generalized and specific to the need, with the objective to eradicate the deficiency in the need and focusing the attention of the deprived individual on a target. To acquire and consume the needed substance is to sate or satiate the deprived need, which ensures survival. The process is highly automatic and, theoretically, fundamental across all humans, perhaps all mammals, similar to core affect (Barrett et al., 2007).

Criteria for primary drives

Specific criteria indicating what constitutes a primary drive are difficult to find, with the exception of Bridges (1936), which predates the classic work from Hull (1943, 1952). Based on considerations above, I propose that criteria would include:

1. Universality: The need is innate and common to nearly all humans, and possibly all vertebrates, similar to core affect (Hull, 1952; Spence, 1956; Barrett et al., 2007).
2. Biological requirement for survival: The need is necessary and not acquired or conditioned.
3. Emerges in deprivation: The drive is highly repeatable in response to the recurrence of need deprivation (Allen et al., 2017).
4. Subjective feeling of tension: Deprivation of the need has a psychological consequence. The condition of deprivation is typically unpleasant, like discomfort, which may be strong (e.g., an urge or craving) and may even be the dominant sensation in some situations. The tension is both generalized and specific to the need (e.g., stomach pangs in response to hunger).
5. Physical manifestations and symptoms: There are observable changes in the physical state, such as altered locomotor activity (e.g., the muscles shake in response to being antsy), along with emotional expression (e.g., being flushed).
6. Consumption: Behaviors are observed to consume the need (Allen et al., 2017).
7. Relief: Tension (thus, motivation) rapidly decreases with the provision of the needed stimulus (i.e., a "rapid diminution of motivational stimulus"; Seward, 1956).
8. Satiation and Over-consumption: A sense of being "full," a motivational null-point, while having too much results in unpleasant sensations (Allen et al., 2017).
9. Developmental time course across the lifespan: The drive is exhibited early in infancy (or even before birth), is visible throughout infancy and childhood, and changes with aging (Bridges, 1936).
10. Under homeostatic control: The need has a circadian rhythm, typically. It is reproduced daily and may change seasonally (Budnick et al., 2022).
11. Responsiveness to other internal and external stimuli: Qualities of the internal environment (e.g., the body) and the external environment (e.g., either provocative or dull situations) can stimulate it (Loewenstein, 1996; Seli et al., 2014).
12. Approach and avoidance: Include aversions and appetites (e.g., humans crave fresh and avoid salty water; are repulsed by rotten food; Seward and Seward, 1937; Skinner et al., 2009; Stults-Kolehmainen et al., 2020a). Qualities of the stimulus matter as they are relevant for survival.
13. Biological mechanisms: There needs to be evidence of multi-system biological control to constitute a drive, including hormones, neuropeptides, brain circuitry, the microbiome, etc. (Allen et al., 2017; Dohnalová et al., 2022).

Drives differ from reflexes, instincts, basic psychological needs, impulses, habits, and predispositions (Seward and Seward, 1937; though in a circular definition, Szondi described drive as "an instinctual need that has the power of driving the behavior of an individual"; Szondi, 1972). Seward and Seward (1937) explain how drives differ from reflexes, "which are readily performed, such as blinking, coughing, and withdrawing from easily avoided cutaneous stimuli." While there is some obvious overlap, drives differ from basic psychological needs, such as the basic need to belong (Baumeister and Leary, 1995; Tomova et al., 2020), and competence and autonomy (Ryan and Deci, 2007). Instincts differ from drives in that they can be easily externally provoked and do not need any conscious awareness. Conrad (2021) defines instincts as, "innate and unlearned biological processes realized in fixed action patterns that are direct expressions of the twin goals of natural selection: survival and

TABLE 1 Some classic, primary (i.e., "genuine") drives, including bodily movement and physical activity.

	Need	Behavior / action (voluntary)	Associated bodily functions (many involuntary)	Need state of deprivation (negative tension)	Descriptor	Physical manifestations and symptoms*	Psychological desire (positive tension)	Satiation state / descriptor
1	Food	Ingestion, eating	Digestion, absorption, defecation	Hunger	Hungry, peckish	Stomach growls and tightens	Appetite	Fullness, full
2	Water	Ingestion, drinking	Hydration, urination	Thirst	Thirsty, parched	Dry mouth and throat, headache	Water appetite	Quenched, slaked
3	Sleep	Sleeping	Rest, convalescence	Somnolence, fatigue	Sleepy, tired	Drooping, slouching	Sleep appetence	Rested
4	Sex	Copulation	Sexual arousal/ receptivity, erection, orgasm	Sexual frustration	Concupiscent, aroused	Genital arousal, pacing and distracted movements, nocturnal emissions	Libido, arousal	Satisfied
5	Movement	Physical activity (PA), ambulation, exercise, moving	Non-exercise activity thermogenesis (NEAT); spontaneous PA	Restlessness	Restless, antsy, fidgety	Shaking muscles, stretching limbs, sweating, pacing, fidgeting, tapping	Appetence, activation	Exertiated †

Exertiated is a stopping state, whereas "exerting" would be a starting or continuing state. "Exertiate" is the verb. In creating this term, we also considered "acti-fied," the portmanteau of "active" and "satisfied," but this may be confused with the word "actify," which sometimes means "to start, activate or put into action".

†Portmanteau of "exert"/"exercise" and "satiated".

*There are generalized physical symptoms common to many/most needs (e.g., restlessness) as well as specific and localized ones.

reproduction." A common example is a mother's instinct to protect her young in danger (Bridges, 1936). The stress reactions of fight and flight, now more accurately reconceptualized as "freeze, flight, fight, or fright," may be more pertinent (Bracha et al., 2004). The idea of "impulse" is similar to drive in that it has been poorly defined, but ostensibly these are separate but potentially related constructs (Gardner, 2015; Brand and Ekkekakis, 2018; Conrad, 2021). For instance, both drive and impulse may be related to a third construct, urge, which is a feeling of strong desire to approach an object or behavior.

Importantly, drives may or may not have an object or a precise target. "There is no inherent correspondence between a drive and its object in the same way that there is between an instinct and its object" (Conrad, 2021). Conrad goes on to add, "drives are fundamentally forces and may be 'continuously flowing' without any attachment to an object." On the other hand, Conrad also notes that drives may be vector-like, having both force and direction. In line with these notions, the drive for movement may be expressed in a multitude of ways, such as a longing for sport, needing to go for a walk or wanting to get fit and more muscular (i.e., all having direction/ an object), or a *pressing readiness to fidget and move about* (i.e., *not having direction / an object*).

Movement as a primary drive: Criteria 1–3

Movement is needed for survival

My initial arguments that humans have a basic drive to move were published in a former paper (Stults-Kolehmainen et al., 2020a) that, while providing a strong rationale, fell short of emphasizing that movement might be characterized as a *primary drive*. To do so would be to imply that movement is necessary for survival – that there is a physical need – which is nearly universal (criteria 1 and 2, above). The study of drive has frequently been explored in rodent models, where there is strong evidence of a basic drive to move (Garland et al., 2011). However, in an early review on the matter, Lore (1968) has argued that there is inconsistent evidence of an innate drive to move in rodents. However, he included studies using activity deprivation ranging from 5 h to 100 days, thus conflating acute and chronic responses.

Thus far in humans, movement has atypically been included in lists of basic physical needs and thus, primary drives, such as eating, drink, sex, social interactions, etc. (Hull, 1952; Loewenstein, 1996; Tomova et al., 2020). Nevertheless, Bridges (1936), Seward and Seward (1937), and more recently Taormina and Gao (2013) have been direct in the assertion that physical activity (and exercise) is a primary need and drive. Others have been highly suggestive of the point (Tolman, 1932; Collier, 1970; Feige, 1976; Rowland, 1998, 1999, 2016; Reiss, 2004; Schultheiss and Wirth, 2008; de Geus and de Moor, 2011; Kalupahana et al., 2011), and it has been partly established above. In short, movement is necessary for instrumental reasons, for play (Rowland, 1998; Rowland, 2016), exploration for acquisition of rewards, and experiencing and processing novel environmental stimuli (Butler, 1953; Panksepp, 2006; Cabanac, 2006a,b; Schultheiss and Wirth, 2008; Panksepp and Biven, 2012; Frijda, 2016; Parker et al., 2020). There is also a general need for stimulation (Ekkekakis, 2013), such that individuals will even subject themselves to painful electric shocks when faced with nothing else to occupy their minds (Wilson et al., 2014). Ekkekakis (2013) summarized older arguments that indicated that humans have an "inherent propensity," "susceptibility" or "drive for activity."

Clinical manifestations

A case for "drive for activity" has also been made in certain clinical conditions, such as anorexia nervosa (Davis and Woodside, 2002; Scheurink et al., 2010; Casper, 2018, 2022). Aversive sensations associated with a lack of movement are also hallmarks of various disorders, such as Restless Leg Syndrome (Garcia-Borreguero et al., 2011; Khan et al., 2017), akathisia (Iqbal et al., 2007), exercise addiction/dependence (Hausenblas and Downs, 2002; Ferreira et al., 2006; Garland et al., 2011; Lichtenstein and Jensen, 2016; Stults-Kolehmainen et al., 2022b), and hyperactivity (Willerman, 1973; Scheurink et al., 2010). Some of the earliest observations of this go back over 100 years, such as a case of a girl with akathisia who was rarely able to stop moving (James, 1907). With hypokinetic disorders, such as Parkinson's and depression, there may be a total loss of desire and urge to move, characterized as motor apathy or psychomotor retardation (Sinha et al., 2013; Busch et al., 2016; Stults-Kolehmainen et al., 2022b). Collectively, I have called the disorders characterized as very high or very low in motor urge as Movement Urge Dysfunction Disorders (MUDD), which seem to fall along a movement urge dysfunction spectrum (MUDS; Stults-Kolehmainen et al., 2022b). This proposition is supported in the Parkinson's literature and elsewhere as conditions characterized by hypo- and hyper-dopaminergic states in the cortico-striatal circuits (Sinha et al., 2013). Until recently, however, a strong case was not made for the general population of healthy adults (Stults-Kolehmainen et al., 2020a, 2021b, 2022a). To support the point, one would need to assert that movement is (has been) a common need for all (most) humans and is (has been) needed for survival – not requiring conditioning. Thus, the first two criteria seem to be satisfied.

Movement deprivation

It appears that the 3rd criterion from the above list (i.e., deprivation) is met as well. Seward and Seward (1937) note that with "prolonged rest, the refreshed organism requires activity to restore equilibrium." Arousal emerges when movement is deprived, such as prolonged sitting and physical restraint (Zuckerman et al., 1968; Ravussin et al., 1986; Reardon et al., 2008; Bouwens et al., 2018), which is highly repeatable and has been observed in primates (Butler, 1953) and humans (Stults-Kolehmainen et al., 2021b, 2022a; Budnick et al., 2022). Under restrained conditions humans feel "intense uneasiness or craving" or "pressing readiness" or tension, perhaps similar to appetite (Loewenstein, 1996; Ferreira et al., 2006); a comparison propelled by Rowland (1998). Almost anyone can identify with the discomfort of sitting for prolonged periods, feelings of being antsy, jittery, squirmy, restless and/or fidgety, and the relief provided by movement (Levine et al., 2005; Seli et al., 2014). They are also observed in various conditions, such as forced bed rest (DeRoshia and Greenleaf, 1993; Ishizaki et al., 2002), loss of playtime/recess (Jarrett et al., 1998), being constrained during an MRI scan or metabolic testing (Ravussin et al., 1986; Aoyagi et al., 2003; Heilmaier et al., 2011), sudden decline in one's usual exercise routine or mandated detraining (Mondin et al., 1996; Sugawara et al., 2001), quarantine / confinement (Zuckerman et al., 1968; Shalev, 2008; Blacutt et al., 2021; Stults-Kolehmainen et al., 2021a; Filgueiras and Stults-Kolehmainen, 2022), and sensory deprivation (Morgan et al., 2013).

Here are some specific examples:

1. The use of physical restraints in older adults, ostensibly to prevent falls while moving, causes large increases in anxiety and exacerbates agitation (Scherder et al., 2010).
2. Solitary confinement with movement restriction results in dramatic effects to physical and mental health, and, concordantly, international law mandates 1 h of exercise time per day (Shalev, 2008). As movement is a basic need, it is also considered by some to be a human right.
3. College-aged male participants who were physically restricted with straps to a form-fitting bed for 8 h had large increases in somatic complaints, feelings of discomfort, and "muscle tightness, sweating, pain in joints, urge to urinate, and itching" (Zuckerman et al., 1968).
4. Even in restricted environmental stimulus training (REST – a float tank designed for sensory deprivation), which is designed for relaxation, "a tension develops which can be called a 'stimulus-action' hunger; hidden methods of self-stimulation develop: twitching muscles, … stroking one finger with another, etc." (Lilly, 2022).
5. In their studies of daily energy expenditure, Ravussin et al. (1986) and colleagues constrained participants to a nondescript metabolic chamber for 24 h and did not permit them any kind of physical exercise, which resulted in increased spontaneous physical activity (SPA). They noted that, "Because the subjects were not allowed to carry out physical exercise, such as isometric exercises or calisthenics, it is possible that such activity represents an unconscious need to be active."

Activitystat – the physical activity set point

Consequently, there may be an energy expenditure set point, under biological control, resulting in drive to move when the level of required activity is not met, and lower drive when there is too much or sudden bursts of activity (Rowland, 1998, 2016; Garland et al., 2011). Bennett (1995) wrote of the general idea of biological control of movement,

> "As with breathing, elimination, and sexual activity, there can be considerable ambiguity about the degree of volition in the timing, frequency, and circumstances of any particular act of eating or exercise. In the moment, snacking [and movement] may appear to be altogether subject to conscious control; in the aggregate, however, such behavior assumes a certain biologic inevitability."

The drive for movement may, alternatively, be a mere consequence of the drive for energy homeostasis, or central nervous system stimulation (Rowland, 1998; Wilson et al., 2014). Rowland coined the term "activitystat" in reference to a homeostatic center of control that keeps total daily energy expenditure (TDEE) relatively stable. To maintain the set point, subtle and perhaps unconscious adjustments may be automatically applied to modulate resting metabolic rate, incidental or spontaneous physical activity, as well as voluntary exercise. There is mixed evidence that when exercise suddenly increases, NEAT (i.e., kcals of non-exercise activity) may decrease (King et al., 2007; Westerterp, 2018). A recent study purporting to test the activitystat model with various training protocols did not find support for the idea (Gomersall et al., 2016). However, a test of this model with provision of activity, but not deprivation of activity, is a poor test of the framework. There is less direct evidence that sudden declines in activity may result in increases in caloric expenditure, but it is possible that this is due to insufficient methods of investigation.

The subjective feeling of drive (felt tension): Criterion 4

Drives are associated with strong signals and subjective feelings of urge and tension, which change rapidly with consumption, satiation, and over-consumption. If humans have a drive to move, what is the proper term for the feeling of tension associated with its deprivation? A lack of food results in hunger and feeling hungry; a lack of water, thirst and being thirsty, a lack of sleep, fatigue and feeling tired (see Table 1). Historically, a lack of movement was not a problem, and thus no strong word is associated with the state of deprivation, at least in English. Older literature has utilized terms, such as "necessity of body exercise," "volitional promptings," "intense uneasiness," "craving," and "pressing readiness" (Bain, 1855; Baldwin, 1891, 1894; Shirley, 1929; Hill, 1956; Finger and Mook, 1971). Several candidates might be worthy to succinctly describe "feeling deprived of movement": feeling antsy, fidgety, driven, cooped up, hyper, wired, agitated, on edge or edgy, restless, squirmy, jittery, wound up, keyed up, stir crazy, having cabin fever, or other overlapping terms also referring to being energized (Jarrett et al., 1998; Emerson, 2020; Stults-Kolehmainen et al., 2022b). Just like psychosomatic sensations of fatigue and energy, feelings of restlessness could be construed as being solely physical and/or mental (Herring and O'Connor, 2009). Sensations of energy and fatigue are moderately correlated with desires and wants to move and rest (Stults-Kolehmainen et al., 2021b). Feeling antsy has connotations of an external source of stimulation (i.e., literally "ants in the pants"), and "cooped up" typically refers to conditions of constraint, while being "wired" usually refers to consumption of excess caffeine or other external stimuli (Levitt et al., 1993) and "feeling hyper" often describes responses to medications (Hauser and Zesiewicz, 1997; Rabkin et al., 2004). Many other terms also exist: drive for activity (Casper, 2018, 2022), urges, cravings, and appetence (Ferreira et al., 2006). The collection of these has been generally referred to as "affectively-charged motivation states" (ACMS) for physical activity (Stults-Kolehmainen et al., 2020a, 2022a). Lastly, it's important to note that for those with exercise addiction/dependence, abstaining from movement may result in sensations of withdrawal and cravings for exercise (Hausenblas and Downs, 2002; Garland et al., 2011; Lichtenstein and Jensen, 2016). Overall, "urges to move are well-documented in situations where such sensations are bothersome and unproductive" (Stults-Kolehmainen et al., 2022b).

Criteria 5–12

For criteria 5–12, I provide brief evidence.

Criterion 5 (Physical manifestations): Studies of participants in situations of deprivation, mentioned above, discuss various physical responses, like spontaneous and nervous fidgeting (Ravussin et al., 1986). In interviews, undergraduate honors students have indicated that they feel mental and physical symptoms, such as being jittery and antsy, with legs stretching out and twitching when deprived of movement (Stults-Kolehmainen et al., 2022a).

Criterion 6 (Consumption): Empirical evidence specifically connecting the constructs of need, deprivation, felt tension, and resulting behavior is lacking. However, motivation states to move (i.e., desire, want, urge, craving), as measured by the CRAVE scale (Stults-Kolehmainen et al., 2021b), were associated with intentions to be active in the following 0–30 and 30–60 min time frames (Budnick et al., 2022).

Criterion 7 (Relief): With consumption (e.g., moving), there should be reductions in negative affect built up from deprivation. As one example, older adults who were released from restraints and allowed to move and exercise experienced reductions in agitation and arousal (Scherder et al., 2010).

Criterion 8 (Satiation and over-consumption): Excessive movement is associated with fatigue, soreness, pain, and alterations to locomotion, which may be construed as signals of satiation with movement (Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2014, 2016), but are not necessary for satiation to manifest. Satiation might be better indicated by alterations to motivation states. With a maximal treadmill test, desires to move dropped 24%, and desires to rest increased 74%, both of which were large effect sizes (Stults-Kolehmainen et al., 2021b). Evidence of satiation also comes from compensation studies, which show that when activity is very high, NEAT decreases (Garland et al., 2011; Westerterp, 2018). The formally constructed notion of exercise satiation is a recent development that has been typically applied to eating disorders (Barker et al., 2022) but likely also applies for healthy populations. My colleagues and I have coined the term "exertiated" to denote when a person feels satisfied and/or satiated with physical activity (see Table 1).

Criterion 9 (Lifespan development): Movement tendencies are observed even in the fetal stage and are considered predictors of infant health (Perry et al., 2022). Movement, muscle tone, and reflexes immediately after birth are likewise important. According to Bridges (1936), the drive to move rhythmically is exhibited in the first month of life, "General exercise and rest are the first noticeable forms of infant behavior," the purpose being, "sensory exploration and utilization of the environment." She notes that the "drive for locomotion" (ambulation) is exhibited at 12–24 months, and these drives are related to the need for more advanced exploration and exploitation of the environment. Rowland has commented extensively on drive for movement in children that wanes with adolescence (Rowland, 1998, 1999, 2016).

Criterion 10 (Homeostatic control): Movement varies systematically over the course of the day, week, and year (Beighle et al., 2008; Budnick et al., 2022). Recent data from adults monitored 6 times a day for 8 days indicates that motivation states to move are like a biorhythm for over 80% of people. In other words, the majority of individuals have a circadian curve for movement drive (Budnick et al., 2022), similar to eating and sleeping. See above for the related idea of "activitystat."

Criterion 11 (Responsiveness to internal and external stimuli): Exogenous factors, such as daylight, caffeine, illicit drugs, prescription medications, and music, highly influence locomotion (Levitt et al., 1993; Hauser and Zesiewicz, 1997; Kaplan et al., 1997; Rabkin et al., 2004; Tucker and Gilliland, 2007; Stults-Kolehmainen et al., 2020a, 2022b). Internal stimuli, like joint pain in individuals with low back pain disorders, regularly propels them to fidget and shift their bodies, sometimes multiple times every minute, in order to relieve pressure and avoid discomfort (Dunk and Callaghan, 2010; Beitel et al., 2016). Psychological stress results in displacement behaviors, such as pacing and stroking one's hair (Troisi, 2002; Mohiyeddini et al., 2013). A lack of stimulation or monotony may also result in activation of drive (Seli et al., 2014).

Criterion 12 (Approach and avoidance): Humans have an innate desire to move, particularly in youth, but they also have strong aversions for movement. For instance, when in the thralls of physical pain (e.g., in this case, before movement even starts) most people actively avoid movement – the extreme of which is kinesiophobia (Lundberg et al., 2006; Beitel et al., 2016; Glaviano et al., 2019; Stults-Kolehmainen et al., 2020a). Also, physical labor and exercise in vigorous intensities are sources of punishing sensations, which are in themselves drive to stop moving. However, physical work and its sensations can be conditioned to have less impact. Brown (1955) attempted to explain the interactions between drive (in this case, drive to stop moving and rest) and conditioning (e.g., to move more).

> "Under some conditions, it might be predicted that the intense [and painful] proprioceptive stimulation and [fatiguing] muscular strain due to prolonged work should have drive-like effects [to stop and/or avoid movement]. But if an organism gets appropriately reinforced training, it can acquire a tolerance for the stimulative effects of repetitive muscular effort that is little short of astounding. Rats and pigeons can be trained to make hundreds of responses for a single bite of food if the percentage of reinforcement is high initially, and if the reduction in frequency of reinforcement with further trials is sufficiently gradual. In such instances, apparently, the stimulation accruing from a multitude of successive reactions does not function as a drive [to stop movement], since behavior, such as resting, though followed by the cessation of such [painful] stimulation, is not strengthened."

Robinson and Berridge (2013) have demonstrated how aversive and punishing sensations can be transformed quickly into strongly desired stimuli *via* the activation of mesocorticolimbic circuitry, which ostensibly applies to physical activity as well.

Movement as a secondary drive

Primary needs and drives are distinguished from secondary needs and drives, the latter of which are not directly needed for survival but help to optimize survival. Secondary needs have also been referred to as "quasi-needs" (Marrow, 1977). Hull asserted that some reinforcing behaviors, like seeking money, are secondary drives (Hull, 1952). According to Baumeister and Vohs (2007), "Secondary or acquired drives are those that are culturally determined or learned, such as the drive to obtain money, intimacy, or social approval." Bridges (1936) adds, "Any acquired habit is a drive to some extent," which is influenced by development; "The primary drives become further differentiated and directed towards varying specific ends with increasing age." It seems likely that some movement behaviors (e.g., structured exercise) fall within this category. It should be noted that in previous manuscripts, I have indicated that wants and desires for movement may be primary (i.e., want for movement itself) versus secondary (e.g., want to move in order to achieve something else; Stults-Kolehmainen et al., 2022b). For instance, one may feel antsy and want to move (i.e., a primary want or desire), or one may want a drink of water and thus feel urged to get up and go the kitchen (i.e., a secondary want or desire).

The influence of drive on behavior

How does drive influence behavior? Nietzsche provided one way of describing how drives impact action, which is concordant with the notion of incentive salience (Berridge and Robinson, 1998; Salamone and Correa, 2002). As described by Conrad (2021),

> "The drives (1) identify features of the world as salient, (2) induce an affective response to that object [e.g., an urge or craving] that (3) justify a certain evaluation of the world consonant with that affective response, and (4) impel one toward a certain (set of) behavior(s). Put more parsimoniously, the drives are dispositional states that induce evaluative orientations."

Hull's formula

Hull (1943, 1952) was interested in creating precise formulas to predict behavior from drive, predicated on the idea of stimulus–response. In this case, the response was the "excitation potential" (${}_{S}E_{R}$) - the likelihood that stimulus (s) would result in response (r). His basic formula included: (1) drive strength (D), which was essentially the time of deprivation, and (2) habit strength (${}_{S}H_{R}$), conditioned from repeated reinforcing trials (Martens, 1971). Later, other factors in his formulas included: (3) intensity of the stimulus triggering the behavior (V), such as light or a bolus of carbohydrate, and (4) incentive (the potential pleasure that the stimulus can provide; K). Further developing more complex models, Hull added: (5) any delay to acquire the stimulus, (6) reactive inhibition or satiation resulting from continued exposure to the stimulus, (7) conditioned inhibition that does not dissipate over time, and other factors, such as the "reaction threshold." Importantly, the strongest responses are for stimuli that reduce tension (i.e., *negative reinforcement*) *while also enhancing pleasure* (i.e., *positive reinforcement*; Seward, 1956; Allen et al., 2017).

How this might apply to movement could be demonstrated in the following example. A child constrained to a desk will be conditioned to sitting (${}_{S}H_{R}$) as part of adapting to schoolwork but will also freely engage in movement during recess. A lack of movement over the course of morning studies results in drive (D) – a motivation state. Approaching the hour of recess is a stimulus that will activate an anticipatory response (V), and the incentive of playing a fun game provides a powerful forecasted reward (K). Moreover, any delay in recess beyond the normal time will result in growing arousal and discomfort (i.e., tension). "Drive" here may be observed with physical manifestations of tension, such as fidgeting, pacing, swaying, shifting of the body, sweating, etc. This affect may be modulated, however, by additional training to sit still. The eventual engagement in play will, more than likely, swiftly result in reduced tension, as predicted by Hull (1952).

Drive reduction theory

Hull's drive theory was not just a theory of how the organism responds to deprivation of needs (Hull, 1952). His Drive Reduction Theory was a paradigm of motivation, learning, and the development of habits. The organism is motivated to eliminate aversive feelings, which he later called cravings, and will behave to do so (Hilgard and Bower, 1975). In the case of hunger, it will feel peckish and will search for food (*via* movement) to reduce those pangs. Inevitably, the deprivation occurs again, and the organism repeats the behavior that previously reduced the drive, developing a habit. Importantly, reducing a sensation of drive was the principal reinforcement for human behavior (and not merely the attainment of pleasure, for instance).

Several criticisms of Drive Reduction Theory led to its relegation.

1. It is highly formulaic and unwieldy, and experimentation from Skinner provided cleaner experimental design (Skinner and Morse, 1958; Smith, 2000).
2. Not all human behavior has the goal of reducing tension. Clearly, humans are highly driven to attain pleasure (Young, 1966) and not just reduce arousal.
3. On the other hand, it is easy to observe contra-hedonic processes, in other words, pain seeking (Riediger et al., 2009).
4. Drive Reduction Theory was principally sidelined, however, because of observations that consumption of wanted and needed stimuli did not always result in reductions in drive and arousal.

To follow this last point, sometimes, there is increased arousal with consumption. A famous example is a person who leaves the comfort of sitting to ride a roller coaster – the sensation seeker looking for more tension (i.e., arousal) – not less (Brown, 1955). In the school recess example above, Hull's theory, as modified by Brown (1955), predicts that the play will result in increased arousal. Since this time, sensation seeking has been well accepted (Babbitt et al., 1990a,b; Rhodes and Smith, 2006). More recently, the idea that "some like it vigorous" (Ekkekakis et al., 2005); in other words, some people prefer strenuous levels of activity and can readily tolerate high intensities. Importantly, it appears that Hull conflated the concepts of displeasure with arousal in his ideas about tension. In these examples, there will be strong reduction in negative affect (i.e., reduced sense of displeasure) and enhanced positive affect, as commonly observed in studies of exercise (Jones and Zenko, 2021). Consequently, Drive Reduction Theory has faded; nevertheless, the idea of drive has persisted because it aligns with observed data (Allen et al., 2017).

Affectively-charged motivation states and the WANT model

Can Drive Reduction Theory be rehabilitated and melded with the widely accepted Hedonic Theory? In his thorough critique of both frameworks, Seward (1956) acknowledged that, "Since the two theories are not strictly incompatible, it is possible to accept both. Indeed, the foregoing evidence strongly indicates that both drive reduction and incentive play a part in reinforcement." Recent work has attempted to combine classic work on aspects of drive theory with hedonic theory and other recent frameworks of physical activity behavior (Brand and Ekkekakis, 2018; Stults-Kolehmainen et al., 2020a). I highlight the Wants and Aversions for Neuromuscular Tasks (WANT) model, which has been discussed extensively elsewhere (Stults-Kolehmainen et al., 2020a,b, 2021b, 2022a,b; Budnick et al., 2022; Filgueiras et al., 2022). In the WANT model, humans are motivated to reduce tension (as in Drive Reduction Theory) and to approach pleasure (as in Hedonic Theory; Young, 1966). Moreover, this model emphasizes the subjective feelings of wanting or desiring to move, which are called affectively-charged motivation states (ACMS). ACMS to move may be felt weakly, such as a want, or strongly, such as an urge or craving. Importantly though, while drive sensations (e.g., tense arousal), which are considered motivation states, are typically considered unpleasant, sensations of wanting to move may be experienced as pleasant. This is well documented, for instance, in the concepts of groove and swing (Janata et al., 2012, 2018; Stults-Kolehmainen et al., 2022b), which are the ability of music to stimulate pleasurable desires to move the body. Thus, ACMS and the WANT model incorporate affective tone. Interestingly, in a recent study, arousal was a stronger predictor of motivation states to move than affective valence (Budnick et al., 2022), and arousal and affective valence did not interact to predict ACMS (likely because the study was underpowered). Lastly, the WANT model includes dimensions of (A) Move versus Rest motivation combined with (B) approach and avoidance motivation (Skinner et al., 2009). In other words, there is also a drive to "not move" (see Criterion 12). Addressing both, Bridges (1936) comments, "[The child has] a tendency to arrestation of movement upon sudden extensive change or intense sensory impact. Accumulated experience makes of this reaction a drive to avoid the obnoxious and whatever threatens personal security," and "Advantageous rest pauses between explorations."

Problems with the concept of drive for movement

There are several serious challenges to the idea that bodily movement and exercise are basic needs resulting in drive processes. These have been addressed in other papers (Stults-Kolehmainen et al., 2020a, 2021b) but are worth extending in this current manuscript. To start, one might believe that movement is simply a *bodily function*, just like breathing, urination, or defecation – something organisms do that is devoid of motivation. However, one might make the case then that sexual behavior is simply a bodily function. Nonetheless, it is typically included as a drive - as it is essential for survival, at least as a species, but also because later in life progeny assist in extended care. In some sense, movement may be an even higher drive, a *superordinate drive* because it is necessary to acquire food, water and to engage in sex, etc. (the same case could be made for breathing). A second issue is that the drive to move is conflated with psychological drives, such as (a) the need for autonomy and independence (e.g., children learning to stand, walk), (b) as well as the needs for competence and productivity (e.g., attempts to accomplish things), (c) the need for social interaction (Tomova et al., 2020), and/or (d) the need for stimulation and sensation seeking (e.g., a need for thrills; Babbitt et al., 1990a,b; Watten, 1997; Rhodes and Smith, 2006; Ryan and Deci, 2007; Wilson et al., 2014). For example, conditions of being "cooped up" and "stir crazy" likely combine noticeable increases in the drive to move along with concomitant upticks in the drive for social interaction (Tomova et al., 2020). It is not within the scope of this manuscript to address this issue, but it could be the case that drives and wants are hierarchical, similar to the hierarchies delineated by Maslow (1943, 1987), Taormina and Gao (2013), or Sonstroem and Morgan (1989).

Does a drive to move need to exist?

A more significant critique could be stated as, "movement is just the means to the ends." In other words, movement is not reinforced in itself, and people do not move just for the sake of moving. To put it differently, movement is merely instrumental or utilitarian. It is true that movement accomplishes many things for us– it is a means to an end. It accomplishes, up until the modern age, almost everything needed for sustenance. Through movement, we may acquire food, labor to produce goods, propagate, even shake our muscles to become warm (Garland et al., 2011). Moreover, movement allows us to not only exploit, but also explore our world (Butler, 1953; Inzlicht et al., 2014) and to remove obstructions in the process. As Bridges (1936) notes, humans have a "strong utilitarian drive for adaptive exploitation" – accomplished by our limbs. Consequently, one might conclude that it requires no reinforcement as well as no drive to energize it.

Would a [strong] drive to move do more harm than good?

As established above, movement is very useful, but it comes at a cost and must be counter-balanced. Humans also strive to "avoid undue expenditure of energy," and "rest allows other interests to come into force and direct behavior" to allow "processes of organization and action planning or thought" to take place (Bridges, 1936). If movement was as lucrative as food or sleep, we may not stop, which would detract from other needs, mitigate adaptation and possibly be destructive to the body. Indeed, this is substantial risk for those with akathisia or exercise addiction/dependence (Lichtenstein and Jensen, 2016), and most well-trained athletes know the importance of balancing exercise and rest. Consequently, while classic drives have strong signals, like the drive for food (pangs or hunger) or the drive for sleep (tiredness), humans have developed relatively weak signals to move (as well as relatively weak signals to *not* sleep - e.g., when awakening). Furthermore, movement has been so instrumental and necessary for survival that strong signals to move were unnecessary. Up until the modern time, the drives for food, water, etc. (with their signals) were mostly sufficient to initiate and maintain necessary movement. Rather, we have strong signals to stop movement (i.e., pain and soreness). Nevertheless, the urge to rest is not simply a contra-drive in opposition to movement, but rather works in concert with it to maximize adaptation, an idea gaining greater ground (Stults-Kolehmainen et al., 2020a, 2021b, 2022a).

Appetite and appetence for movement

All of this being said, how do we rectify these issues with the fact that some people, and maybe many people, do move just for the sake of moving? Even when it is not necessary to move, people do it anyway. Likewise, people eat, rest, and have sex, even when there is no compelling need to do so, and there is no buildup of tension to release. These activities may all provide a source of pleasure, and engaging in them is not to just rid oneself of tension. However, it is generally agreed that movement and exercise are not highly pleasurable for most people, and aversions associated with movement may certainly be a large barrier for movement for some (McBeth et al., 2010). On the other hand, movement may not be a large source of aversive sensations either. With the balance of reinforcement at play, it might be concluded that movement is generally agreeable (Garland et al., 2011; Stults-Kolehmainen et al., 2020a). One can imagine that people have an "appetite" to move (Rowland, 1998), which has been called "appetence" (Ferreira et al., 2006). The drive and desire to move does exist, mostly because bodily movement is the vehicle by which we accomplish things, but it is regulated relatively without notice, usually only rising into awareness when it becomes disordered (e.g., Restless Legs Syndrome) or bothersome (with prolonged deprivation; Stults-Kolehmainen et al., 2022b) or when a person is specifically queried about it (Stults-Kolehmainen et al., 2020b, 2021b, 2022a).

If humans have a basic drive to move, why do not they?

This is a particularly vexing issue for some of those who are least active – middle-aged to older adults from WEIRD (i.e., Western, educated, industrialized, rich and democratic) populations (Henrich et al., 2010). One might argue that the need to move is a phenotype heterogeneously distributed across the population. I believe that a stronger argument, however, is again from Bridges (1936), who argues that drives are developmental and vary across the lifespan. It is obvious that most children have a strong drive to move. Easy is it to find a child that enjoys frolicking – engaging in playful movement, which is highly stimulating for growth, maturation and socialization (Stults-Kolehmainen et al., 2020a). Movement seems to be a strong drive from birth, peaking around the age of maximal physical development. In this regard, as one ages, the urge to move declines as it is less useful to develop the body and mind – there is a switch from an emphasis on development to maintenance and slowing down decay. In short, movement loses its "adaptive value" as one ages. Middle-aged and older people ostensibly experience diminished drive to move, and there is some evidence from a study that followed people for 2 years that the desire to move decreased with age (Stults-Kolehmainen et al., 2021b). It may also be the case that drive is attenuated through repeated pressure in childhood to remain still and control impulses (Seli et al., 2014). Observations such as these do not lead to a conclusion that there is no drive to move. Consider another basic drive – sex. Like movement - desire for sex varies across the lifetime. Children have apparently no drive for sex, and it ostensibly diminishes with age for most of the population. Simply put, just because children, the infirm and elderly have minimal libido does not mean that sex drive does not exist.

Drives are malleable to time and place - and certainly era as well. As with previous comments above, one should note that rapid technological advancement has changed the dynamics of desire, but not expunged them. As Bridges states (Bridges, 1936), a drive "undergoes processes of development and change of form in response to environmental condition."

Changes may follow several routes. Drives can be counter-conditioned according to Hull's (1943, 1952) basic formulas. For instance, children usually learn to sit and be still. Drives are also highly responsive to internal and external (i.e., endogenous and exogenous) environmental stimuli (Loewenstein, 1996). The modern, obesogenic world provides an overload of stimulation, but perhaps a lack of natural environmental stimuli (e.g., light, to which movement was ostensibly paired; Lake and Townshend, 2006; Wilson et al., 2014).

Competing stimuli and drive may overpower (i.e., overtake) or overshadow (e.g., drown out) drive for movement. Alternatively, the need for movement may be satiated by digital movement stimuli provided in rich content from social media memes, short video clips, television, and video games (Rowland, 1998). The average person is also much larger than before (Wong et al., 2022), and this increased size is associated with aversions to movement, such as painful sensations in the joints, skin friction, and other nuisances (Speck et al., 2014; Purim et al., 2015).

Future research

Negative reinforcement

Rapid progress is being made in theory development for physical activity, exercise and sedentary behaviors. However, the dominant perspective at this juncture is on affect and the reinforcing power of pleasure (Ekkekakis and Zenko, 2016; Williams and Bohlen, 2019; Jones and Zenko, 2021). Emphasis is also placed on punishment (experience of pain) and aversions associated with exercise, typically above ventilatory threshold (Ekkekakis et al., 2005, 2011). Negative reinforcement is typically considered in terms of reductions in anxiety and depressed mood and the analgesic effect of exercise (for some people in some situations; Bartholomew et al., 1996, 2005; Busch et al., 2016). Rarely are the various sources of displeasure comprehensively included, however (Backhouse et al., 2007). In short, most models of physical activity motivation do not include basic drive, which may be a source of considerable displeasure, arousal, and tension for many people, particularly those who are healthy and younger, but also for those suffering from a wide range of conditions (Stults-Kolehmainen et al., 2022b). Future developments should consider all of these factors (see Table 2).

Appetitive versus reflective desires

Future research should consider interactions between: (1) appetitive (e.g., hedonic-oriented) and reflective (e.g., cognitive) sources of desire (Williams and Bohlen, 2019), (2) need states versus appetence, (3) primary versus secondary drives/wants and, (4) the various primary drives. For instance, when satiated with food, individuals report lower desire to move (Budnick et al., 2022), which may be related to processes of digestion. Basic drive, however, is not dependent on appetite or reflection and is highly automatic; thus, it should be considered within the domain of automaticity and Type 1 behavioral processes (Brand and Ekkekakis, 2018). Lastly, could subjective feelings of drive to move be misattributed to other sources of tension? Feelings of being antsy (due to a lack of movement) could be attributed to external sources of stress, such as work anxiety.

TABLE 2 Examples of sensations of tension that may result in physical movement.

		Source of stimulus*	
		Internal (Innate/ Endogenous)	External (Exogenous)
Valence of stimulus	Negative	Drive, pain, depressed mood	Work stress, social anxiety
	Positive	Runner's high	Groove†

*See Seward and Seward (1937).
†Sensation of wanting to move in response to music.

Measurement

Measuring drive continues to be a challenge and varies with one's definition of it (see above). The behavioral manifestations (e.g., locomotion) may be measured by direct observation (Galton, 1885) or with subjective (Seli et al., 2014) and objective measures of fidgeting, such as Nintendo Wii Balance boards (Seli et al., 2014). Tension, the result of deprivation (i.e., of movement) may be detected indirectly through tools that have been developed to measure affective valence (e.g., Feeling Scale) and arousal (e.g., Felt Arousal Scale). The transient want or need of movement (i.e., the subjectively felt motivation state) may also be measured with the CRAVE and ARGE scales, which have 13-item and 2-item versions (Stults-Kolehmainen et al., 2021b; Filgueiras et al., 2022). There is no known instrument to measure associated feelings (e.g., fidgetiness, restlessness, antsiness) and motor changes, such as trembling, shaking, raking of the limbs, etc. (Tiidus, 2008). Direct observation in the laboratory is sorely needed to witness and document these phenomena.

Mechanisms

These data should be combined with biomarkers likely associated with drive for activity, including orexin (i.e., hypocretin), leptin, testosterone, cortisol, dopamine, activity in the nucleus accumbens, ventral tegmental area and substantia nigra, vagal drive/HRV/RSA, genetics and the microbiome (Willerman, 1973; España et al., 2002; Salamone and Correa, 2002; Aoyagi et al., 2003; Furlong et al., 2009; Scheurink et al., 2010; Garland et al., 2011; Casper, 2022; Dohnalová et al., 2022). There is likely huge inter-individual variability in drive, which may be related to stress coping style, temperament, impulse control, personality, and other factors (Rhodes and Smith, 2006; Garland et al., 2011; Seli et al., 2014). Drive for specific types of movement, such as moving in short spurts, or for extended periods of time (Belke and Garland, 2007), may be associated with properties of muscle and may be conditioned as well.

Application

To research methods

The concept of drive might have general application for experimentation and data interpretation in exercise science. Frequently, study participants are asked to refrain from exercise before assessments and training protocols (Aoyagi et al., 2003; SantaBarbara et al., 2020) and/or to take time off from their normal routines (Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2014, 2016). This is ostensibly to ensure that participants have adequate energy, no muscle damage, and any effect of previous training is "washed out," particularly in within-subjects, randomized cross-over trials (Ballmann et al., 2021). However, it should also be considered that depriving movement for individuals accustomed to physical activity results in increased drive or motivation state, perhaps with noticeable increases in arousal, desire to move, and alterations to locomotion (e.g., increased fidgeting, pacing). Therefore, researchers should be mindful of this effect, and ideally, attempt to monitor it as it may influence psychomotor measures. The current author recounts a presentation at a prestigious medical school involving so-called "exercise" in rodents, where a psychiatric researcher presented a protocol that involved depriving rats of their running wheels for several days - and then permitting them access to wheels to observe the effects of "exercise". It may be more accurate to assert that such a protocol is a test of *depriving movement* as opposed to providing exercise, or perhaps both (Rhodes et al., 2003; Malisch et al., 2009; Garland et al., 2011). Such pitfalls could probably be avoided with careful design of experiments and appropriate timing of procedures.

To clinical practice

To reiterate, movement is a basic need and a primary drive, and loss of it may result in rapid decline of health. This is relevant for most of healthcare, but particularly true for surgery, where patients face extended time on the operating table (2+ hours) and days of bed rest. Various machines (e.g., "compression boots") are useful to prevent some of the ill effects of inactivity (e.g., blood clots; Keith et al., 1992). Enhanced recovery protocols (e.g., ERAS) require early ambulation at regular intervals (Pędziwiatr et al., 2018). Patients who engage in this movement gain faster recovery, less pressure ulcers, shorter hospital stays, and fewer complications (Adogwa et al., 2017). There is also potential for pain analgesia and less agitation. In short, exercise is medicine (Pedersen and Saltin, 2015), and movement must be prescribed the same as the dietary regimen, pain management, and breathing/spirometry exercises.

To primary education

Children are most susceptible to the effects of drive, and potentially have the most to gain from movement. Classrooms should be designed to allow for greater movement, and lessons should incorporate physical activity, within reason (Bartholomew and Jowers, 2011). Sometimes small changes to lesson planning (e.g., writing, then reading) can help children to dissipate drive, while also enhancing learning (Elbow, 2004). The benefits of regular playtime and recess from studies are substantial (Ramstetter et al., 2010).

Conclusion

The concept of drive, or motivational energy, as a precipitator of human behavior is an old but re-emerging idea - providing a unique and rarely-considered perspective on physical activity engagement. Drive is the impetus, often automatic and unconscious, to attain needs and thus restore homeostasis - returning to optimal conditions of functioning. Drive states have certain properties, as demonstrated above, such as the experience of deprivation, then tension, consumption, relief and satiation. They are under a large degree of homeostatic control but are also responsive to environmental stimuli and conditioning, including dimensions of approach and avoidance. More practically, it may be operationalized as a motivation state, characterized by negative affect, arousal, and a desire to acquire a need. Older theories of behavior highlighting drive, such as Drive Reduction Theory, have been largely sidelined in favor of higher performing models. Regardless, one may argue that movement is a primary need for most humans, most notably in younger years, but perhaps continuing well into older age. Biological processes evolved in physical bodies that moved, making these functions optimized under such conditions. As such, the need for movement can provide a significant source of tension, the relief of which is negative reinforcement – potentially strengthening the physical activity response. This tension may be measured with the CRAVE and ARGE scales, new instruments developed to evaluate desires, wants, urges, and cravings for physical activity (Stults-Kolehmainen et al., 2021b; Filgueiras et al., 2022). Conditions of being constrained or otherwise deprived of movement may result in alterations in motivation states, along with stoked feelings of being antsy, fidgety, and restless, resulting in concomitant changes in non-exercise activity thermogenesis (NEAT). However, comprehensive studies have yet to be earnestly conducted in humans. Nevertheless, this conceptualization may be useful for generating new models of behavior, such as the WANT model (Stults-Kolehmainen et al., 2020a), which will boost our understanding of movement behaviors, including physical activity and exercise.

Data availability statement

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Acknowledgments

Thanks to Brandon Alderman (Rutgers University, New Brunswick, NJ), Sunao Akashi Slayton (Smilow Cancer Hospital, Yale New Haven Hospital, New Haven CT), Riley Avila (Teachers College – Columbia University, New York, NY), Jessica L. Barker (University of Minnesota, St. Paul, MN), Amanda Divin (Texas A&M University, Commerce, TX), Paul McKee (Duke University, Raleigh, NC), Fabio Amador Bueno (Connecticut State Community College Nursing Program, New Haven, CT), Michael Busa (University of Massachusetts, Amherst, MA), Rebecca Koenigsberg (Yale New Haven Hospital, New Haven, CT), Philip R. Stanforth (The University of Texas, Austin, TX), and John B. Bartholomew (The University of Texas, Austin, TX) for insights and technical assistance making this work possible. The leadership of Yale New Haven Hospital (Division of Digestive Health, New Haven, CT) is also greatly appreciated, including Rebecca Lamberti and Bethany Mulone.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adogwa, O., Elsamadicy, A. A., Fialkoff, J. D., ChenG, J. S., Khalid, S. I., Karikari, I. O., et al. (2017). Early ambulation decreases length of hospital stay, perioperative complications, and improves functional outcomes in elderly patients undergoing surgery for correction of adult degenerative scoliosis. *Spine J.* 17, S111–S112. doi: 10.1097/BRS.0000000000002189

Alderman, R. B. (1974). *Psychological behavior in sport*. Philadelphia, PA: WB Saunders Company.

Allen, W. E., Denardo, L. A., Chen, M. Z., Liu, C. D., Loh, K. M., Fenno, L. E., et al. (2017). Thirst-associated preoptic neurons encode an aversive motivational drive. *Science* 357, 1149–1155. doi: 10.1126/science.aan6747

American Psychological Association (2022). Drive [online]. APA. Available at: https://dictionary.apa.org/drive [Accessed December 17, 2022].

Aoyagi, N., Ohashi, K., and Yamamoto, Y. (2003). Frequency characteristics of long-term heart rate variability during constant-routine protocol. *Am. J. Phys. Regul. Integr. Comp. Phys.* 285, R171–R176. doi: 10.1152/ajpregu.00661.2002

Babbitt, T., Rowland, G., and Franken, R. (1990a). Sensation seeking and participation in aerobic exercise classes. *Personal. Individ. Differ.* 11, 181–183. doi: 10.1016/0191-8869(90)90011-f

Babbitt, T., Rowland, G. L., and Franken, R. E. (1990b). Sensation seeking - preoccupation with diet and exercise regiments. *Personal. Individ. Differ.* 11, 759–761. doi: 10.1016/0191-8869(90)90264-r

Backhouse, S. H., Ekkekakis, P., Biddle, S. J. H., Foskett, A., and Williams, C. (2007). Exercise makes people feel better but people are inactive: paradox or artifact? *J. Sport Exerc. Psychol.* 29, 498–517. doi: 10.1123/jsep.29.4.498

Bain, A. (1855). *The senses and the intellect*, London, John W. Parker & Son.

Baldwin, J. M. (1891). *Handbook of psychology: Feeling and will*, New York, Henry Holt & Company.

Baldwin, J. M. (1894). *Mental development in the child and the race: Methods and processes*., New York, Macmillan.

Ballmann, C. G., McCullum, M. J., Rogers, R. R., Marshall, M. R., and Williams, T. D. (2021). Effects of preferred vs. nonpreferred music on resistance exercise performance. *J. Strength Cond. Res.* 35, 1650–1655. doi: 10.1519/JSC.0000000000002981

Barker, J. L., Kolar, D., Lazzer, A. S.-D., and Keel, P. K. (2022). Exercise satiation: A novel theoretical conceptualization for problematic exercise observed in eating disorders. *Int. J. Eat. Disord.* 55, 176–179. doi: 10.1002/eat.23635

Barrett, L. F., Mesquita, B., Ochsner, K. N., and Gross, J. J. (2007). The experience of emotion. *Annu. Rev. Psychol.* 58, 373–403. doi: 10.1146/annurev.psych.58.110405.085709

Bartholomew, J. B., and Jowers, E. M. (2011). Physically active academic lessons in elementary children. *Prev. Med.* 52, S51–S54. doi: 10.1016/j.ypmed.2011.01.017

Bartholomew, J. B., Lewis, B. P., Linder, D. E., and Cook, D. B. (1996). Post-exercise analgesia: replication and extension. *J. Sports Sci.* 14, 329–334. doi: 10.1080/02640419608727718

Bartholomew, J. B., Morrison, D., and Ciccolo, J. T. (2005). Effects of acute exercise on mood and well-being in patients with major depressive disorder. *Med. Sci. Sports Exerc.* 37, 2032–2037. doi: 10.1249/01.mss.0000178101.78322.dd

Bartholomew, J. B., Stults-Kolehmainen, M. A., Elrod, C. C., and Todd, J. S. (2008). Strength gains after resistance training: the effect of stressful, negative life events. *J. Strength Cond. Res.* 22, 1215–1221. doi: 10.1519/JSC.0b013e318173d0bf

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* 117, 497–529. doi: 10.1037/0033-2909.117.3.497

Baumeister, R., and Vohs, K. (2007). *Drive theory. Encyclopedia of social psychology*. Thousand Oaks Thousand Oaks, California: SAGE Publications, Inc.

Beighle, A., Alderman, B., Morgan, C. F., and Masurier, G. L. (2008). Seasonality in children's pedometer-measured physical activity levels. *Res. Q. Exerc. Sport* 79, 256–260. doi: 10.1080/02701367.2008.10599488

Beitel, M., Stults-Kolehmainen, M., Cutter, C. J., Schottenfeld, R. S., Eggert, K., Madden, L. M., et al. (2016). Physical activity, psychiatric distress, and interest in exercise group participation among individuals seeking methadone maintenance treatment with and without chronic pain. *Am. J. Addict.* 25, 125–131. doi: 10.1111/ajad.12336

Belke, T. W., and Garland, T. (2007). A brief opportunity to run does not function as a reinforcer for mice selected for high daily wheel-running rates. *J. Exp. Anal. Behav.* 88, 199–213. doi: 10.1901/jeab.2007.88-199

Bennett, W. I. (1995). Beyond overeating. *N. Engl. J. Med.* 332, 673–674. doi: 10.1056/NEJM199503093321009

Berridge, K. C., and Robinson, T. E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Res. Rev.* 28, 309–369. doi: 10.1016/s0165-0173(98)00019-8

Biddle, S. J. H. (1995). "Exercise motivation across the life span" in *European perspective on exercise and sport psychology*. ed. S. J. H. Biddle (Champaign, IL: Human Kinetics)

Biddle, S. J. (2022). Barriers to physical activity: time to change? A preventive medicine Golden Jubilee editorial. *Prev. Med.* 163:107193. doi: 10.1016/j.ypmed.2022.107193

Blacutt, M., Filgueiras, A., and Stults-Kolehmainen, M. (2021). Prevalence and incidence of stress, depression, and anxiety symptoms among Brazilians in quarantine across the early phases of the Covid-19 crisis. *medRxiv*. doi: 10.1101/2021.09.07.21263246

Bouwens, J. M., Fasulo, L., Hiemstra-Van Mastrigt, S., Schultheis, U. W., Naddeo, A., and Vink, P. (2018). Effect of in-seat exercising on comfort perception of airplane passengers. *Appl. Ergon.* 73, 7–12. doi: 10.1016/j.apergo.2018.05.011

Bracha, H. S., Ralston, T. C., Matsukawa, J. M., Williams, A. E., and Bracha, A. S. (2004). Does "fight or flight" need updating? *Psychosomatics* 45, 448–449. doi: 10.1176/appi.psy.45.5.448

Brand, R., and Ekkekakis, P. (2018). Affective–reflective theory of physical inactivity and exercise. *German J. Exerc. Sport Res.* 48, 48–58. doi: 10.1007/s12662-017-0477-9

Bridges, K. M. B. (1936). The development of the primary drives in infancy. *Child Dev.* 7, 40–56.

Brown, J. S. (1955). Pleasure-seeking behavior and the drive-reduction hypothesis. *Psychol. Rev.* 62, 169–179. doi: 10.1037/h0047034

Budnick, C. J., Stults-Kolehmainen, M. A., Dadina, C., Bartholomew, J. B., Boullosa, D., Ash, G. I., et al. (2022). Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal. *SportRxiv*. doi: 10.51224/SRXIV.217

Bull, F. C., AL-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., et al. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* 54, 1451–1462. doi: 10.1136/bjsports-2020-102955

Busch, A. M., Ciccolo, J. T., Puspitasari, A. J., Nosrat, S., Whitworth, J. W., and Stults-Kolehmainen, M. (2016). Preferences for exercise as a treatment for depression. *Ment. Health Phys. Act.* 10, 68–72. doi: 10.1016/j.mhpa.2015.12.004

Butler, R. A. (1953). Discrimination learning by rhesus monkeys to visual-exploration motivation. *J. Comp. Physiol. Psychol.* 46, 95–98. doi: 10.1037/h0061616

Butt, D. S. (1976). *Psychology of sport*, New York, Van Nostrand Reinhold.

Cabanac, M. (2006a). "Exertion and pleasure from an evolutionary perspective" in *Psychobiology of physical activity*. eds. E. O. Acevedo and P. Ekkekakis (Champaign, IL: Human Kinetics)

Cabanac, M. (2006b). Sensory pleasure optimizes muscular work. *Clin. Invest. Med.* 29, 110–116.

Carver, C. S., and White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the Bis/BAS scales. *J. Pers. Soc. Psychol.* 67, 319–333. doi: 10.1037//0022-3514.67.2.319

Casper, R. C. (2018). Not the function of eating, but spontaneous activity and energy expenditure, reflected in "restlessness" and a "drive for activity" appear to be dysregulated in anorexia nervosa: treatment implications. *Front. Psychol.* 9:2303. doi: 10.3389/fpsyg.2018.02303

Casper, R. C. (2022). Restlessness and an increased urge to move (drive for activity) in anorexia nervosa may strengthen personal motivation to maintain caloric restriction and may augment body awareness and proprioception: A lesson from leptin Administration in Anorexia Nervosa. *Front. Psychol.* 13:885274. doi: 10.3389/fpsyg.2022.885274

Chekroud, S. R., Gueorguieva, R., Zheutlin, A. B., Paulus, M., Krumholz, H. M., Krystal, J. H., et al. (2018). Association between physical exercise and mental health in 1·2 million individuals in the USA between 2011 and 2015: a cross-sectional study. *Lancet Psychiatry* 5, 739–746. doi: 10.1016/S2215-0366(18)30227-X

Cheval, B., Radel, R., Neva, J. L., Boyd, L. A., Swinnen, S. P., Sander, D., et al. (2018). Behavioral and neural evidence of the rewarding value of exercise behaviors: A systematic review. *Sports Med.* 48, 1389–1404. doi: 10.1007/s40279-018-0898-0

Collier, G. H. (1970). Work- A weak reinforcer. *Trans. N. Y. Acad. Sci.* 32, 557–576.

Conrad, J. A. (2021). Drive theory, redux: a history and reconsideration of the drives. *Int. J. Psychoanal.* 102, 492–518. doi: 10.1080/00207578.2020.1848389

Conroy, D. E., and Berry, T. R. (2017). Automatic affective evaluations of physical activity. *Exerc. Sport Sci. Rev.* 45, 230–237. doi: 10.1249/jes.0000000000000120

Crane, J. D., MacNeil, L. G., Lally, J. S., Ford, R. J., Bujak, A. L., Brar, I. K., et al. (2015). Exercise-stimulated interleukin-15 is controlled by AMPK and regulates skin metabolism and aging. *Aging Cell* 14, 625–634. doi: 10.1111/acel.12341

Davis, C., and Woodside, D. B. (2002). Sensitivity to the rewarding effects of food and exercise in the eating disorders. *Compr. Psychiatry* 43, 189–194. doi: 10.1053/comp.2002.32356

De Geus, E. J., and DE Moor, M. H. (2011). "Genes, exercise, and psychological factors" in *Genetic and molecular aspects of sports performance*. eds. C. Bouchard and E. P. Hoff Man (Oxford: Blackwell Publishing)

De Sousa, A. F. M., Medeiros, A. R., Benitez-Flores, S., Del Rosso, S., Stults-Kolehmainen, M., and Boullosa, D. A. (2018b). Improvements in attention and cardiac autonomic modulation after a 2-weeks Sprint interval training program: A Fidelity approach. *Front. Physiol.* 9:241. doi: 10.3389/fphys.2018.00241

De Sousa, A. F. M., Medeiros, A., Del Rosso, S., Stults-Kolehmainen, M., and Boullosa, D. (2018a). The influence of exercise and physical fitness status on attention: a systematic review. *Int. Rev. Sport Exerc. Psychol.* 12, 202–234. doi: 10.1080/1750984x.2018.1455889

Deroshia, C. W., and Greenleaf, J. E. (1993). Performance and mood-state parameters during 30-day 6 degrees head-down bed rest with exercise training. *Aviat. Space Environ. Med.* 64, 522–527.

Dohnalová, L., Lundgren, P., Carty, J. R. E., Goldstein, N., Wenski, S. L., Nanudorn, P., et al. (2022). A microbiome-dependent gut–brain pathway regulates motivation for exercise. *Nature* 612, 739–747. doi: 10.1038/s41586-022-05525-z

Donnelly, J. E., Blair, S. N., Jakicic, J. M., Manore, M. M., Rankin, J. W., and Smith, B. K. (2009). Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med. Sci. Sports Exerc.* 41, 1532–1471. doi: 10.1249/MSS.0b013e3181ae46a1

Dunk, N. M., and Callaghan, J. P. (2010). Lumbar spine movement patterns during prolonged sitting differentiate low back pain developers from matched asymptomatic controls. *Work* 35, 3–14. doi: 10.3233/wor-2010-0953

Ekkekakis, P. (2013). "Pleasure from the exercising body: two centuries of changing outlooks in psychological thought" in *Routledge handbook of physical activity and mental health*. ed. P. Ekkekakis (New York: Routledge)

Ekkekakis, P., and Brand, R. (2021). "Exercise motivation from a post-cognitivist perspective: affective-reflective theory" in *Motivation and self-regulation in sport and exercise*. eds. C. Englert and I. Taylor (New York: Routledge)

Ekkekakis, P., Hall, E. E., and Petruzzello, S. J. (2005). Some like it vigorous: measuring individual differences in the preference for and tolerance of exercise intensity. *J. Sport Exerc. Psychol.* 27, 350–374. doi: 10.1123/jsep.27.3.350

Ekkekakis, P., Parfitt, G., and Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: decennial update and Progress towards a tripartite rationale for exercise intensity prescription. *Sports Med.* 41, 641–671. doi: 10.2165/11590680-000000000-00000

Ekkekakis, P., and Zenko, Z. (2016). "Escape from cognitivism: exercise as hedonic experience" in *Sport and exercise psychology research: From theory to practice*. eds. M. Raab, P. Wyllemann, R. Seiler, A. M. Elbe and A. Hatzigeorgiadis (Amsterdam: Elsevier)

Elbow, P. (2004). Write first: putting writing before reading is an effective approach to teaching and learning. *Educ. Leadersh.* 62, 8–14.

Emerson, K. G. (2020). Coping with being cooped up: social distancing during COVID-19 among 60+ in the United States. *Rev. Panam. Salud Publica* 44:e81. doi: 10.26633/RPSP.2020.81

España, R. A., Plahn, S., and Berridge, C. W. (2002). Circadian-dependent and circadian-independent behavioral actions of hypocretin/orexin. *Brain Res.* 943, 224–236. doi: 10.1016/S0006-8993(02)02653-7

Feige, K. (1976). Wesen und Problematik der Sportmotivation. *Sportunterricht* 5, 4–7.

Ferreira, A., Lamarque, S., Boyer, P., Perez-Diaz, F., Jouvent, R., and Cohen-Salmon, C. (2006). Spontaneous appetence for wheel-running: a model of dependency on physical activity in rat. *Eur. Psychiatry* 21, 580–588. doi: 10.1016/j.eurpsy.2005.02.003

Filgueiras, A., and Stults-Kolehmainen, M. (2022). Risk factors for potential mental illness among Brazilians in quarantine due to COVID-19. *Psychol. Rep.* 125, 723–741. doi: 10.1177/0033294120976628

Filgueiras, A., Stults-Kolehmainen, M. A., Boullosa, D., Sinha, R., Bartholomew, J. B., Mckee, P., et al. (2022). The CRAVE and ARGE scales for motivation states for physical activity and sedentarism: Brazilian Portuguese translation and single-item versions. *SportRxiv*. doi: 10.51224/SRXIV.224

Finger, F. W., and Mook, D. G. (1971). Basic drives. *Annu. Rev. Psychol.* 22, 1–38. doi: 10.1146/annurev.ps.22.020171.000245

Fiuza-Luces, C., Garatachea, N., Berger, N. A., and Lucia, A. (2013). Exercise is the real polypill. *Physiology* 28, 330–358. doi: 10.1152/physiol.00019.2013

Freud, S. (1964). "Three essays on the theory of sexuality" in *The standard edition of the complete psychological works of Sigmund Freud*. eds. J. Strachey and S. Freud (London: Vintage)

Frijda, N. H. (2016). The evolutionary emergence of what we call "emotions". *Cognit. Emot.* 30, 609–620. doi: 10.1080/02699931.2016.1145106

Fryar, C. D., Carroll, M. D., Gu, Q., Afful, J., and Ogden, C. L. (2021). Anthropometric reference data for children and adults: United States, 2015-2018. 3.

Furlong, T. M., Vianna, D. M. L., Liu, L., and Carrive, P. (2009). Hypocretin/orexin contributes to the expression of some but not all forms of stress and arousal. *Eur. J. Neurosci.* 30, 1603–1614. doi: 10.1111/j.1460-9568.2009.06952.x

Galton, F. (1885). The measure of fidget. *Nature* 32, 174–175. doi: 10.1038/032174b0

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., et al. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med. Sci. Sports Exerc.* 43, 1334–1359. doi: 10.1249/MSS.0b013e318213fefb

Garcia-Borreguero, D., Stillman, P., Benes, H., Buschmann, H., Chaudhuri, K. R., Rodriguez, V. M. G., et al. (2011). Algorithms for the diagnosis and treatment of restless legs syndrome in primary care. *BMC Neurol.* 11:12. doi: 10.1186/1471-2377-11-28

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychol. Rev.* 9, 277–295. doi: 10.1080/17437199.2013.876238

Garland, T., Schutz, H., Chappell, M. A., Keeney, B. K., Meek, T. H., Copes, L. E., et al. (2011). The biological control of voluntary exercise, spontaneous physical activity and daily energy expenditure in relation to obesity: human and rodent perspectives. *J. Exp. Biol.* 214, 206–229. doi: 10.1242/jeb.048397

Glaviano, N. R., Baellow, A., and Saliba, S. (2019). Elevated fear avoidance affects lower extremity strength and squatting kinematics in women with patellofemoral pain. *Athl. Train. Sports Health Care* 11, 192–200. doi: 10.3928/19425864-20181029-01

Gomersall, S. R., Maher, C., English, C., Rowlands, A. V., Dollman, J., Norton, K., et al. (2016). Testing the activitystat hypothesis: a randomised controlled trial. *BMC Public Health* 16:900. doi: 10.1186/s12889-016-3568-x

Greenleaf, J. E., and Kozlowski, S. (1982). Physiological consequences of reduced physical activity during bed rest. *Exerc. Sport Sci. Rev.* 10, 84–119.

Greenwood, B. N., and Fleshner, M. (2019). Voluntary wheel running: a useful rodent model for investigating mechanisms of stress robustness and exercise motivation. *Curr. Opin. Behav. Sci.* 28, 78–84. doi: 10.1016/j.cobeha.2019.02.001

Hausenblas, H. A., and Downs, D. S. (2002). Exercise dependence: a systematic review. *Psychol. Sport Exerc.* 3, 89–123. doi: 10.1016/s1469-0292(00)00015-7

Hauser, R. A., and Zesiewicz, T. A. (1997). Sertraline for the treatment of depression in Parkinson's disease. *Move. Dis.* 12, 756–759. doi: 10.1002/mds.870120522

Heilmaier, C., Theysohn, J. M., Maderwald, S., Kraff, O., Ladd, M. E., and Ladd, S. C. (2011). A large-scale study on subjective perception of discomfort during 7 and 1.5 T MRI examinations. *Bioelectromagnetics* 32, 610–619. doi: 10.1002/bem.20680

Henrich, J., Heine, S. J., and Norenzayan, A. (2010). Most people are not WEIRD. *Nature* 466:29. doi: 10.1038/466029a

Herring, M. P., and O'connor, P. J. (2009). The effect of acute resistance exercise on feelings of energy and fatigue. *J. Sports Sci.* 27, 701–709. doi: 10.1080/02640410902777385

Higgins, S., Pomeroy, A., Bates, L. C., Paterson, C., Barone Gibbs, B., Pontzer, H., et al. (2022). Sedentary behavior and cardiovascular disease risk: an evolutionary perspective. *Front. Physiol.* 13:962791. doi: 10.3389/fphys.2022.962791

Hilgard, E. R., and Bower, G. H. (1975). *Theories of learning*, Englewood Cliffs, NJ, Prentice-Hall.

Hill, W. F. (1956). Activity as an autonomous drive. *J. Comp. Physiol. Psychol.* 49, 15–19. doi: 10.1037/h0044786

Hull, C. L. (1943). *Principles of behavior: An introduction to behavior theory*., New York, Appleton-Century.

Hull, C. L. (1952). *A behavior system; an introduction to behavior theory concerning the individual organism*. New Haven, CT: Yale University Press.

Hyde, E. T., Whitfield, G. P., Omura, J. D., Fulton, J. E., and Carlson, S. A. (2021). Trends in meeting the physical activity guidelines: muscle-strengthening alone and combined with aerobic activity, United States, 1998–2018. *J. Phys. Act. Health* 18, S37–S44. doi: 10.1123/jpah.2021-0077

Inzlicht, M., Schmeichel, B. J., and Macrae, C. N. (2014). Why self-control seems (but may not be) limited. *Trends Cogn. Sci.* 18, 127–133. doi: 10.1016/j.tics.2013.12.009

Iqbal, N., Lambert, T., and Masand, P. (2007). Akathisia: problem of history or concern of today. *CNS Spectr.* 12, 1–16. doi: 10.1017/s1092852900026201

Ishizaki, Y., Ishizaki, T., Fukuoka, H., Kim, C. S., Fujita, M., Maegawa, Y., et al. (2002). Changes in mood status and neurotic levels during a 20-day bed rest. *Acta Astronaut.* 50, 453–459. doi: 10.1016/s0094-5765(01)00189-8

James, W. (1907). The energies of men. *Philos. Rev.* 16, 1–20. doi: 10.2307/2177575

Janata, P., Peterson, J., Ngan, C., Keum, B., Whiteside, H., and Ran, S. (2018). Psychological and musical factors underlying engagement with unfamiliar music. *Music. Percept.* 36, 175–200. doi: 10.1525/mp.2018.36.2.175

Janata, P., Tomic, S. T., and Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *J. Exp. Psychol. Gen.* 141, 54–75. doi: 10.1037/a0024208

Jarrett, O. S., Maxwell, D. M., Dickerson, C., Hoge, P., Davies, G., and Yetley, A. (1998). Impact of recess on classroom behavior: group effects and individual differences. *J. Educ. Res.* 92, 121–126. doi: 10.1080/00220679809597584

Jones, L., and Zenko, Z. (2021). "Strategies to facilitate more pleasant exercise experiences" in *Essentials of exercise and sport psychology: An open access textbook*. eds. Z. Zenko and L. Jones (Society for Transparency, Openness, and Replication in Kinesiology), 242–270.

Kalupahana, N. S., Moustaid-Moussa, N., Kim, J. H., Voy, B. H., Bassett, D., Bray, M. S., et al. (2011). "The regulation of physical activity by genetic mechanisms: is there a drive to be active?" in *Genetic and molecular aspects of sport performance*. eds. C. Bouchard and E. P. Hoffman (Hoboken, NJ: John Wiley & Sons)

Kaplan, G. B., Greenblatt, D. J., Ehrenberg, B. L., Goddard, J. E., Cotreau, M. M., Harmatz, J. S., et al. (1997). Dose-dependent pharmacokinetics and psychomotor effects of caffeine in humans. *J. Clin. Pharmacol.* 37, 693–703. doi: 10.1002/j.1552-4604.1997.tb04356.x

Katsafanas, P. (2018). "The Emergence of the Drive Concept and the Collapse of the Animal/ Human Divide", *Animals: A History, OXFORD PHILOSOPHICAL CONCEPTS*. eds. P. Adamson and G. Fay Edwards (New York: Oxford Academic).

Keith, S. L., Mclaughlin, D. J., Anderson, F. A., Cardullo, P. A., Jones, C. E., Rohrer, M. J., et al. (1992). Do graduated compression stockings and pneumatic boots have an additive effect on the peak velocity of venous blood flow? *Arch. Surg.* 127, 727–730. doi: 10.1001/archsurg.1992.01420060107016

Khan, F. H., Ahlberg, C. D., Chow, C. A., Shah, D. R., and Koo, B. B. (2017). Iron, dopamine, genetics, and hormones in the pathophysiology of restless legs syndrome. *J. Neurol.* 264, 1634–1641. doi: 10.1007/s00415-017-8431-1

Khmaladze, I., Leonardi, M., Fabre, S., Messaraa, C., and Mavon, A. (2020). The skin interactome: a holistic "genome-microbiome-exposome" approach to understand and modulate skin health and aging. *Clin. Cosmet. Investig. Dermatol.* 13, 1021–1040. doi: 10.2147/CCID.S239367

Kim, Y. S., Park, Y. S., Allegrante, J. P., Marks, R., Ok, H., Ok Cho, K., et al. (2012). Relationship between physical activity and general mental health. *Prev. Med.* 55, 458–463. doi: 10.1016/j.ypmed.2012.08.021

King, N. A., Caudwell, P., Hopkins, M., Byrne, N. M., Colley, R., Hills, A. P., et al. (2007). Metabolic and behavioral compensatory responses to exercise interventions: barriers to weight loss. *Obesity* 15, 1373–1383. doi: 10.1038/oby.2007.164

Lake, A., and Townshend, T. (2006). Obesogenic environments: exploring the built and food environments. *J. R. Soc. Promot. Heal.* 126, 262–267. doi: 10.1177/1466424006070487

Landers, D. M. (1980). The arousal-performance relationship revisited. *Res. Q. Exerc. Sport* 51, 77–90. doi: 10.1080/02701367.1980.10609276

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., et al. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 380, 219–229. doi: 10.1016/s0140-6736(12)61031-9

Levine, J. A., Eberhardt, N. L., and Jensen, M. D. (1999). Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science* 283, 212–214. doi: 10.1126/science.283.5399.212

Levine, J. A., Lanningham-Foster, L. M., Mccrady, S. K., Krizan, A. C., Olson, L. R., Kane, P. H., et al. (2005). Interindividual variation in posture allocation: possible rote in human obesity. *Science* 307, 584–586. doi: 10.1126/science.1106561

Levitt, A. J., Joffe, R. T., Moul, D. E., Lam, R. W., Teicher, M. H., Lebegue, B., et al. (1993). Side effects of light therapy in seasonal affective disorder. *Am. J. Psychiatry* 150, 650–652. doi: 10.1176/ajp.150.4.650

Lichtenstein, M. B., and Jensen, T. T. (2016). Exercise addiction in CrossFit: prevalence and psychometric properties of the exercise addiction inventory. *Addict. Behav. Rep.* 3, 33–37. doi: 10.1016/j.abrep.2016.02.002

Lilly, J. C. (2022). The Isolation Tank Experiences [Online]. Available AT: http://www.johnclilly.com/stagesx.html [Accessed December 18, 2022 2022].

Loewenstein, G. (1996). Out of control: visceral influences on behavior. *Organ. Behav. Hum. Decis. Process.* 65, 272–292. doi: 10.1006/obhd.1996.0028

Lore, R. K. (1968). Activity-drive hypothesis: effects of activity restriction. *Psychol. Bull.* 70, 566–574. doi: 10.1037/h0026780

Lundberg, M., Larsson, M., Ostlund, H., and Styf, J. (2006). Kinesiophobia among patients with musculoskeletal pain in primary healthcare. *J. Rehabil. Med.* 38, 37–43. doi: 10.1080/16501970510041253

Lutz, R. S., Stults-Kolehmainen, M. A., and Bartholomew, J. B. (2010). Exercise caution when stressed: stages of change and the stress-exercise participation relationship. *Psychol. Sport Exerc.* 11, 560–567. doi: 10.1016/j.psychsport.2010.06.005

Malisch, J. L., Breuner, C. W., Kolb, E. M., Wada, H., Hannon, R. M., Chappell, M. A., et al. (2009). Behavioral despair and home-cage activity in mice with chronically elevated baseline corticosterone concentrations. *Behav. Genet.* 39, 192–201. doi: 10.1007/s10519-008-9246-8

Marrow, A. J. (1977). *The practical theorist: The life and work of Kurt Lewin*. New York, NY: Teachers College Press.

Martens, R. (1971). Anxiety and motor behavior: A review. *J. Mot. Behav.* 3, 151–179. doi: 10.1080/00222895.1971.10734899

Martens, R. (1974). Arousal and motor performance. *Exerc. Sport Sci. Rev.* 2, 155–188.

Maslow, A. H. (1943). A theory of human motivation. *Psychol. Rev.* 50, 370–396. doi: 10.1037/h0054346

Maslow, A. H. (1987). *Motivation and personality*, Boston, MA, Addison-Wesley.

Mcbeth, J., Nicholl, B. I., Cordingley, L., Davies, K. A., and Macfarlane, G. J. (2010). Chronic widespread pain predicts physical inactivity: results from the prospective EPIFUND study. *Eur. J. Pain* 14, 972–979. doi: 10.1016/j.ejpain.2010.03.005

Mcdonnell, E. I., Zipunnikov, V., Schrack, J. A., Goldsmith, J., and Wrobel, J. (2022). Registration of 24-hour accelerometric rest-activity profiles and its application to human chronotypes. *Biol. Rhythm. Res.* 53, 1299–1319. doi: 10.1080/09291016.2021.1929673

Mohiyeddini, C., Bauer, S., and Semple, S. (2013). Displacement behaviour is associated with reduced stress levels among men but not women. *PLoS One* 8:e56355. doi: 10.1371/journal.pone.0056355

Mondin, G. W., Morgan, W. P., Piering, P. N., Stegner, A. J., Stotesbery, C. L., Trine, M. R., et al. (1996). Psychological consequences of exercise deprivation in habitual exercisers. *Med. Sci. Sports Exerc.* 28, 1199–1203. doi: 10.1097/00005768-199609000-00018

Morgan, P. M., Salacinski, A. J., and Stults-Kolehmainen, M. A. (2013). The acute effects of flotation restricted environmental stimulation technique on recovery from maximal eccentric exercise. *J. Strength Cond. Res.* 27, 3467–3474. doi: 10.1519/JSC.0b013e31828f277e

Musumeci, G., Trovato, F. M., Pichler, K., Weinberg, A. M., Loreto, C., and Castrogiovanni, P. (2013). Extra-virgin olive oil diet and mild physical activity prevent cartilage degeneration in an osteoarthritis model: an in vivo and in vitro study on lubricin expression. *J. Nutr. Biochem.* 24, 2064–2075. doi: 10.1016/j.jnutbio.2013.07.007

Panksepp, J. (2006). Emotional endophenotypes in evolutionary psychiatry. *Prog. Neuro-Psychopharmacol. Biol. Psychiatry* 30, 774–784. doi: 10.1016/j.pnpbp.2006.01.004

Panksepp, J., and Biven, L. (2012). *The archaeology of mind. Neuroevolutionary origins of human emotions*, New York, Norton: W. W. Norton & Company, NY, NY.

Parker, P. R. L., Brown, M. A., Smear, M. C., and Niell, C. M. (2020). Movement-related signals in sensory areas: roles in natural behavior. *Trends Neurosci.* 43, 581–595. doi: 10.1016/j.tins.2020.05.005

Pearce, M., Garcia, L., Abbas, A., Strain, T., Schuch, F. B., Golubic, R., et al. (2022). Association between physical activity and risk of depression: A systematic review and meta-analysis. *JAMA Psychiatry* 79, 550–559. doi: 10.1001/jamapsychiatry.2022.0609

Pedersen, B. K., and Saltin, B. (2015). Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scand. J. Med. Sci. Sports* 25, 1–72. doi: 10.1111/sms.12581

Pędziwiatr, M., Mavrikis, J., Witowski, J., Adamos, A., Major, P., Nowakowski, M., et al. (2018). Current status of enhanced recovery after surgery (ERAS) protocol in gastrointestinal surgery. *Med. Oncol.* 35:95. doi: 10.1007/s12032-018-1153-0

Perry, S. E., Hockenberry, M. J., Cashion, M. C., Alden, K. R., Olshansky, E., and Lowdermilk, D. L. (2022). *Maternal child nursing care-E-book* Elsevier Health Sciences. https://www.elsevier.com/books/maternal-child-nursing-care/perry/978-0-323-77671-4

Purim, K. S. M., Titski, A. C. K., and Leite, N. (2015). Dermatological aspects influencing the practice of physical activities by obese individuals. *Fisioterapia em Movimento* 28, 837–850. doi: 10.1590/0103-5150.028.004.AR02

Rabkin, J. G., Mcelhiney, M. C., Rabkin, R., and Ferrando, S. J. (2004). Modafinil treatment for fatigue in HIV+ patients: a pilot study. *J. Clin. Psychiatry* 65, 1688–1695. doi: 10.4088/jcp.v65n1215

Raichlen, D. A., Pontzer, H., Zderic, T. W., Harris, J. A., Mabulla, A. Z., Hamilton, M. T., et al. (2020). Sitting, squatting, and the evolutionary biology of human inactivity. *Proc. Natl. Acad. Sci.* 117, 7115–7121. doi: 10.1073/pnas.1911868117

Ramstetter, C. L., Murray, R., and Garner, A. S. (2010). The crucial role of recess in schools. *J. Sch. Health* 80, 517–526. doi: 10.1111/j.1746-1561.2010.00537.x

Ravussin, E., Lillioja, S., Anderson, T. E., Christin, L., and Bogardus, C. (1986). Determinants of 24-hour energy expenditure in man. Methods and results using a respiratory chamber. *J. Clin. Invest.* 78, 1568–1578. doi: 10.1172/JCI112749

Reardon, J., Payan, J., Miller, C., and Alexander, J. (2008). Optimal class length in marketing undergraduate classes: an examination of preference, instructor evaluations, and student performance. *J. Mark. Educ.* 30, 12–20. doi: 10.1177/0273475307312193

Rebar, A. L., Gardner, B., Rhodes, R. E., and Verplanken, B. (2018). "The measurement of habit" in *The psychology of habit: theory, mechanisms, change, and contexts*. ed. B. Verplanken (Cham: Springer International Publishing)

Reiss, S. (2004). Multifaceted nature of intrinsic motivation: the theory of 16 basic desires. *Rev. Gen. Psychol.* 8, 179–193. doi: 10.1037/1089-2680.8.3.179

Rhodes, J. S., Garland, T. Jr., and Gammie, S. C. (2003). Patterns of brain activity associated with variation in voluntary wheel-running behavior. *Behav. Neurosci.* 117, 1243–1256. doi: 10.1037/0735-7044.117.6.1243

Rhodes, R. E., Mcewan, D., and Rebar, A. L. (2019). Theories of physical activity behaviour change: a history and synthesis of approaches. *Psychol. Sport Exerc.* 42, 100–109. doi: 10.1016/j.psychsport.2018.11.010

Rhodes, R. E., and Smith, N. E. I. (2006). Personality correlates of physical activity: a review and meta-analysis. *Br. J. Sports Med.* 40, 958–965. doi: 10.1136/bjsm.2006.028860

Riediger, M., Schmiedek, F., Wagner, G. G., and Lindenberger, U. (2009). Seeking pleasure and seeking pain: differences in prohedonic and contra-hedonic motivation from adolescence to old age. *Psychol. Sci.* 20, 1529–1535. doi: 10.1111/j.1467-9280.2009.02473.x

Robinson, M. J. F., and Berridge, K. C. (2013). Instant transformation of learned repulsion into motivational "wanting". *Curr. Biol.* 23, 282–289. doi: 10.1016/j.cub.2013.01.016

Rosenberger, M. E., Fulton, J. E., Buman, M. P., Troiano, R. P., Grandner, M. A., Buchner, D. M., et al. (2019). The 24-hour activity cycle: A new paradigm for physical activity. *Med. Sci. Sports Exerc.* 51, 454–464. doi: 10.1249/mss.0000000000001811

Rowland, T. W. (1998). The biological basis of physical activity. *Med. Sci. Sports Exerc.* 30, 392–399. doi: 10.1097/00005768-199803000-00009

Rowland, T. W. (1999). Adolescence: A" risk factor" for physical inactivity. President's Council on Physical Fitness and Sports Research Digest.

Rowland, T. (2016). *Biologic regulation of physical activity*. Champaign, IL: Human Kinetics.

Ryan, R. M., and Deci, E. L. (2007). "Active human nature: self-determination theory and the promotion and maintenance of sport, exercise and health" in *Intrinsic motivation and self-determination in exercise and sport*. eds. M. S. Haggar and N. L. D. Chatzisarantis (Champaign, IL: Human Kinetics)

Salamone, J. D., and Correa, M. (2002). Motivational views of reinforcement: implications for understanding the behavioral functions of nucleus accumbens dopamine. *Behav. Brain Res.* 137, 3–25. doi: 10.1016/s0166-4328(02)00282-6

Santabarbara, N. J., Nosrat, S., Whitworth, J. W., and Ciccolo, J. T. (2020). Acute psychological effects of resistance exercise in men with symptoms of muscle dysmorphia: a pilot study. *J. Strength Cond. Res.* 37, 277–283. doi: 10.1519/jsc.0000000000003615

Scherder, E. J. A., Bogen, T., Eggermont, L. H. P., Hamers, J. P. H., and Swaab, D. F. (2010). The more physical inactivity, the more agitation in dementia. *Int. Psychogeriatr.* 22, 1203–1208. doi: 10.1017/S1041610210001493

Scheurink, A. J. W., Boersma, G. J., Nergardh, R., and Sodersten, P. (2010). Neurobiology of hyperactivity and reward: agreeable restlessness in anorexia nervosa. *Physiol. Behav.* 100, 490–495. doi: 10.1016/j.physbeh.2010.03.016

Schultheiss, O. C., and Wirth, M. M. (2008). *Biopsychological aspects of motivation. Motivation and action, 2nd*. New York, NY, US: Cambridge University Press.

Seli, P., Carriere, J. S., Thomson, D. R., Cheyne, J. A., Martens, K. A. E., and Smilek, D. (2014). Restless mind, restless body. *J. Exp. Psychol. Learn. Mem. Cogn.* 40, 660–668. doi: 10.1037/a0035260

Seward, J. P. (1956). Drive, incentive, and reinforcement. *Psychol. Rev.* 63, 195–203. doi: 10.1037/h0048229

Seward, G., and Seward, J. P. (1937). Internal and external determinants of drives. *Psychol. Rev.* 44, 349–363.

Shalev, S. (2008). A Sourcebook on Solitary Confinement. *SSRN Electronic Journal*. doi: 10.2139/ssrn.2177495

Shirley, M. (1929). Spontaneous activity. *Psychol. Bull.* 26, 341–365. doi: 10.1037/h0073516

Sinha, N., Manohar, S., and Husain, M. (2013). Impulsivity and apathy in Parkinson's disease. *J. Neuropsychol.* 7, 255–283. doi: 10.1111/jnp.12013

Skinner, G. W., Mitchell, D., and Harden, L. M. (2009). Avoidance of physical activity is a sensitive indicator of illness. *Physiol. Behav.* 96, 421–427. doi: 10.1016/j.physbeh.2008.11.004

Skinner, B. F., and Morse, W. H. (1958). Fixed-interval reinforcement of running in a wheel. *J. Exp. Anal. Behav.* 1, 371–379. doi: 10.1901/jeab.1958.1-371

Smith, L. (2000) in *Encyclopedia of psychology*. ed. A. E. Kazdin (New York: Oxford University Press)

Sonstroem, R. J., and Morgan, W. P. (1989). Exercise and self-esteem: rationale and model. *Med. Sci. Sports Exerc.* 21, 329–337. doi: 10.1249/00005768-198906000-00018

Speck, R. M., Bond, D. S., Sarwer, D. B., and Farrar, J. T. (2014). A systematic review of musculoskeletal pain among bariatric surgery patients: implications for physical activity and exercise. *Surg. Obes. Relat. Dis.* 10, 161–170. doi: 10.1016/j.soard.2013.08.001

Spence, K. W. (1956). *Behavior theory and conditioning*, New Haven, CT, Yale University.

Stults-Kolehmainen, M. A., and Bartholomew, J. B. (2012). Psychological stress impairs short-term muscular recovery from resistance exercise. *Med. Sci. Sports Exerc.* 44, 2220–2227. doi: 10.1249/MSS.0b013e31825f67a0

Stults-Kolehmainen, M. A., Bartholomew, J. B., and Sinha, R. (2014). Chronic psychological stress impairs recovery of muscular function and somatic sensations over a 96 hour period. *J. Strength Cond. Res.* 28, 2007–2017. doi: 10.1519/JSC.0000000000000335

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Boullosa, D., Janata, P., Koo, B. B., et al. (2022b). Urges to move and other motivation states for physical activity in clinical and healthy populations: A scoping review protocol. *Front. Psychol.* 13:901272. doi: 10.3389/fpsyg.2022.901272

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Gilson, T. A., Ash, G. I., Mckee, P. C., et al. (2020a). Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front. Psychol.* 11:568390. doi: 10.3389/fpsyg.2020.568390

Stults-Kolehmainen, M. A., Blacutt, M., Fogelman, N., Gilson, T. A., Stanforth, P. R., Divin, A. L., et al. (2021b). Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front. Psychol.* 12:568286. doi: 10.3389/fpsyg.2021.568286

Stults-Kolehmainen, M. A., Blacutt, M., Gilson, T. A., Stanforth, P., Divin, A. L., Bartholomew, J. B., et al. (2020b). I want to move my body - right now! The CRAVE scale to measure state motivation for physical activity and sedentary behavior. *MedrXiv*. doi: 10.1101/2020.08.31.20184945

Stults-Kolehmainen, M. A., Ciccolo, J. T., Bartholomew, J. B., Seifert, J., and Portman, R. S. (2013a). Age and gender-related changes in exercise motivation among highly active individuals. *Athletic Insight* 5, 45–63.

Stults-Kolehmainen, M., Filgueiras, A., and Blacutt, M. (2021a). Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. *medRxiv* 2020.05.12.20099374. doi: 10.1101/2020.05.12.20099374

Stults-Kolehmainen, M. A., Gilson, T. A., and Abolt, C. J. (2013b). Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. *J. Sport Behav.* 36, 306–327.

Stults-Kolehmainen, M., Gilson, T., Santabarbara, N., Mckee, P., Sinha, R., Bartholomew, J., et al. (2022a). Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups. *SportRxiv*. doi: 10.51224/SRXIV.189

Stults-Kolehmainen, M. A., Lu, T., Ciccolo, J. T., Bartholomew, J. B., Brotnow, L., and Sinha, R. (2016). Higher chronic psychological stress is associated with blunted affective responses to strenuous resistance exercise: RPE, pleasure, pain. *Psychol. Sport Exerc.* 22, 27–36. doi: 10.1016/j.psychsport.2015.05.004

Stults-Kolehmainen, M. A., and Sinha, R. (2014). The effects of stress on physical activity and exercise. *Sports Med.* 44, 81–121. doi: 10.1007/s40279-013-0090-5

Sugawara, J., Murakami, H., Maeda, S., Kuno, S., and Matsuda, M. (2001). Change in post-exercise vagal reactivation with exercise training and detraining in young men. *Eur. J. Appl. Physiol.* 85, 259–263. doi: 10.1007/s004210100443

Szondi, L. (1972). *Lehrbuch der Experimentellen Triebdiagnostik, Bd. 2, Testband*. München, Ausdrucksformen. Eine Studie zu den Szondi-Test-Personen.

Taormina, R. J., and Gao, J. H. (2013). Maslow and the motivation hierarchy: measuring satisfaction of the needs. *Am. J. Psychol.* 126, 155–177. doi: 10.5406/amerjpsyc.126.2.0155

Tenenbaum, G., and Bar-Eli, M. (1995). *Personality and intellectual capabilities in sport psychology*. International Handbook of Personality and Intelligence. Plenum Press.

Tiidus, P. M. (2008). *Skeletal muscle damage and repair*, Champaign, IL, Human Kinetics.

Tolman, E. C. (1932). *Purposive behavior in animals and men*, London, England, Century/Random House UK.

Tomova, L., Wang, K. L., Thompson, T., Matthews, G. A., Takahashi, A., Tye, K. M., et al. (2020). Acute social isolation evokes midbrain craving responses similar to hunger. *Nat. Neurosci.* 23, 1597–1605. doi: 10.1038/s41593-020-00742-z

Troisi, A. (2002). Displacement activities as a behavioral measure of stress in nonhuman primates and human subjects. *Stress Int. J. Biol. Stress* 5, 46–53. doi: 10.1080/10253890290012378

Tucker, P., and Gilliland, J. (2007). The effect of season and weather on physical activity: A systematic review. *Public Health* 121, 909–922. doi: 10.1016/j.puhe.2007.04.009

Usdhhs (2018). *2018 physical activity guidelines advisory committee scientific report*. Washington, DC: U.S. Department of Health and Human Services.

Ussery, E. N., Whitfield, G. P., Fulton, J. E., Galuska, D. A., Matthews, C. E., Katzmarzyk, P. T., et al. (2021). Trends in self-reported sitting time by physical activity levels among US adults, NHANES 2007/2008–2017/2018. *J. Phys. Act. Health* 18, S74–S83. doi: 10.1123/jpah.2021-0221

Vicente-Rodríguez, G. (2006). How does exercise affect bone development during growth? *Sports Med.* 36, 561–569. doi: 10.2165/00007256-200636070-00002

Walton-Geer, P. S. (2009). Prevention of pressure ulcers in the surgical patient. *AORN J.* 89, 538–552. doi: 10.1016/j.aorn.2008.12.022

Watten, R. G. (1997). Use of drugs, coping styles, mental absorption and some outcomes related to health and social activity. *Eur. Addict. Res.* 3, 192–198. doi: 10.1159/000259177

Westerterp, K. R. (2018). Exercise, energy balance and body composition. *Eur. J. Clin. Nutr.* 72, 1246–1250. doi: 10.1038/s41430-018-0180-4

Wilde-Frenz, J., and Schulz, H. (1983). Rate and distribution of body movements during sleep in humans. *Percept. Mot. Skills* 56, 275–283. doi: 10.2466/pms.1983.56.1.275

Willerman, L. (1973). Activity level and hyperactivity in twins. *Child Dev.* 44, 288–293. doi: 10.2307/1128049

Williams, D. M. (2023). A meta-theoretical framework for organizing and integrating theory and research on motivation for health-related behavior. *Front. Psychol.* 14:1130813. doi: 10.3389/fpsyg.2023.1130813

Williams, D. M., and Bohlen, L. C. (2019). "Motivation for exercise: Reflective desire versus hedonic dread" in *APA handbook of sport and exercise psychology, volume 2: Exercise psychology*. eds. M. H. Anshel, S. J. Petruzzello and E. E. Labbé (Washington, DC, US: American Psychological Association)

Wilson, T. D., Reinhard, D. A., Westgate, E. C., Gilbert, D. T., Ellerbeck, N., Hahn, C., et al. (2014). Just think: the challenges of the disengaged mind. *Science* 345, 75–77. doi: 10.1126/science.1250830

Winget, C. M., and Deroshia, C. W. (1986). 6 - Psychosocial and Chronophysiological Effects Of Inactivity and Immobilization. *Inactivity: Physiological Effects*. eds. H. Sandler and J. Vernikos (Cambridge MA: Academic Press), 123–147. https://www.sciencedirect.com/science/article/pii/B9780126185102500105

Wong, M. C., Mccarthy, C., Fearnbach, N., Yang, S., Shepherd, J., and Heymsfield, S. B. (2022). Emergence of the obesity epidemic: 6-decade visualization with humanoid avatars. *Am. J. Clin. Nutr.* 115, 1189–1193. doi: 10.1093/ajcn/nqac005

Young, P. T. (1966). Hedonic organization and regulation of behavior. *Psychol. Rev.* 73, 59–86. doi: 10.1037/h0022630

Zubek, J. (1964). Effects of prolonged sensory and perceptual deprivation. *Br. Med. Bull.* 20, 38–42. doi: 10.1093/oxfordjournals.bmb.a070280

Zuckerman, M., Persky, H., Link, K. E., and Basu, G. K. (1968). Responses to confinement: an investigation of sensory deprivation, social isolation, restriction of movement and set factors. *Percept. Mot. Skills* 27, 319–334. doi: 10.2466/pms.1968.27.1.319

TYPE Original Research
PUBLISHED 18 April 2023
DOI 10.3389/fspor.2023.1094288

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Sports and Active Living

RECEIVED 09 November 2022
ACCEPTED 16 March 2023
PUBLISHED 18 April 2023

CITATION
Budnick CJ, Stults-Kolehmainen M, Dadina C, Bartholomew JB, Boullosa D, Ash GI, Sinha R, Blacutt M, Haughton A and Lu T (2023) Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal.
Front. Sports Act. Living 5:1094288.
doi: 10.3389/fspor.2023.1094288

Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal

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Introduction: Motivation to be physically active and sedentary is a transient state that varies in response to previous behavior. It is not known: (a) if motivational states vary from morning to evening, (b) if they are related to feeling states (arousal/hedonic tone), and (c) whether they predict current behavior and intentions. The primary purpose of this study was to determine if motivation states vary across the day and in what pattern. Thirty adults from the United States were recruited from Amazon MTurk.
Methods: Participants completed 6 identical online surveys each day for 8 days beginning after waking and every 2–3 h thereafter until bedtime. Participants completed: (a) the CRAVE scale (Right now version) to measure motivation states for Move and Rest, (b) Feeling Scale, (c) Felt Arousal Scale, and (d) surveys about current movement behavior (e.g., currently sitting, standing, laying down) and intentions for exercise and sleep. Of these, 21 participants (mean age 37.7 y; 52.4% female) had complete and valid data.
Results: Visual inspection of data determined that: a) motivation states varied widely across the day, and b) most participants had a single wave cycle each day. Hierarchical linear modelling revealed that there were significant linear and quadratic time trends for both Move and Rest. Move peaked near 1500 h when Rest was at its nadir. Cosinor analysis determined that the functional waveform was circadian for Move for 81% of participants and 62% for Rest. Pleasure/displeasure and arousal independently predicted motivation states (all p's < .001), but arousal had an association twice as large. Eating, exercise and sleep behaviors, especially those over 2 h before assessment, predicted current motivation states. Move-motivation predicted current body position (e.g., laying down, sitting, walking) and intentions for exercise and sleep more consistently than rest, with the strongest prediction of behaviors planned for the next 30 min.
Discussion: While these data must be replicated with a larger sample, results suggest that motivation states to be active or sedentary have a circadian

waveform for most people and influence future behavioral intentions. These novel results highlight the need to rethink the traditional approaches typically utilized to increase physical activity levels.

KEYWORDS

affectively charged, motivation states, affect, arousal, exercise, physical activity, sedentary activity, body position, sleep

Introduction

Levels of physical activity remain low and levels of sedentarism remain high despite substantial efforts to improve these behaviors on a national and global scale (1, 2). Sophisticated new models, such as the Affect and Health Behavior Framework (AHBF) (3, 4), Affective Reflective Theory of Physical Inactivity (ART) (5), the dual process model from Conroy (6), and the behavior change wheel (7) have all identified impulses and motivation states as potential targets for intervention. This is in line with the Research Domain Criteria (RDoC) from the National Institute of Mental Health that has prioritized identifying behavioral "elements" for further exploration (8). In this vein, the WANT model (Wants and Aversions for Neuromuscular Tasks) was recently developed to understand how motivation states for movement and sedentarism operate (9). This model indicates that they work loosely and asynchronously. For instance, one may be high or low in motivation for both physical activity and rest simultaneously, or one may have shifting motivation for movement but not rest. These changes which facilitate flexible and adaptive behavior in response to stressful situations (9). Furthermore, using the CRAVE scale (Cravings for Rest and Volitional Energy Expenditure) (10), it has been determined that motivation states to move and rest morph quickly in response to a variety of stimuli and situations, such as exercise or periods of sitting, with effect sizes in the moderate to large range (10–12).

A key question currently centers on how motivation states vary across the day and the pattern of that variation—linear, curvilinear, or random/chaotic. Motivation to move and rest might follow a circadian pattern (13), which may have a stronger level of influence on behavior than many other factors. These assertions are typically based on observations of rodents and other animals (13), but little is known about daily fluctuations in human motivation to move or rest. The primary source of information comes from clinical populations, including those with Restless Leg Syndrome (RLS), which demonstrate altered patterns of urges to move with a circadian pattern peaking just after bedtime (14, 15). In fact, the urge to move is the defining feature of this disorder. In terms of physical activity itself, there have been recent calls to understand movement and sedentarism from a 24-hour activity perspective (16). These behaviors appear to have diurnal variation for most people (17) with the majority of adults (ages 18–60 y) having a relatively consistent pattern of activity from 10am to 6pm and of rest typically occurring from 11pm to 6am (18, 19). A recent qualitative study with focus groups with 17 college honors students found that a major theme surrounding motivation states was "change and stability". Some participants indicated fluctuations in the desire to move and rest on a moment by moment, hourly, and daily level (12), which was partially validated with quantitative data collected pre- and post-interviews.

Alternatively, changes in motivation may be due to more random processes related to shifting conditions. Resnicow (20) argued that processes of change in motivation are chaotic. He has argued for a more quantum perspective of behavior change, and suggested that "motivation arrives as opposed to being planned" (21), being often akin to a randomly-occurring epiphany. They may also happen when certain tipping points are reached, and this has been hypothesized by Inzlicht (22) in his assertion that motivation changes in conditions of feeling deprived or overly fatigued. A recent paper attempted to reconcile these various perspectives and subsume them within the construct of motivational drive (23). It is possible that all these processes are at play, and they work in tandem and not necessarily in direct opposition. Unfortunately, there are few data in humans to make any meaningful conclusions about how motivation to be physically active trends over time.

Another pressing issue is that motivation states have rarely been linked concretely to future behavior *in healthy populations*. Until such a link can be firmly established, there is limited usefulness for the concept of highly transient motivation states for physical activity. In clinical populations, such as those with RLS, anorexia nervosa and akathisia, the connection between urges to move and subsequent behavior is well established (14, 15, 24, 25). However, in healthy populations, where there are less bothersome sensations, the link has been largely ignored or even hypothesized to not exist (26). Despite this large gap in knowledge, there are data to support the idea that motivation states co-occur and precede behavior if there are no barriers for subsequent behavior. For instance, qualitative interviews identified that motivation states are the result of previous behaviors and also result in subsequent activity, especially when motivation is very strong, like an urge or craving to work out after having been inactive for a prolonged period of time (12). Further advancement in this area is sorely needed.

Unresolved at this time is whether motivation states are most closely aligned with factors like affect and emotion or to cognitive processes (e.g., deliberation, reflection) and more stable goals. Williams and Bohlen (26) opined that reflection is the primary component of desires for physical activity and exercise, further arguing against the idea that desires for activity might be hedonic or appetitive in nature. Nonetheless, it seems clear that desires and urges to move and rest may also be instigated by and related to a variety of feeling and emotive states, such as elation (9, 27, 28). This is further supported by qualitative data (12) and various models of emotion and motivation for physical activity, such as the AHBF (3, 4), which predict that motivation states are downstream byproducts of transient affect/feeling states. This has a long precedent, perhaps starting with Festinger and the idea that psychological dissonance is a motivation state in which people make efforts to reduce tension (29).

More recently, Kavanaugh (30) coined the term "affectively-charged motivation states" (ACMS) to typify motivation states that are felt with a negative or positive tension. For instance, when indoors and cooped up for long periods, one may feel antsy or fidgety and have a "pressing readiness" to move and be active (9). In response to pleasant music at a high beat rate, one might feel compelled to move the body, which is called "groove" (31). Taylor and colleagues (32) have argued that pleasure/displeasure and arousal/activation are foundational to motivation for activity and perhaps more so than reflective factors. They stated, "Physiological responses to exercise and their generalized core affective labels (i.e., states that vary simply on pleasantness and activation) are motivationally salient because they form the basis of desires that are often contrary to valued goals. Indeed, the central purpose of affect associated with afferent bodily signals is to motivate action" (33–35). In contrast to perspectives that focus mainly on hedonic valence, Brehm and Self (36) have focused on the interface between motivation states and arousal/activation in the prediction of effort. Their concept of the *momentary magnitude of motivational arousal* (MMMA) accounts for both the motive and the amount of effort a person is able and willing to expend on a task. [Interrelations between motivation, hedonic valence, and arousal are demonstrated in **Figure 1**.] Currently, no data link the experience of pleasure/displeasure and arousal/activation with motivation states for movement and sedentarism. However, Stults-Kolehmainen and colleagues (10) did find small to moderate associations with energy and fatigue, which indicates that such associations likely exist.

To address the gaps in the literature discussed above, we used an Ecological Momentary Assessment approach (40), which is designed to capture snapshots throughout the day—in this case, urges to move and rest, arousal, affect, and behavioral intentions. This approach captures inter-individual variability and dynamic patterns of change.

We focused on the following research questions:

1. Do movement and sedentary wants/desires vary across the day? If so, what is the pattern of change?
2. Are there associations with pleasure and arousal, and do these interact?
3. Do previous behaviors impact these wants/desires?
4. Are these wants/desires associated with: (a) current body position (i.e., at the moment of inquiry, such as lying down, sitting, standing, et cetera), (b) current activities (i.e., eating, exercise, and sleep), and (c) intentions for health behaviors over the next few hours?

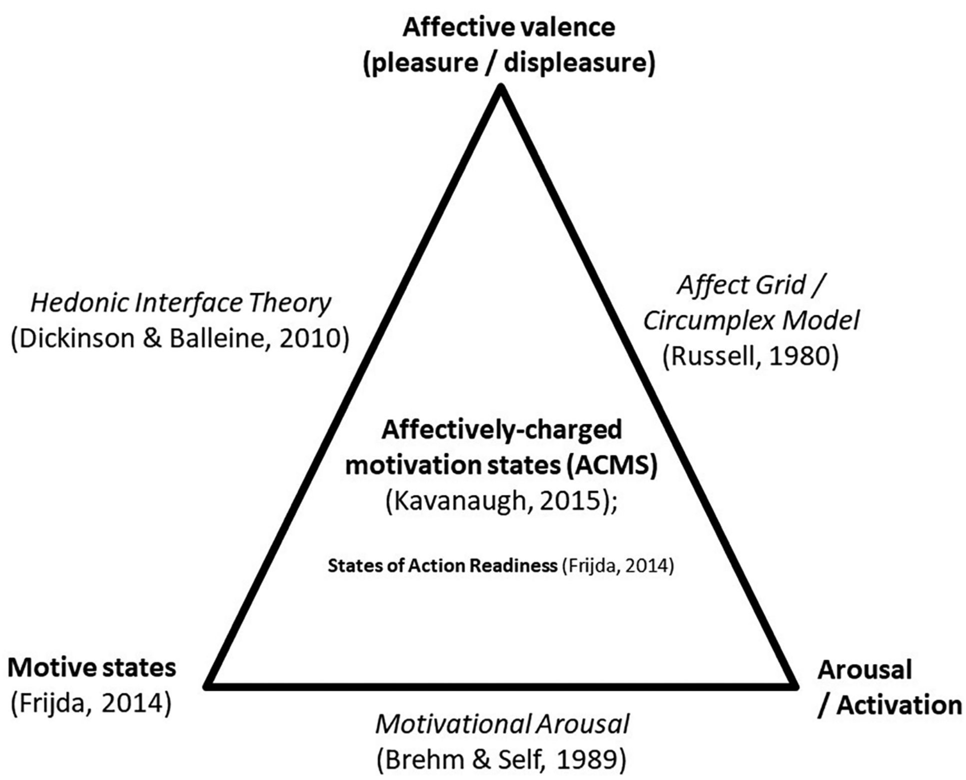

FIGURE 1
Theories of affect and motivation. In this illustration, affectively-charged motivation states (ACMS) (30) are the end product of interactions between the motive state (37), affective valence, and arousal (38). ACMS is a construct distinct but related to the ideas of motivational arousal (36), affect and the hedonic interface (39). A similar concept comes from Frijda (37) (States of Action Readiness), which proposes how ACMS result in motivated behavior.

We hypothesized that there is a high degree of variability throughout the day but made no specific hypothesis for how those changes might manifest. We also hypothesized that previous behaviors would impact motivation states, and in turn, motivation states would be associated with current behaviors and intentions to be active. We lastly hypothesized that there would be an association between feeling states (including hedonic valence and arousal) and motivation states.

Methods and materials

Participants

Participants were 21 adults residing in the USA (mean age 37.7 y; 52.4% female, 29% people of color) who had complete and valid data.

Procedures

Subject recruitment

Thirty participants were recruited through MTurk, Amazon's crowdsourcing platform. To complete the assignment, participants had to reside in the USA and be at least 18 years of age for reasons of consent. The data collected on MTurk included participants' race, gender, time zone, state/region of residence, and typical wake up time and bedtime. The MTurk assignment then directed the participants to an informed consent on Google Forms, which included a link to a downloadable informed consent document, as well as a version that could be read on the form itself. Upon fully completing the study according to terms in the consent, participants were awarded $50 USD (see below).

Data collection

After submission of informed consent, participants were promptly emailed regarding when their first survey would be and further instructions on how the study would be conducted. This email included their own link to the main surveys on SurveyMonkey, where two types of surveys were given.

A. The "PAST WEEK" type had two sets of motivation states questions:
   a. one set asking about motivation states "in the past week", and
   b. one set asking about motivation states while the participant took the survey ("right now").
   c. It also asked about Felt Arousal and Feeling "in the past week" and "right now".
B. The "NOW" type survey only consisted of questions pertaining to motivation and affective states at the current moment ("right now").

Both surveys contained the 10 additional closed-ended questions asking about felt arousal (current), hedonic valence (current), sleep, eating, et cetera. Each participant took the first survey type (A) at the beginning and end of the study. Participants were instructed to take the second survey type (B) 6 times per day for 8 days and were encouraged to take the survey once after waking up, once before going to sleep, and to spread the other four surveys apart throughout the day as much as possible. An Amazon Web Services EC2 instance was used as an email bot to remind participants to take surveys. Each participant was emailed six times throughout the day with their survey link and a reminder to spread the surveys apart and to take one after waking up and one before going to bed.

To be deemed eligible for the $50 payout, certain standards had to be met by each participant: (1) no less than 45 surveys submitted, (2) both "past week" CRAVE surveys submitted (Type A), (3) each survey took at least 30 s to complete (45 for Type A surveys), (4) no less than 3 surveys were submitted on a particular day, and (5) surveys were spread out across the day, i.e., surveys should not be submitted more than once in a particular 1-hour period. We chose the benchmark of 45 surveys because this would result in between 5 and 6 surveys per day. This would ensure that we received observations throughout each day for all 8 days.

All data was collected between July 2nd, 2021, and July 11th, 2021, with the majority of data collected between July 2nd, 2021, and July 9th, 2021. Around 1,400 surveys were collected, and 1,031 surveys were used for the study from 21 participants with complete and valid data. Participants submitted an average of 49.1 surveys per person (SD = 1.41, range = 46–51).

Instrumentation

CRAVE scale: Levels of motivation states to move and rest were self-recorded and submitted by participants using the Cravings for Rest and Volitional Energy Expenditure (CRAVE) Scale, a 13-item questionnaire consisting of statements regarding physical activity and sedentarism attached to 11-point Likert items. A subset of five items regard physical activity, e.g.,: "At this very moment, I want/desire to *move my body*". Another subset of five items regard sedentarism, e.g.,: "At this very moment, I want/desire to *just sit down*". The last three items are filler items that are not used for analysis. For each item, a participant would assign a number from zero to ten showing their agreement with the statement at the moment of taking the survey ("right now"). Scores for both subscales range from 0 to 50 with very high scores theoretically representing strong urges or cravings to move or rest. Participants also completed the "past week" version of the scale twice, which retrospectively assessed motivation states for the week before the study and the week during the study. These scales have excellent psychometric properties, as assessed over a series of 6 studies (10, 12). For the remainder of this paper "Move-NOW" and "Rest-NOW" refer to scores of the right-now version of the CRAVE scale. Concordantly, the terms "Move-WEEK" and "Rest-WEEK" refer to the scores of the CRAVE scale that assess motivation retrospectively over the past week.

Feeling Scale (*FS*): Affective valence (pleasure/displeasure), as conceptualized from the Circumplex Model, was recorded with the Feeling Scale (41). This is a single-item, 11-point bi-polar measure ranging from −5 (*very bad*) to +5 (*very good*); 0 represented *neutral*. The FS exhibits correlations ranging from .52 to .88 with the valence scale of the Self-Assessment Manikin (SAM) (42); and from .41 to .59 with the valence scale of the Affect Grid (AG) (38). Affective valence is an effective measure of pleasure/displeasure during exercise (43, 44).

Felt Arousal Scale (*FAS*): Activation/arousal was recorded with the Felt Arousal Scale of the Telic State Measure (45). This is a single-item self-report measure used extensively in exercise research (44, 46, 47). This 6-point scale ranges from 1 (*low arousal*) to 6 (*high arousal*). Correlations of the FAS with the SAM arousal scale range from .45 to .70. Correlations with the arousal scale of the AG range from .47 to .65.

Health behaviors over the last two + hours: Recent eating, sleeping, and exercise behaviors were assessed with three similar multiple-choice questions, with options indicating actions done 0–30 min ago, 30–60 min ago, 1–2 h ago, and 2 + hours ago. Eating had the additional option of "I am eating right now" and exercise had additional options of "I am exercising right now" and "I haven't exercised yet today".

Health behavior intentions for the next two + hours: Future eating, sleeping, and exercise intentions were assessed with 3 multiple choice questions, asking when participants next planned to sleep, eat, and exercise. Options included "in 0–30 min", "in 30–60 min", "in 1–2 hours" and "in 2 + hours". For exercise, there was an additional option of "I am not going to exercise for the rest of the day".

Body position: Body position was recorded with a multiple-choice list of lying down, sitting, standing (while leaning on something), standing (upright, not leaning), walking, exercising (other than walking), and other (please specify).

Bathroom Urge: Additionally, participants recorded how much of an urge they felt to use the restroom at the end of the survey on a Likert scale of 1–5. The urge to urinate is highly related to desires to move, which can confound data. It also was used as an indicator of any problems with the other data.

Data analysis

To provide evidence bearing on the research questions outlined above using longitudinal data, we utilized hierarchical linear modeling (HLM, multilevel modeling) with observations (Level 1) nested within participants (Level 2). This resulted in 1,031 observations nested within the 21 participants with complete and valid data. We followed the recommendations of Raudenbush and Bryk (48). Thus, we first computed an intercepts only model to ensure that subsequent models provided a better fit to the data. Concerning CRAVE move scores, the intercepts only model showed that CRAVE scores significantly differed [$b = 17.71$, $p < .001$, $CI_{95\%}$ (15.68, 19.73)] in the absence of any predictors. Between participant differences accounted for 12% of the observed variance in CRAVE move scores (*ICC* = .12). Similarly, CRAVE rest scores significantly differed in the intercepts only model [$b = 21.43$, $p < .001$, $CI_{95\%}$ (18.01, 24.85)] and showed more between subject variability (22%, *ICC* = .22) than observed for CRAVE move scores.

For each model containing a Level 1 predictor, we evaluated both random intercepts and random coefficients models retaining the model that provided the best fit to the data. To ensure concise reporting all model information is presented in relevant tables and text simply describes the nature of the observed relationships. All analyses were computed in *R* (version 4.1.2 [2021-11-01] (49) using the LME4 package (50), which incorporates Satterthwaite's degrees of freedom method (51). When using CRAVE scores to predict binary behavioral intentions, we used the general linear model (glmer) and specified the binomial family of distributions, which is appropriate when conducting binary logistic multilevel models on binary outcome data. Of note, odds ratio values less than one indicate that an increase in the *X* variable results in a decrease in the *Y* variable, and for odds ratios greater than one an increase in *X* corresponds with an increase in *Y*. The odds ratios also indicate the likelihood of an increase in *Y* given a one unit increase in continuous *X*. For example, CRAVE move scores significantly predict whether one intends to not stand (0) or stand (1). We observed an odds ratio of 1.05. This indicates that for every one unit increase in CRAVE move scores the likelihood of intending to stand were 1.05 times higher compared to not intending to stand.

Longitudinal data was also analyzed with Cosinor analysis to determine if participants had a circadian waveform. This analysis assumes either a normal or gamma distribution for outcomes. Cosinor parameters include mesor, acrophase, amplitude, nadir, and a test for rhythmicity. Such an analysis has been used for diurnal variations in heart rate and sleep (52), salt sensitivity in hypertension (53), peak expiratory flow in COPD (54), blood cardiac troponin T concentration (55) and others. Each participant's data was analyzed separately per the method developed by Doyle et al. (52). If either beta value was significant ($p < .05$), it was considered a circadian curve. Data was visually inspected with predicted curves for verification.

Results

Means, standard deviations, and correlations between outcome variables for baseline and the final day are presented in **Table 1**. Collapsed across all measurement periods, the mean (SD) for Move-Now was 17.74 (SD = 12.97) and for Rest-NOW was 21.35 (SD = 16.25).

Do movement and rest wants/desires vary across the day? How do they vary?

Hierarchical linear modelling

To determine the influence of time on CRAVE move and rest scores we regressed the linear, cubic, and quadratic trends of time on CRAVE scores while allowing intercepts to vary across participants. When considering CRAVE move scores, we observed significant linear [$b = .024$, $p < .001$, $CI_{95\%}$ (.012,.035)] and quadratic time trends ($b = -0.0000000054$, $p < .001$, $CI_{95\%}$

TABLE 1 Correlation matrices demonstrating associations between CRAVE factors with pleasure/displeasure and arousal/activation, both as measured "right now" (A) and "over the past week" (B).

(A) "Right now" (RN)	CRAVE-Move-RN @baseline	CRAVE-Rest-RN @baseline	Pleasure/displeasure-RN @baseline	Arousal-RN @baseline	CRAVE-Move-RN @last day	CRAVE-Rest-RN @last day	Pleasure/displeasure-RN @last day	Arousal-RN @last day
CRAVE-Move-RN @baseline	1	−0.68**	0.18	0.54*	−0.01	−0.02	−0.16	−0.17
CRAVE-Rest-RN @baseline		1	−0.38	−0.29	−0.10	0.54*	−0.16	0.02
Pleasure/displeasure-RN @baseline			1	−0.13	0.14	−0.44*	0.51*	0.08
Arousal-RN @baseline				1	0.25	0.05	−0.29	0.27
CRAVE-Move-RN @last day					1	−0.55**	0.19	0.78**
CRAVE-Rest-RN @last day						1	−0.58**	−0.35
Pleasure/displeasure-RN @last day							1	0.32
Arousal-RN @last day								1
Mean and standard deviation	21.48 ± 11.33	20.95 ± 15.33	2.14 ± 1.85	2.29 ± 1.01	21.19 ± 11.44	15.43 ± 13.11	2.24 ± 2.14	2.29 ± 1.35
(B) "Past week" (PW)	**CRAVE-Move-PW @baseline**	**CRAVE-Rest-PW @baseline**	**Pleasure/displeasure-PW @baseline**	**Arousal-PW @baseline**	**CRAVE-Move-PW @last day**	**CRAVE-Rest-PW @last day**	**Pleasure/displeasure-PW @last day**	**Arousal-PW @last day**
CRAVE-Move-PW @baseline	1	−0.70**	0.53*	0.49*	0.55**	−0.65**	0.31	0.63**
CRAVE-Rest-PW @baseline		1	−0.49*	−0.17	−0.35	0.87**	−0.48*	−0.42
Pleasure/displeasure-PW @baseline			1	0.01	0.26	−0.54*	0.45*	0.32
Arousal-PW @baseline				1	0.48*	−0.07	0.30	0.71**
CRAVE-Move-PW @last day					1	−0.48*	0.33	0.52*
CRAVE-Rest-PW @last day						1	−0.52*	−0.33
Pleasure/displeasure-PW @last day							1	0.29
Arousal-PW @last day								1
Mean and standard deviation	30.10 ± 8.68	17.14 ± 13.87	1.81 ± 1.91	3.33 ± 1.20	28.19 ± 9.39	16.00 ± 11.61	2.33 ± 1.77	2.71 ± 1.0

*$p < .05$.
**$p < .01$.

[−0.0000000081, −0.0000000027]; the cubic time trend was non-significant (p =.49). CRAVE move scores increased from 0000 h until 1500 h and decreased from 1500 h to 0000 h (**Figure 2A**). As shown in **Figure 3**, this pattern was consistent when both collapsing across days and examining individual daily recordings.

Time also showed significant linear ($b = -.030$, $p < .001$, $CI_{95\%}$ [−0.044, −0.017] and quadratic trends [$b = 0.0000000051$, $p = .002$, $CI_{95\%}$ (0.000000018, 0.0000000083)] on CRAVE rest scores. Examination of **Figure 2B** indicates that CRAVE rest scores decreased from 0000 h until 1500 h at which time they increased from 1500 h until 0000 h. This pattern also occurred both when collapsing across days and examining daily variation (see **Figure 4**).

Cosinor analysis

Cosinor analysis found that 81% of participants had a circadian curve for Move and 62% had one for Rest. See **Figures 5A,B** for examples of these analyses for participant 17. Thus, both CRAVE Move and Rest scores appear to vary across the day and exhibit a quadratic pattern where scores increase or decrease early in the day and then begin to reverse during mid afternoon.

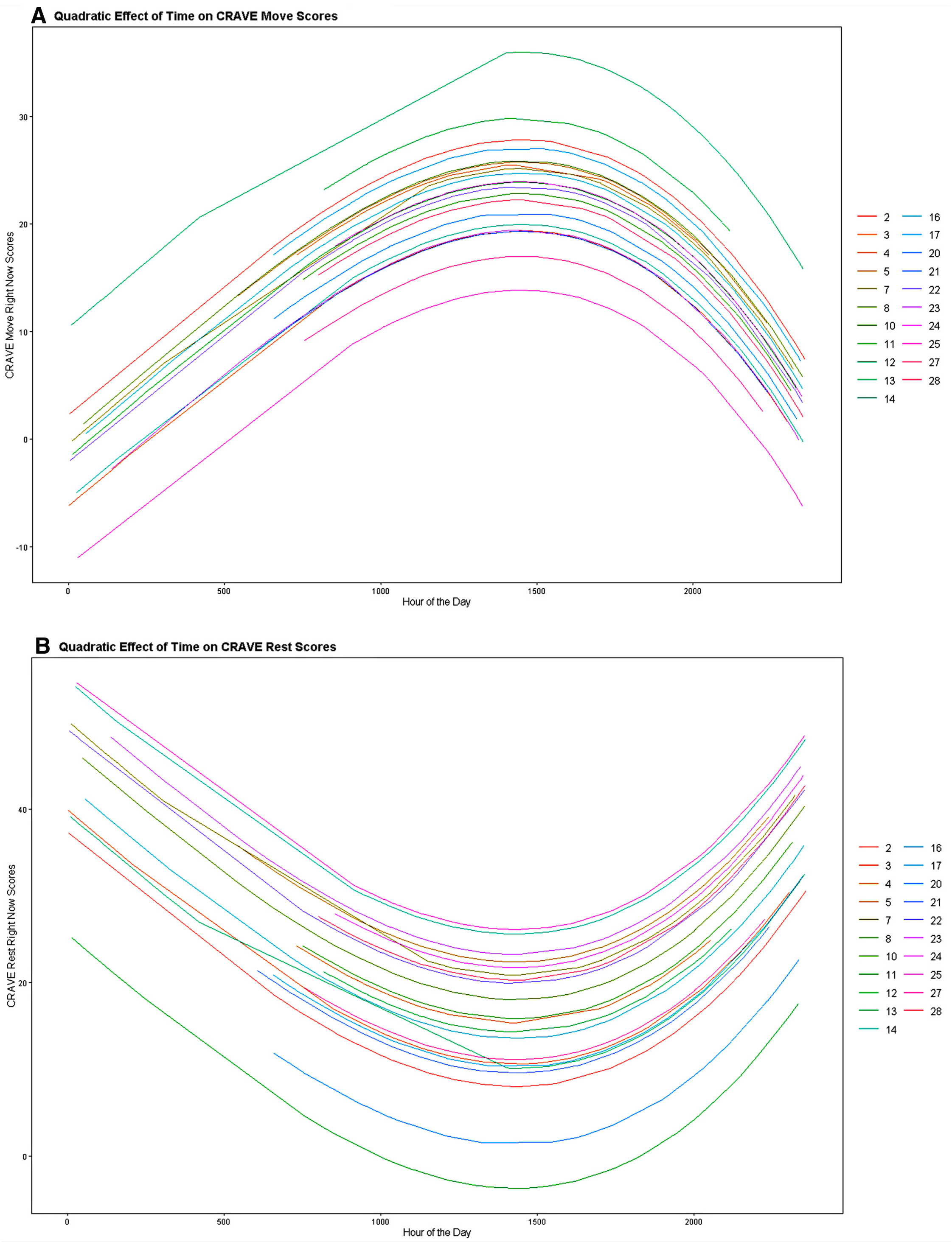

FIGURE 2
Linear and quadratic associations of time with motivation states to move (A) and rest (B). Note that on initial inspection, these figures seem to be perfect mirrored images—which suggests that Move and Rest desire are measuring either end of a singular construct. However, looking closely at the colors reveals that the rank order shifts across participants, and there is a smaller correlation between Move and Rest than at first glance.

Is there an association with pleasure?

Move

At Days 1 and 8, Move-NOW correlations with pleasure (assessed "now") were small (Day 1: $r = .18$, Day 8: $r = .19$).

The random coefficients model best fit the data when using pleasure to predict CRAVE move scores ($X^2[2] = 62.29$, $p < .001$) with approximately 28% of the variance due to participant clustering ($ICC = .28$). For each unit increase in felt pleasure right now, CRAVE move scores increased 3.38 units

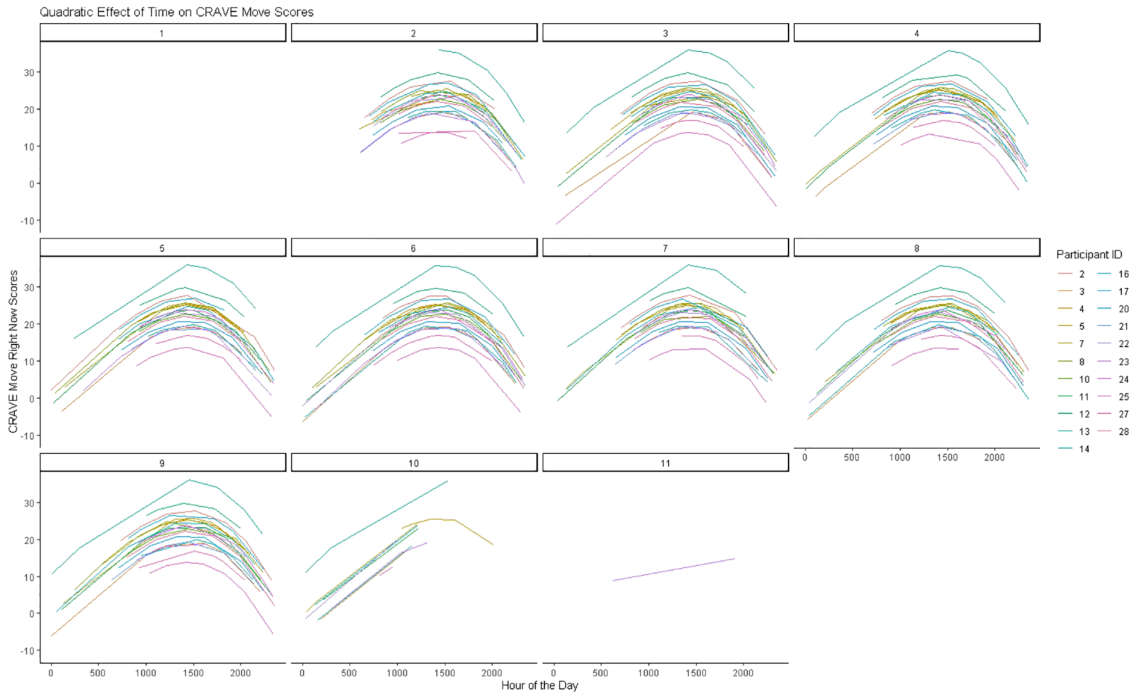

FIGURE 3
Predicted changes in move motivation states over 8 days.

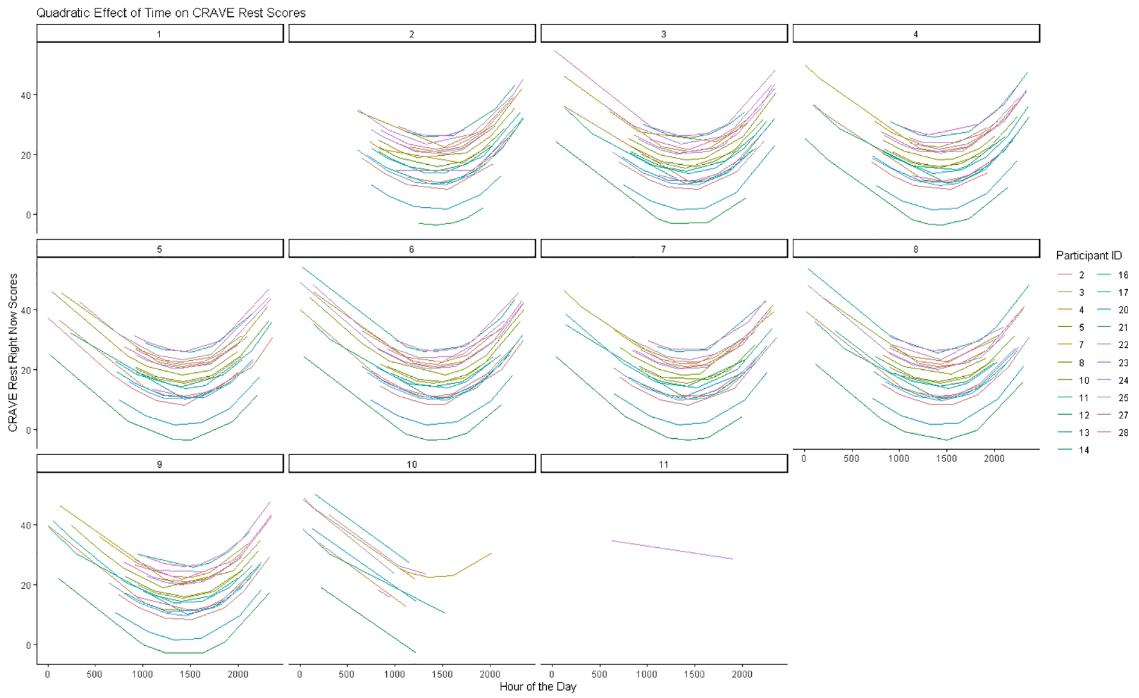

FIGURE 4
Predicted changes in rest motivation states over 8 days.

[$b = 3.38$, $p < .001$, $CI_{95\%}$ (2.40, 4.37)]. Importantly, this result was similar even when controlling for linear and quadratic time trends [$b = 2.96$, $p < .001$, $CI_{95\%}$ (2.17, 3.76)].

Rest

At Days 1 and 8, Rest-NOW correlations with pleasure were small to moderate (Day 1: $r = -.38$, Day 8: $r = -.58$).

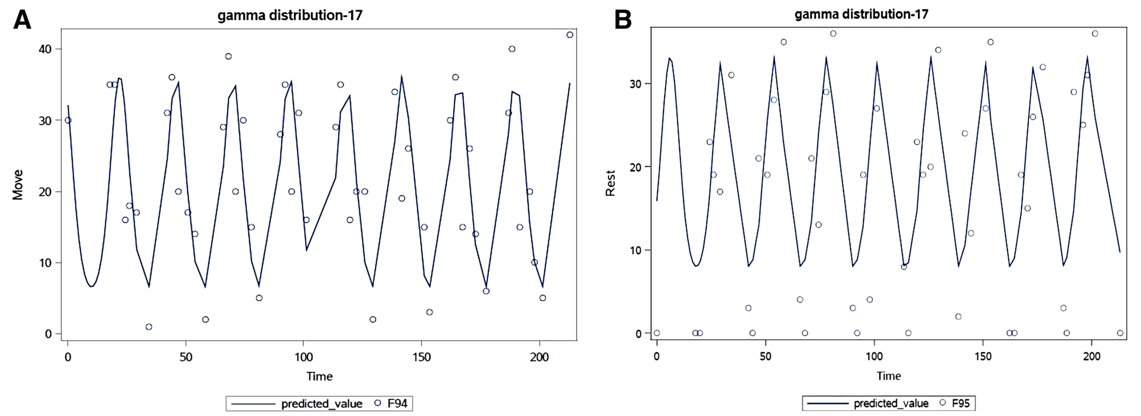

FIGURE 5
Example cosinor analysis for participant 17 for move (A) and rest (B) over 200 h.

Similarly, the random coefficients model presented the best fit to the data when predicting CRAVE rest scores from felt pleasure right now [$X^2(2) = 49.74$, $p < .001$] with between subject clustering accounting for approximately 27% of the variance ($ICC = .27$). For each unit increase in felt pleasure right now, CRAVE rest scores tended to decrease by 3.91 units [$b = -3.91$, $p < .001$, $CI_{95\%}$ (−5.02, −2.81)]. This finding also held even when controlling for the linear and quadratic time trends [$b = -3.41$, $p < .001$, $CI_{95\%}$ (−4.31, −2.51)]. Therefore, pleasure felt in the current moment explains unique variance beyond that explained by the time trends in CRAVE move and rest scores.

These finding suggest there is a relationship between pleasure, and both CRAVE Move and Rest scores. Specifically, as felt pleasure increases Move scores increase, and Rest scores decrease.

Is there an association with arousal?

Move

At Days 1 and 8, Move-NOW correlations with arousal/activation (assessed "now") were moderate (Day 1: $r = .54$, Day 8: $r = .78$).

The random coefficients model exhibited the best fit to the data [$X^2(2) = 80.72$, $p < .001$] with between-subject effects accounting for 28% of the variance in CRAVE move scores ($ICC = .28$). In this model each one unit increase in felt arousal right now predicted a 6.39 unit increase in CRAVE move scores [$b = 6.39$, $p < .001$, $CI_{95\%}$ (5.03, 7.74)]; these results remained consistent [$b = 5.47$, $p < .001$, $CI_{95\%}$ (4.26, 6.67)] even when statistically accounting for any potential influence of linear or quadratic time.

Rest

At Days 1 and 8, NOW correlations with arousal/active were small (Day 1: $r = -.35$, Day 8: $r = -.35$).

When examining CRAVE rest scores, results suggest that the random coefficients model best fit the data [$X^2(2) = 69.09$, $p < .001$]. Between-subject clustering accounted for 39% of the variance in CRAVE rest scores ($ICC = .39$). For each one unit increase in felt arousal right now, CRAVE rest scores tended to decrease by 6.49 units [$b = -6.4$, $p < .001$, $CI_{95\%}$ (−8.14, −4.84)]. Importantly, these results held and were similar in magnitude [$b = -5.35$, $p < .001$, $CI_{95\%}$ (−6.83, −3.88)] even when statistically controlling for both the linear and quadratic effects of time. Together these results suggest that despite an observed time variation in CRAVE move and rest scores, increased felt arousal uniquely increases CRAVE move and decreases CRAVE rest scores.

Thus, arousal does associate with both CRAVE Move and Rest scores in a similar pattern as observed for pleasure. As arousal increased Move scores increased and Rest scores decreased.

Do pleasure and arousal interact on CRAVE scores?

To explore whether pleasure and arousal present additive or multiplicative effects on CRAVE scores we next examined more complex models where pleasure, arousal, and their interaction term predicted CRAVE scores. Concerning CRAVE move scores, the random coefficients model provided the best fit to the data [$X^2(5) = 112.58$, $p < .001$]. The results suggested additive effects such that both self-reported pleasure [$b = 1.14$, $p = .011$, $CI_{95\%}$ (0.26, 2.02)] and arousal [$b = 5.46$, $p < .001$, $CI_{95\%}$ (3.97, 6.95)] predicted increased CRAVE move scores. The pleasure and arousal interaction failed to achieve significance in this model [$b = .13$, $p = .26$, $CI_{95\%}$ (−0.10, 0.36)].

When examining CRAVE rest scores, the random coefficients model also represented the best fit to the data [$X^2(5) = 73.33$, $p < .001$]. In this model, increased pleasure [$b = -2.14$, $p < .001$, $CI_{95\%}$ (−3.21, −1.07)] and arousal [$b = -5.90$, $p < .001$, $CI_{95\%}$ (−7.69, −4.12)] predicted decreased CRAVE rest scores. The interaction term also failed to achieve traditional significance levels when examining the pleasure and arousal interaction in this model [$b = .17$, $p = .26$, $CI_{95\%}$ (−0.13, 0.47)]. These results suggest that both perceived pleasure and arousal uniquely (additively) contribute variance when predicting CRAVE move and rest scores.

Our results do not suggest a pleasure by arousal interaction on CRAVE scores. Rather these results indicate that both pleasure and arousal additively influence CRAVE.

Do previous behaviors impact wants/desires for movement and rest?

To determine whether previous behaviors predicted CRAVE move or rest scores we examined several outcomes of relevance. For each of the analyses reported in the following, the predictor variable was coded 0 (an absence of that behavior) or 1 (engaging in that behavior). In-text discussion is centered on significant findings; however, full results for all predictor variables are available in **Table 2**.

Participants who reported eating 1 to 2 h before the survey, not exercising on the survey day, exercising while completing the survey, sleeping 1 to 2 h before the survey, and sleeping over two hours before the survey also reported higher CRAVE move scores. Yet participants who ate over two hours before the survey, exercised over two hours before the survey, and slept zero to 30 min before the survey tended to report lower CRAVE move scores. As shown in **Table 2**, all other variables failed to contribute significant variance to predicting CRAVE scores.

Concerning CRAVE rest scores, eating during the survey, not exercising on the day of the survey, exercising during the survey, and sleeping over two hours before the survey each resulted in lower CRAVE rest scores. Eating over two hours before the survey and exercising over two hours before the survey resulted in increased CRAVE rest scores. All other predictors failed to explain unique variance in CRAVE rest scores. Overall, these findings suggest some past behaviors do influence both Move and Rest scores.

Do wants/desires for movement and rest impact future behavioral intentions? (multilevel logistic regression analyses)

As noted in the Data Analysis section, to determine whether CRAVE move and rest scores influence behavioral intentions, we entered both move and rest scores as predictors of the various behavioral intentions in binary logistic multilevel models (0 = absence of the behavior; 1 = presence of the behavior). We observed that for each unit increase in CRAVE move scores the likelihood of currently being in a standing position, currently walking, engaging in other exercise, exercising now, exercising 0 to 30 min later, exercising 30 to 60 min later, and sleeping over 2 h later were higher. Alternatively, for each unit increase in CRAVE move scores the likelihood of intending to sit during the survey, sleep 0 to 30 min later, and sleep one to two hours later was lower. We also observed that for each unit increase in CRAVE rest scores, the likelihood of lying down during the survey and to sleep zero to 30 min later were higher. Yet for each unit decrease in CRAVE rest scores the likelihood of intending to exercise one to two hours later, exercise over two hours later, and sleep over two hours later were lower. Overall, these results suggest that CRAVE scores likely can predict future behavioral intentions. See **Table 3**.

Discussion

The current data provide novel insights into the dynamics of motivation states for physical activity and rest—they vary diurnally, are influenced by recent behaviors (e.g., exercise, eating and sleep), and predict future intentions to be active. Importantly, this is the first study to demonstrate that the motivation to move and be sedentary in humans varies like a

TABLE 2 Previous behaviors predicting CRAVE move and rest scores.

Predictor Variables	CRAVE Move Scores			CRAVE Rest Scores		
	b	$CI_{95\%}$	*p*	*b*	$CI_{95\%}$	*p*
Currently Eating	*2.63*	*−0.01, 5.27*	*.05*	**−4.00**	**−7.12, −0.89**	**.01**
Ate 0 to 30 Minutes Ago	0.88	−1.24, 2.99	.42	−1.57	−4.06, 0.92	.22
Ate 30 to 60 Minutes Ago	2.02	−0.59, 4.63	.13	−1.53	−6.40, 1.55	.33
Ate 1 to 2 Hours Ago	**2.63**	**0.62, 4.65**	**.01**	−2.04	−4.42, 0.35	.09
Ate Over 2 Hours Ago	**−3.68**	**−6.31, −1.04**	**.01**	**3.92**	**0.74, 7.10**	**.02**
Did Not Exercise Today	**4.80**	**1.23, 8.39**	**.01**	**−6.44**	**−10.31, −2.57**	**.001**
Exercising Now	**16.94**	**11.70, 22.19**	**<.001**	**−13.32**	**−19.58, −7.06**	**<.001**
Exercised 0 to 30 Minutes Ago	0.71	−2.74, 4.17	.69	−0.87	−4.95, 3.20	.67
Exercised 30 to 60 Minutes Ago	*3.39*	*−0.05, 6.82*	*.05*	−2.88	−6.93, 1.18	.16
Exercised 1 to 2 Hours Ago	−0.16	−3.30, 2.99	.92	1.09	−2.61, 4.80	.56
Exercised Over 2 Hours Ago	**−8.51**	**−11.01, −6.01**	**<.001**	**9.83**	**6.99, 12.66**	**<.001**
Slept 0 to 30 Minutes Ago	**−6.06**	**−9.74, −2.38**	**.001**	*4.72*	*−0.13, 9.57*	*.056*
Slept 30 to 60 Minutes Ago	−1.67	−6.62, 3.28	.51	1.32	−4.84, 7.47	.68
Slept 1 to 2 Hours Ago	**4.60**	**1.02, 8.18**	**.01**	−3.59	−7.82, 0.65	.10
Slept Over 2 Hours Ago	**2.77**	**0.98, 4.57**	**.002**	**−2.68**	**−4.80, −0.56**	**.01**

Note. **Bold** = significant at $p < .05$; *underlined italics* = p between .05 and .06.

TABLE 3 CRAVE move and rest scores predicting body position, exercise and eating at the time of the surveys and future intentions to eat, exercise and sleep 2 + hours into the future.

Dependent Variables	CRAVE Move				CRAVE Rest			
	Log-Odds	Odds ratio	Predicted %	*p*	Log-Odds	Odds ratio	Predicted %	*p*
Lying Down	−0.041	–	–	0.07	**0.072**	**1.07**	**0.52**	**<.001**
Sitting	**−0.030**	**0.97**	**0.49**	**0.01**	−0.017	–	–	0.10
Leaning on Something	0.006	–	–	0.81	−0.030	–	–	0.16
Standing	**0.052**	**1.05**	**0.51**	**0.005**	−0.016	–	–	0.31
Walking	**0.118**	**1.13**	**0.53**	**<.001**	0.004	–	–	0.91
Other Exercise	**0.131**	**1.14**	**0.53**	**0.036**	−0.061	–	–	0.49
Currently Eating	0.001	–	–	0.97	−0.016	–	–	0.27
Eating 0 to 30 Minutes Later	−0.025	–	–	0.22	−0.031	–	–	0.07
Eating 30 to 60 Minutes Later	0.013	–	–	.40	0.015	–	–	0.25
Eating 1 to 2 Hours Later	0.017	–	–	0.19	−0.016	–	–	0.16
Eating Over 2 Hours Later	−0.012	–	–	0.26	0.009	–	–	0.31
Exercising Now	**0.177**	**1.19**	**0.54**	**<.001**	0.049	–	–	0.21
Exercising 0 to 30 Minutes Later	**0.098**	**1.10**	**0.53**	**<.001**	0.004	–	–	0.86
Exercising 30 to 60 Minutes Later	**0.077**	**1.08**	**0.52**	**0.005**	0.004	–	–	0.86
Exercising 1 to 2 Hours Later	0.014	–	–	0.45	**−0.039**	**0.96**	**0.49**	**0.024**
Exercising Over 2 Hours Later	−0.010	–	–	0.44	**−0.033**	**0.97**	**0.49**	**0.004**
Sleeping 0 to 30 Minutes Later	**−0.0279**	**0.76**	**0.43**	**<.001**	**0.08**	**1.08**	**0.52**	**0.005**
Sleeping 30 to 60 Minutes Later	−0.058	–	–	0.28	0.074	–	–	0.07
Sleeping 1 to 2 Hours Later	**−0.059**	**0.94**	**0.49**	**0.04**	0.018	–	–	0.39
Sleeping Over 2 Hours Later	**0.150**	**1.16**	**0.54**	**<.001**	**−0.069**	**0.93**	**0.48**	**<.001**

Note. **Bold** = significant at $p < .05$.

biorhythm. Using both hierarchical linear modeling (HLM) and Cosinor analysis, we found that desires/urges to move and rest followed a circadian pattern, with a peak around 1500 h for Move and a similar nadir for Rest. Also, for the first time, recent eating and sleeping were found to be associated with current motivation states to move and rest. Exercise was particularly related with these desires. In logistic regression models, motivation states to move and rest predicted current exercise and body position (e.g., standing, walking), which is what one would expect, thus providing additional validation of the CRAVE scale (10). More importantly, motivation states predicted intentions to exercise and sleep in the near term (i.e., 0–2 h). Of note, this is the first study to make this conclusion in a healthy population. Lastly, feeling states were associated with desire to move and rest, with arousal/activation having nearly twice the influence as pleasure/displeasure. These data compliment and augment what we have found from 7 previous studies investigating motivation states—specifically, people have transient desires to move and rest that are influenced by previous behaviors (9–12, 14).

The major finding from this investigation was that motivation states vary in a manner that is like a circadian curve. Cosinor analysis found that 81% of individuals had a circadian curve for Move and 62% for Rest. Why Rest was lower is difficult to explain but may be due to the dysregulated sleeping patterns commonly found today (56). Many biological variables are under circadian control, including cortisol (with a peak 30 min after awakening), blood pressure, sex hormones (e.g., testosterone peaks in the afternoon), growth hormone (e.g., covarying with REM sleep), body temperature, and other biomarkers (57–60). Positive and negative affect (61), as well as sensations of energy, fatigue, and pain, have also been found to vary in a circadian manner, for some individuals (59). Some researchers have emphasized that changes in motivation are due to random factors (20) or may be more functional, such as in deprivation and satiation models (62), or toggle between states of exploration (i.e., leisure) and exploitation (i.e., labor), as in the Elaborated Process of self-regulation (22). Our data could be complementary with these models, but they largely suggest that motivation states are highly influenced by diurnal factors. See Stults-Kolehmainen et al. (12) for greater discussion.

Recent (i.e., 0–2 h) exercise and sleeping behaviors were associated with motivation states to move and rest in a very complicated set of associations. As one might expect, during exercise, desire to move was higher and desire to rest was lower, both by more than one standard deviation. Two or more hours after exercise, the opposite occurred (>½ standard deviation for both). Between these times, there was no association. This pattern may be due to differences in the transient feelings that follow exercise. Some have an exercise afterglow with a bout of exercise, while others are fatigued (63); numerous interpersonal and exercise-related factors likely have an influence on motivation (64). For sleep, it was clear that recent awakening was associated with less desire to move and more to rest, which conforms to what is known about sleep inertia (65). The reverse was true two hours after awakening. These data are concordant with previous investigations that periods of heightened movement and rest result in changes in desire to move (10, 12). In these studies, however, we found that maximal exercise had an immediate and large impact on motivation states (i.e., Move decreases, Rest increases), and periods of prolonged sitting resulted in small to moderate increases in the desire to move. Further studies should elucidate how different exercise modes and intensities may modulate these changes.

Eating was associated with the desire to move and rest—also in a complicated fashion. First, Move and Rest motivation states were associated with current eating behavior– which is slightly counter-intuitive as it seems like one would not want to be moving during eating. There are various explanations for this observation. First, in the modern era of multi-tasking, feeding times are frequently utilized to watch media (66), complete various chores and responsibilities, and prepare for upcoming important tasks (67). Second, there may simply be greater energy availability from ingesting nutrients, spurring motivation. Nevertheless, digestion is a process that takes time, which is a counterargument. Third, some data demonstrate that demonstrate that even a simple rinse of carbohydrate in the mouth is sufficient to spur effort for movement, perhaps by activating motivation centers of the brain (68). Fourth, the simple movements of lifting the hand to the mouth during eating might be construed as relevant by some participants. Indeed, participants in former studies have indicated this (12). Interestingly, having eaten 1–2 h ago was associated with greater desire to move, but 2 + hours was associated with less. Again, this might make sense from the standpoint of digestion and blood glucose kinetics and autonomic responses during digestion (69). There might be an optimal period of energy availability, which would promote greater desire to move. It also seems to align with advice with various sports nutrition experts that meals should be timed appropriately before a workout (70) depending upon the individual need of nutrients and the exercise demands. Further research is warranted on this issue given the complexity of these factors and their potential interactions.

Current body position and future health behavior intentions (for exercise and sleep) were predicted by motivation states to move and rest. There was a clear pattern of influence of motivation states to move on position of the body. Sitting was associated with lower Move scores. Standing, walking, and exercise were associated with higher Move (in that order). Lying down, on the other hand, was associated with greater Rest. Importantly, current exercise and future intentions for exercise up to 1 h was predicted by Move, with exercising at the time of the survey associated with the strongest desire to move, as one might expect. Intentions for behavior greater than 1 h in advance were not associated with Move and Rest, with the exception of plans to sleep > 2 h, which were associated with greater Move and less Rest desire. Log odds in the logistic regression indicate that a one-point increase in motivation to move was associated with a 1.10 times (53%) greater likelihood of intending to exercise in the next 30 min and a 1.08 times (52%) greater likelihood of intending to move in the next 30–60 min. Finally, neither desires to move nor rest predicted future eating intentions—a behavior most closely linked to the desire for food (67).

The current study provides additional evidence of the validity of the concept of ACMS for movement and rest, and for the WANT model of motivated behavior for physical activity. These postulates were supported: (A) that desires are separate, (B) they are highly transient, (C) they change based on previous behaviors, (D) they work loosely and asynchronously, and (E) they differ from emotions and psychosomatic sensations. Each are explicated below.

A) As with previous studies (10–12), there were moderate correlations (−.68, −.55) between desires to move and rest/be sedentary.
B) There were significant linear and quadratic effects of time on Move and Rest scores, indicating steady change across the day.
C) Eating, sleeping and exercise behaviors all influenced subsequent CRAVE assessments.
D) The differential influences of motivation states for movement and rest on health behaviors, particularly exercise and sleep, provide some support for the tenet that ACMS work loosely and asynchronously. While we found no evidence that they were totally concordant (e.g., desires to move and rest changing the same direction), there was evidence that body position and exercise behavior had varying influences on the desire to move or rest.
E) Motivation states were associated with both pleasure/displeasure and arousal (activation). Furthermore, activation had nearly twice the influence of feeling states. Our previous studies have found that motivation states are also related to perceived energy and fatigue (10). These data appear to support the idea that motivation states have a strong affective component, which may be felt as tension, and have been called affectively-charged motivation states (ACMS) (30). Perhaps it's worth noting that while a substantial portion of the variance was explained by affect and arousal, there was substantial variance in CRAVE move and rest scores at Level 2, the person level of analysis. This variance likely reflects the influence of individual differences (e.g., personality, trait move/rest preferences) that may modify the reported relationships—an avenue for future research (71, 72).

Motivation states likely derive from a variety of inputs, including: (1) a basic drive to move (23, 73), (2) necessity of movement to accomplish tasks (simple instrumental value), (3) reflection (26, 74), and (4) reward (75). These relationships may further differ based on individual traits.

Study limitations

Despite the novelty and importance of these data, there were some limitations. First, we did not screen for movement or sleep problems or diminished or excessive urges for movement and sleep, the so-called movement urge dysfunction disorders (MUDD) (14, 15). Furthermore, we did not assess movement and sedentarism with objective measures of exercise, physical activity, sleep, et cetera, nor did we assess for exogenous sources that may influence motivation states, like caffeine (76, 77), medication use (78), or environmental factors known to strongly affect motivation, like music (31). Unfortunately, little is known about participants' background (e.g., employment status, income, occupation, normal work hours, and overall health status), all of which may be relevant. For instance, nurses working third shift have altered physical activity patterns (79), have a larger body mass index, and frequently suffer from fatigue and declining health (80).

Additionally, the sample size at level two of our statistical models was $n = 21$. The current literature has yet to delineate clear guidelines regarding the optimal number of clusters required for a multilevel model to be considered adequately powered; suggestions range from as little as 10 clusters to as many as 50 or more clusters depending on model complexity, design, the number of observations within each cluster, and other considerations (81, 82). We had 1,031 observations at level one, and we did not test any level two predictors in our models. Given that person-level (level two) variance explained approximately 12% of differences in CRAVE-Move and 22% of differences in CRAVE-Rest scores in the absence of predictors, our models simply controlled for those person-level differences (allowed individual slopes to vary) to focus on the relationships among the level one predictor variables and CRAVE-Move and Rest scores. Future research could build on this work by examining person-level factors (i.e., individual differences, such as personality, need for stimulation, et cetera) that influence baseline CRAVE-Move and Rest score differences.

Still the current approach is valid given that modeling level two variance (accounting for unmeasured individual differences) is particularly important, especially when the numbers of clusters is small (83). Our models also used restricted maximum likelihood (REML) for estimation– a method shown to perform well even with 10 or fewer clusters (83–85). Thus, our statistical approach is consistent with recent suggestions in the literature for analyzing multilevel data with small level two sample sizes. Similar work examining the influence of variables nested within individuals across time appears in the literature and reports similar level two sample sizes as collected in this work (e.g., (83, 86, 87). Still, as with any research, future work collecting larger samples is necessary to further confirm these results and extend generalizability to larger and more diverse populations. We utilized two sophisticated analytic techniques, but each comes with their own limits, and there does not appear to be a perfect technique for the analysis of circadian data. For instance, the cosinor approach may be too restrictive for some individuals, as it assumes that the circadian pattern is always a cosine shape (19).

Future research

Future research possibilities have been extensively discussed in our recent manuscripts (9, 10, 12, 14), but regarding these data, several studies are suggested as follow ups.

1. Examine whether motivation states predict actual physical activity and rest/sedentary behaviors with both experimental procedures in the laboratory and in natural settings.
2. Understand why specific behaviors (e.g., eating, sleeping) seem to hold influence relative to others on motivation states.
3. Determine the frequency of mismatch between desires to move and the ability to move, given modern environments that constrain movement.
4. Compare the influence of avoidance motivation (e.g., aversions/diswants) on activity and rest, as depicted by the WANT model, in relation to approach motivation.
5. Examine motivation and affective states during task (i.e., during exercise), which is now possible because single-item versions of the CRAVE subscales were recently developed in both English and Portuguese (11).
6. Understand how motivation states fluctuate during recovery from exercise, because the experience of affect during this period predicts future exercise behavior (88).
7. Calculate variations over other time frames, such as weekly, seasonally or annually (89).
8. Conduct experiments to determine the relationship of CRAVE (motivation to move and rest) with biomarkers that also vary in a circadian pattern, such as sex hormones and cortisol.
9. Understand whether various kinds of disease and disorders are associated with disrupted circadian rhythmicity of motivation states, such as Alzheimer's (90).
10. Differentiate motivation states for various chronotypes, including larks (morningness chronotype) vs. night owls (evening chronotype), or alternatively, roadrunners (active in the afternoon), penguins (low overall activity), hummingbirds (high overall activity) and other proposed chronotypes (19, 61).
11. Conduct just-in-time adaptive interventions (JITAI) (91) to maximize opportunities when people experience "CRAVE moments" (moments when the desire to move is high), and perhaps intervene to promote desires when they are low.
12. Given the initial nature of this work, we did not conduct cross-lagged analyses of the data; however, future work should consider how CRAVE scores on one day influence important outcomes on following days.

Application

These data likely have real world application for the promotion of physical activity, exercise training and even workplace productivity. For those wishing to maximize the effectiveness of exercise, it may make sense to align training sessions with a time frame when motivation for movement is naturally high instead of attempting to generate motivation at times when it is lacking. For an average person, peak motivation to move is around 15:00 h, so it may make sense to exercise on the incline before the peak (~14:00–15:00 h) so peak motivation coincides with the end of exercise. Working out >2 h after awakening may be sufficient, at least not close to bedtime. It also appears that motivation is higher in a window of 1–2 h after eating.

Desire to move is associated with higher levels of pleasure/lower levels of displeasure. More pertinently, higher levels of arousal/activation are associated with the desire to move to an even greater degree. This suggests that one strategy to improve motivation to move is by promoting incidental affect, hedonic tone and, perhaps, by energizing action. Psychological stress and poor mood are well-established barriers for physically active behaviors (12, 92–95). When faced with these situations, it would be helpful to connect individuals who are suffering with resources to help them cope, or to lower barriers elsewhere for initiating physical activity. It seems likely that many individuals are most motivated to move during the workday, and in the evening time motivation to move is diminishing—the time when most people attempt to go to the gym (96). Given this, it may make sense to promote movement in the workplace. Such a strategy may also improve workplace productivity (97). An intervention may be as simple as encouraging workers to stand up and move, which we demonstrated was associated with greater desires to be physically active (but not lesser desire to rest). While this is not a causal relationship, one might imagine that the simple act of standing up might promote desires to move, which can be taken advantage of later down the line. Qualitative data supports the ideas of inertia and momentum as strong forces impacting the desire to move (12). Finally, it is important to consider aspects of the exercise regimen, such as modality and intensity, which positively influence motivation for exercise by eliciting a positive affective response (98).

Conclusion

This is the first study to investigate the natural variation of motivation for movement and sedentary behaviors across the day, finding that desires to move and rest resembled a biorhythm. Individuals wanted to move the most around 3:00 in the afternoon, approximately the same time their desire to rest was at its lowest. As with our former investigations, recent behavior (over the last 2 + hours) appeared to alter motivation states. Specifically, in the case of recent exercise, we observed that motivation states to move decreased (and to rest increased) two hours after exercise, but there was no change immediately afterwards. Current body position and current exercise behavior was strongly predicted by desires to move and rest indicating that when people are actually moving or in a state of readiness to move, they want to move. To our knowledge, this is also the first study to investigate the role of motivation states on future exercise behavior. Importantly, motivation states to move and rest predicted intentions for exercise and sleep in the near term (0–60 min). While recent eating behaviors predicted desires to move and rest, motivation states did not predict future eating intentions. Finally, motivation states were associated with feeling states, particularly arousal/activation. Overall, these data provided support that motivation states may be affectively-charged, short-lived, impacted by recent behavior, and associated with intentions to behave, as predicted by the WANT model (9).

Data availability statement

The raw data supporting the conclusions of this article are available at this location: https://www.researchgate.net/publication/369550926_CRAVE_circadian_official_dataset_Mar_27_2023.

Ethics statement

The study involved human participants and was reviewed and approved by Teachers College—Columbia University, Protocol 21-282. The participants provided their written informed consent to participate in this study.

Author contributions

The study's concept and procedures were designed by MSK and CD. CD created the online instruments and collected the data. The statistics were conducted by CB, TL, CD, and MB, in that order. The manuscript was written by MS, CB, CD, JB, DB, GA, RS, MB and AH, in that order. Figures and tables were by CB, MS, TL and CD, in that order. All authors contributed to the article and approved the submitted version.

Funding

GA was supported by a fellowship from the Office of Academic Affiliations at the United States Veterans Health Administration, a Robert E. Leet and Clara Guthrie Patterson Trust Mentored Research Award, Bank of America, N.A., Trustee, and American Heart Association Grant #852679 (GA, 2021–2024). DB was supported by Grant RYC2021-031098-I funded by MCIN/AEI/10.13039/501100011033, by "European Union NextGenerationEU/PRTR" and by a productivity research grant (PQ1D) from CNPq (Brazil).

Acknowledgments

The authors wish to thank David Lassiter (AstraZeneka, Stockholm, Sweden) for assistance with early phases of analysis. Cyrus Dadina presented a portion of these data at the Regeneron Westchester Science & Engineering Fair (WESEF; Erica Curran, Dobbs Ferry High School, advisor) in Westchester, NY. Adrian Haughton presented a subset of these data at the North American Society for the Psychology of Sport and Physical Activity (NASPSPA) conference in Kona, Hawaii. Philip R. Stanforth (The University of Texas at Austin) provided technical assistance. A podcast explaining the theoretical framework and the CRAVE scale is presented here: https://www.scipod.global/dr-matthew-stults-kolehmainen-measuring-our-motivation-for-physical-activity-and-sedentary-behaviour/

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Hyde ET, Whitfield GP, Omura JD, Fulton JE, Carlson SA. Trends in meeting the physical activity guidelines: muscle-strengthening alone and combined with aerobic activity, United States, 1998–2018. *J Phys Act Health*. (2021) 18(S1):S37–44. doi: 10.1123/jpah.2021-0077

2. Ussery EN, Whitfield GP, Fulton JE, Galuska DA, Matthews CE, Katzmarzyk PT, et al. Trends in self-reported sitting time by physical activity levels among US adults, NHANES 2007/2008–2017/2018. *J Phys Act Health*. (2021) 18(S1):S74–83. doi: 10.1123/jpah.2021-0221

3. Williams DM, Evans DR. Current emotion research in health behavior science. *Emot Rev*. (2014) 6(3):277–87. doi: 10.1177/1754073914523052

4. Williams DM, Rhodes RE, Conner MT. Conceptualizing and intervening on affective determinants of health behaviour. *Psychol Health*. (2019) 34(11):1267–81. doi: 10.1080/08870446.2019.1675659

5. Brand R, Ekkekakis P. Affective–reflective theory of physical inactivity and exercise. *Ger J Exerc Sport Res*. (2018) 48(1):48–58. doi: 10.1007/s12662-017-0477-9

6. Conroy DE, Berry TR. Automatic affective evaluations of physical activity. *Exerc Sport Sci Rev*. (2017) 45(4):230–7. doi: 10.1249/jes.0000000000000120

7. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci*. (2011) 6(1):42. doi: 10.1186/1748-5908-6-42

8. National Institute of Mental Health. Sensorimotor Dynamics (RDoc Constructs): National Institutes of Health (2022). Available at: https://www.nimh.nih.gov/research/research-funded-by-nimh/rdoc/constructs/sensorimotor-dynamics

9. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Gilson TA, Ash GI, McKee PC, et al. Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front Psychol*. (2020) 11(3076):2–13. doi: 10.3389/fpsyg.2020.568390

10. Stults-Kolehmainen MA, Blacutt M, Fogelman N, Gilson TA, Stanforth PR, Divin AL, et al. Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front Psychol*. (2021) 12:4–19. doi: 10.3389/fpsyg.2021.568286

11. Filgueiras A, Stults-Kolehmainen MA, Boullosa D, Sinha R, Bartholomew JB, McKee P, et al. The CRAVE and ARGE scales for motivation states for physical activity and sedentarism: brazilian Portuguese translation and single-item versions. *SportRxiv*. (2022). doi: 10.51224/SRXIV.224

12. Stults-Kolehmainen M, Gilson T, SantaBarbara N, McKee P, Sinha R, Bartholomew J, et al. Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups. *SportRxiv*. (2022). doi: 10.51224/SRXIV.189

13. Antle MC, Silver R. Circadian insights into motivated behavior. *Behav Neurosci Motiv*. (2015) 27:137–69. doi: 10.1007/7854_2015_384

14. Stults-Kolehmainen MA, Blacutt M, Bartholomew JB, Boullosa D, Janata P, Koo BB, et al. Urges to move and other motivation states for physical activity in clinical and healthy populations: a scoping review protocol. *Front Psychol*. (2022) 13:5. doi: 10.3389/fpsyg.2022.901272

15. Khan FH, Ahlberg CD, Chow CA, Shah DR, Koo BB. Iron, dopamine, genetics, and hormones in the pathophysiology of restless legs syndrome. *J Neurol*. (2017) 264(8):1634–41. doi: 10.1007/s00415-017-8431-1

16. Rosenberger ME, Fulton JE, Buman MP, Troiano RP, Grandner MA, Buchner DM, et al. The 24-hour activity cycle: a new paradigm for physical activity. *Med Sci Sports Exerc*. (2019) 51(3):454–64. doi: 10.1249/mss.0000000000001811

17. Di J, Spira A, Bai J, Urbanek J, Leroux A, Wu M, et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. *Stat Biosci*. (2019) 11(2):371–402. doi: 10.1007/s12561-019-09236-4

18. Xiao L, Huang L, Schrack JA, Ferrucci L, Zipunnikov V, Crainiceanu CM. Quantifying the lifetime circadian rhythm of physical activity: a covariate-dependent functional approach. *Biostatistics*. (2014) 16(2):352–67. doi: 10.1093/biostatistics/kxu045

19. McDonnell EI, Zipunnikov V, Schrack JA, Goldsmith J, Wrobel J. Registration of 24-hour accelerometric rest-activity profiles and its application to human chronotypes. *Biol Rhythm Res*. (2022) 53(8):1299–319. doi: 10.1080/09291016.2021.1929673

20. Resnicow K, Page SE. Embracing chaos and complexity: a quantum change for public health. *Am J Public Health*. (2008) 98(8):1382–9. doi: 10.2105/AJPH.2007.129460

21. Resnicow K, Vaughan R. A chaotic view of behavior change: a quantum leap for health promotion. *Int J Behav Nutr Phys Act*. (2006) 3(1):1–7. doi: 10.1186/1479-5868-3-25

22. Inzlicht M, Schmeichel BJ, Macrae CN. Why self-control seems (but may not be) limited. *Trends Cogn Sci (Regul Ed)*. (2014) 18(3):127–33. doi: 10.1016/j.tics.2013.12.009

23. Stults-Kolehmainen MA. Humans have a basic physical and psychological need to move the body: physical activity as a primary drive. *SportRxiv*. (2022). doi: 10.51224/SRXIV.236

24. Casper RC, Voderholzer U, Naab S, Schlegl S. Increased urge for movement, physical and mental restlessness, fundamental symptoms of restricting anorexia nervosa? *Brain Behav*. (2020) 10(3):e01556. doi: 10.1002/brb3.1556

25. Iqbal N, Lambert T, Masand P. Akathisia: problem of history or concern of today. *CNS Spectr*. (2007) 12(9):1–13. doi: 10.1017/s1092852900026201

26. Williams DM, Bohlen LC. Motivation for exercise: reflective desire versus hedonic dread. In: Anshel MH, Labbé EE, Petrie TA, Petruzzello SJ, Steinfeldt JA, editors. *APA Handbook of sport and exercise psychology, volume 2: Exercise psychology. APA handbooks in psychology series.* Washington, DC, US: American Psychological Association (2019). p. 363–85.

27. Frijda NH. Emotion, cognitive structure, and action tendency. *Cognition and Emotion*. (1987) 1(2):115–43. doi: 10.1080/02699938708408043

28. Frijda NH, Kuipers P, ter Schure E. Relations among emotion, appraisal, and emotional action readiness. *J Pers Soc Psychol*. (1989) 57(2):212–28. doi: 10.1037//0022-3514.57.2.212

29. Elliot AJ, Devine PG. On the motivational nature of cognitive dissonance: dissonance as psychological discomfort. *J Pers Soc Psychol*. (1994) 67(3):382. doi: 10.1037/0022-3514.67.3.382

30. Kavanagh DJ, Andrade J, May J. Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol Rev*. (2005) 112(2):446–67. doi: 10.1037/0033-295x.112.2.446

31. Janata P, Peterson J, Ngan C, Keum B, Whiteside H, Ran S. Psychological and musical factors underlying engagement with unfamiliar music. *Music Percept*. (2018) 36(2):175–200. doi: 10.1525/mp.2018.36.2.175

32. Taylor IM, Whiteley S, Ferguson RA. Disturbance of desire-goal motivational dynamics during different exercise intensity domains. *Scand J Med Sci Sports*. (2022) 32(4):798–806. doi: 10.1111/sms.14129

33. Carver CS, Scheier MF. Chapter one—self-regulatory functions supporting motivated action. In: AJ Elliot, editor. *Advances in motivation science*. Cambridge, MA: Academic Press (2017), Vol. 4, p. 1–37.

34. Craig AD. An interoceptive neuroanatomical perspective on feelings, energy, and effort. *Behav Brain Sci*. (2013) 36(6):685–6. discussion 707–26. doi: 10.1017/s0140525(13001489

35. Loewenstein G. Out of control: visceral influences on behavior. *Organ Behav Hum Decis Process*. (1996) 65(3):272–92. doi: 10.1006/obhd.1996.0028

36. Brehm JW, Self EA. The intensity of motivation. *Annu Rev Psychol*. (1989) 40(1):109–31. doi: 10.1146/annurev.ps.40.020189.000545

37. Frijda NH, Ridderinkhof KR, Rietveld E. Impulsive action: emotional impulses and their control. *Front Psychol*. (2014) 5:1–6. doi: 10.3389/fpsyg.2014.00518

38. Russell JA, Weiss A, Mendelsohn GA. Affect grid: a single-item scale of pleasure and arousal. *J Pers Soc Psychol*. (1989) 57:493–502. doi: 10.1037/0022-3514.57.3.493

39. Dickinson A, Balleine B. Hedonics: the cognitive-motivational interface. In: ML Kringelbach, KC Berridge, editors. *Pleasures of the brain*. Oxford, UK: Oxford University Press (2010). p. 74–84.

40. Dunton GF. Ecological momentary assessment in physical activity research. *Exerc Sport Sci Rev*. (2017) 45(1):48. doi: 10.1249/JES.0000000000000092

41. Hardy CJ, Rejeski WJ. Not what, but how one feels: the measurement of affect during exercise. *J Sport Exerc Psychol*. (1989) 11:304–17. doi: 10.1123/jsep.11.3.304

42. Lang PJ. Behavioral treatment and bio-behavioral assessment: computer applications. In: JB Sidowski, JH Johnson, TA Williams, editors. *Technology in mental health care delivery systems*. Norwood, NJ: Ablex (1980). p. 119–37.

43. Ekkekakis P, Petruzzello SJ. Acute aerobic exercise and affect—current status, problems and prospects regarding dose-response. *Sports Med*. (1999) 28(5):337–74. doi: 10.2165/00007256-199928050-00005

44. Hall EE, Ekkekakis P, Petruzello SJ. The affective beneficence of vigorous exercise revisited. *Br J Health Psychol*. (2002) 7:47–66. doi: 10.1348/135910702169358

45. Svebak S, Murgatroyd S. Metamotivational dominance: a multimethod validation of reversal theory constructs. *J Pers Soc Psychol*. (1985) 48:107–16. doi: 10.1037/0022-3514.48.1.107

46. Stults-Kolehmainen MA, Bartholomew JB. Psychological stress impairs short-term muscular recovery from resistance exercise. *Med Sci Sports Exercise*. (2012) 44 (11):2220–7. doi: 10.1249/MSS.0b013e31825f67a0

47. Stults-Kolehmainen MA, Lu T, Ciccolo JT, Bartholomew JB, Brotnow L, Sinha R. Higher chronic psychological stress is associated with blunted affective responses to strenuous resistance exercise: RPE, pleasure, pain. *Psychol Sport Exerc*. (2016) 22:27–36. doi: 10.1016/j.psychsport.2015.05.004

48. Raudenbush SW, Bryk AS. *Hierarchical linear models: applications and data analysis methods*. 2nd ed Thousand Oaks, CA: Sage (2002). 3–15.

49. R Core Team. R: A Language and environment for statistical computing. Version 4.0 ed. (2021). p. Computer software.

50. Bates D, Mächler M, Bolker B, Walker S. Fitting linear mixed-effects models using lme4. *J Stat Softw*. (2015) 67(1):1–48. doi: 10.18637/jss.v067.i01

51. Kuznetsove A, Brohoff PB, Christensen RHB, Jensen SP. Package "lmertest" [White paper]: CRAN. (2020). Available at: https://cran.r-project.org/web/packages/lmerTest/lmerTest.pdf

52. Doyle MM, Murphy TE, Pisani MA, Yaggi HK, Jeon S, Redeker NS, et al. A SAS macro for modelling periodic data using cosinor analysis. *Comput Methods Programs Biomed*. (2021) 209:106292. doi: 10.1016/j.cmpb.2021.106292

53. Bittle CC Jr., Molina DJ, Bartter FC. Salt sensitivity in essential hypertension as determined by the cosinor method. *Hypertension*. (1985) 7(6 Pt 1):989–94. doi: 10.1161/01.hyp.7.6.989

54. Casale R, Pasqualetti P. Cosinor analysis of circadian peak expiratory flow variability in normal subjects, passive smokers, heavy smokers, patients with chronic obstructive pulmonary disease and patients with interstitial lung disease. *Respiration*. (1997) 64(4):251–6. doi: 10.1159/000196682

55. Fournier S, Iten L, Marques-Vidal P, Boulat O, Bardy D, Beggah A, et al. Circadian rhythm of blood cardiac troponin T concentration. *Clin Res Cardiol*. (2017) 106(12):1026–32. doi: 10.1007/s00392-017-1152-8

56. Fekedulegn D, Innes K, Andrew ME, Tinney-Zara C, Charles LE, Allison P, et al. Sleep quality and the cortisol awakening response (CAR) among law enforcement officers: the moderating role of leisure time physical activity. *Psychoneuroendocrinology*. (2018) 95:158–69. doi: 10.1016/j.psyneuen.2018.05.034

57. Mills JN. Human circadian rhythms. *Physiol Rev*. (1966) 46(1):128–71. doi: 10.1152/physrev.1966.46.1.128

58. Dunlap JC, Loros JJ, DeCoursey PJ. *Chronobiology: biological timekeeping*. Sunderland, MA: Sinauer Associates (2004).

59. Kline CE, Durstine JL, Davis JM, Moore TA, Devlin TM, Zielinski MR, et al. Circadian variation in swim performance. *J Appl Physiol*. (2007) 102(2):641–9. doi: 10.1152/japplphysiol.00910.2006

60. Serin Y, Tek NA. Effect of circadian rhythm on metabolic processes and the regulation of energy balance. *Ann Nutr Metab*. (2019) 74(4):322–30. doi: 10.1159/000500071

61. Clark LA, Watson D, Leeka J. Diurnal variation in the positive affects. *Motiv Emot*. (1989) 13(3):205–34. doi: 10.1007/BF00995536

62. Barker JL, Kolar D, Lazzer AS-D, Keel PK. Exercise satiation: a novel theoretical conceptualization for problematic exercise observed in eating disorders. *Int J Eating Disord*. (2022) 55(2):176–9. doi: 10.1002/eat.23635

63. Boecker H, Sprenger T, Spilker ME, Henriksen G, Koppenhoefer M, Wagner KJ, et al. The Runner's High: opioidergic mechanisms in the human brain. *Cerebral Cortex*. (2008) 18(11):2523–31. doi: 10.1093/cercor/bhn013

64. Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! *Ann Behav Med*. (2008) 35(2):136–49. doi: 10.1007/s12160-008-9025-z

65. Tassi P, Muzet A. Sleep inertia. *Sleep Med Rev*. (2000) 4(4):341–53. doi: 10.1053/smrv.2000.0098

66. Jeong S-H, Fishbein M. Predictors of multitasking with media: media factors and audience factors. *Media Psychol*. (2007) 10(3):364–84. doi: 10.1080/15213260701532948

67. Ogden J, Coop N, Cousins C, Crump R, Field L, Hughes S, et al. Distraction, the desire to eat and food intake. Towards an expanded model of mindless eating. *Appetite*. (2013) 62:119–26. doi: 10.1016/j.appet.2012.11.023

68. Brietzke C, Franco-Alvarenga PE, Coelho-Júnior HJ, Silveira R, Asano RY, Pires FO. Effects of carbohydrate mouth rinse on cycling time trial performance: a systematic review and meta-analysis. *Sports Med*. (2019) 49(1):57–66. doi: 10.1007/s40279-018-1029-7

69. Teff KL. Visceral nerves: vagal and sympathetic innervation. *J Parenter Enteral Nutr*. (2008) 32(5):569–71. doi: 10.1177/0148607108321705

70. Kerksick CM, Arent S, Schoenfeld BJ, Stout JR, Campbell B, Wilborn CD, et al. International society of sports nutrition position stand: nutrient timing. *J Int Soc Sports Nutr*. (2017) 14:33. doi: 10.1186/s12970-017-0189-4

71. Stults-Kolehmainen MA, Ciccolo JT, Bartholomew JB, Seifert J, Portman RS. Age and gender-related changes in exercise motivation among highly active individuals. *Athletic Insight*. (2013) 5(1):45–63. Available at: https://www.researchgate.net/publication/234111759_Age_and_Gender-related_Changes_in_Exercise_Motivation_among_Highly_Active_Individuals

72. Stults-Kolehmainen MA, Gilson TA, Abolt CJ. Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. *J Sport Behav*. (2013) 36(3):320–3. Available at: https://www.researchgate.net/publication/234111733_Feelings_of_acceptance_and_intimacy_among_teammates_predict_motivation_in_intercollegiate_sport

73. Feige K. Wesen und problematik der sportmotivation. *Sportunterricht*. (1976) 5:4–7.

74. Davis WA. The two senses of desire. *Philos Stud*. (1984) 45(2):181–95. doi: 10.1007/BF00372477

75. Cheval B, Radel R, Neva JL, Boyd LA, Swinnen SP, Sander D, et al. Behavioral and neural evidence of the rewarding value of exercise behaviors: a systematic review. *Sports Med*. (2018) 48(6):1389–404. doi: 10.1007/s40279-018-0898-0

76. Kaplan GB, Greenblatt DJ, Ehrenberg BL, Goddard JE, Cotreau MM, Harmatz JS, et al. Dose-Dependent pharmacokinetics and psychomotor effects of caffeine in humans. *J Clin Pharmacol*. (1997) 37(8):693–703. doi: 10.1002/j.1552-4604.1997.tb04356.x

77. Duncan MJ, Smith M, Cook K, James RS. The acute effect of a caffeine-containing energy drink on mood state, readiness to invest effort, and resistance exercise to failure. *J Strength Cond Res*. (2012) 26(10):2858–65. doi: 10.1519/JSC.0b013e318241e124

78. Tripathi R, Reich SG, Scorr L, Guardiani E, Factor SA. Lurasidone-Induced tardive syndrome. *Mov Disord Clin Pract*. (2019) 6(7):601–4. doi: 10.1002/mdc3.12812

79. van de Langenberg D, Vlaanderen JJ, Dollé MET, Rookus MA, van Kerkhof LWM, Vermeulen RCH. Diet, physical activity, and daylight exposure patterns in night-shift workers and day workers. *Ann Work Expo Health*. (2019) 63(1):9–21. doi: 10.1093/annweh/wxy097

80. Books C, Coody LC, Kauffman R, Abraham S. Night shift work and its health effects on nurses. *Health Care Manag (Frederick)*. (2020) 39(3):122–7. doi: 10.1097/hcm.0000000000000297

81. Nezlek JB. An introduction to multilevel modeling for social and personality psychology. *Soc Personal Psychol Compass*. (2008) 2(2):842–60. doi: 10.1111/j.1751-9004.2007.00059.x

82. Luo W, Li H, Baek E, Chen S, Lam KH, Semma B. Reporting practice in multilevel modeling: a revisit after 10 years. *Rev Educ Res*. (2021) 91(3):311–55. doi: 10.3102/0034654321991229

83. Bolin JH, Finch WH, Stenger R. Estimation of random coefficient multilevel models in the context of small numbers of level 2 clusters. *Educ Psychol Meas*. (2019) 79(2):217–48. doi: 10.1177/0013164418773494

84. Hair JF Jr, Fávero LP. Multilevel modeling for longitudinal data: concepts and applications. *RAUSP Manag J*. (2019) 54:459–89. doi: 10.1108/RAUSP-04-2019-0059

85. McNeish DM, Stapleton LM. The effect of small sample size on two-level model estimates: a review and illustration. *Educ Psychol Rev*. (2016) 28(2):295–314. doi: 10.1007/s10648-014-9287-x

86. Budnick CJ, Santuzzi AM. Seeking reemployment in nonmetropolitan America. *J Employ Couns*. (2013) 50(4):146–53. doi: 10.1002/j.2161-1920.2013.00033.x

87. Harms R. Self-regulated learning, team learning and project performance in entrepreneurship education: learning in a lean startup environment. *Technol Forecast Soc Change*. (2015) 100:21–8. doi: 10.1016/j.techfore.2015.02.007

88. Williams DM, Dunsiger S, Ciccolo JT, Lewis BA, Albrecht AE, Marcus BH. Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol Sport Exerc*. (2008) 9 (3):231–45. doi: 10.1016/j.psychsport.2007.04.002

89. Parker M, Challet E, Deputte B, Ract-Madoux B, Faustin M, Serra J. Seasonal effects on locomotor and feeding rhythms in indoor cats. *J Vet Behav*. (2022) 48:56–67. doi: 10.1016/j.jveb.2021.05.005

90. Witting W, Kwa I, Eikelenboom P, Mirmiran M, Swaab DF. Alterations in the circadian rest-activity rhythm in aging and Alzheimer's disease. *Biol Psychiatry*. (1990) 27(6):563–72. doi: 10.1016/0006-3223(90)90523-5

91. Hardeman W, Houghton J, Lane K, Jones A, Naughton F. A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity. *Int J Behav Nutr Phys Act*. (2019) 16(1):31. doi: 10.1186/s12966-019-0792-7

92. Stults-Kolehmainen MA, Sinha R. The effects of stress on physical activity and exercise. *Sports Med*. (2014) 44(1):81–121. doi: 10.1007/s40279-013-0090-5

93. Ruissen GR, Beauchamp MR, Puterman E, Zumbo BD, Rhodes RE, Hives BA, et al. Continuous-Time modeling of the bidirectional relationship between incidental affect and physical activity. *Ann Behav Med*. (2022) 56(12):1284–99. doi: 10.1093/abm/kaac024

94. Stults-Kolehmainen MA, Tuit K, Sinha R. Lower cumulative stress is associated with better health for physically active adults in the community. *Stress*. (2014) 17 (2):157–68. doi: 10.3109/10253890.2013.878329

95. Stults-Kolehmainen M, Filgueiras A, Blacutt M. Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. *medRxiv*. (2021):2020.05.12.20099374. doi: 10.1101/2020.05.12.20099374

96. Chirazi M. Study regarding the activity of the fitness centres from the city of Iasi. *Bull Trans Univ Brasov Ser IX, Sci Human Kinet*. (2017) 10(1):69–75.

97. Engelen L, Chau J, Young S, Mackey M, Jeyapalan D, Bauman A. Is activity-based working impacting health, work performance and perceptions? A systematic review. *Build Res Inf*. (2019) 47(4):468–79. doi: 10.1080/09613218.2018.1440958

98. Ekkekakis P, Brand R. Exercise motivation from a post-cognitivist perspective: affective-reflective theory. In: C Englert, I Taylor, editors. *Motivation and self-regulation in sport and exercise*. New York: Routledge (2021). p. 20–40.

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 26 April 2023
DOI 10.3389/fpsyg.2023.1133583

OPEN ACCESS

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RECEIVED 29 December 2022
ACCEPTED 12 April 2023
PUBLISHED 26 April 2023

CITATION
Heredia-León DA, Manzano-Sánchez D, Gómez-Mármol A and Valero-Valenzuela A (2023) Prediction of the adherence to sports practice of young Ecuadorians based on the perception of the coach's interpersonal style.
Front. Psychol. 14:1133583.
doi: 10.3389/fpsyg.2023.1133583

Prediction of the adherence to sports practice of young Ecuadorians based on the perception of the coach's interpersonal style

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Based on the framework of the self-determination theory, the present study aimed to test a predictive model in the Ecuadorian sports context by using autonomy support as a trigger, which was mediated by basic psychological needs and later by autonomous motivation. This procedure was used to predict the intention to be physically active and was carried out on 280 athletes from the province of Azuay (Ecuador) aged between 12 and 20 years (M = 15.28; SD = 1.71). Different scales were used to measure the perception of the interpersonal style of autonomy supported by the coach. The scales employed included the degree of satisfaction of basic psychological needs, motivation to practice sports, and intention to be physically active. A structural equation analysis revealed that perceived autonomy support positively predicted basic psychological needs, which in turn positively predicted autonomous motivation and, as a result, the athletes' intentions to be physically active. It was concluded that coaches' support for the interpersonal style of autonomy can benefit the development of basic psychological needs as well as autonomous motivation, which in turn can increase young athletes' intentions to be physically active. Future research is also recommended to verify this predictive model and to encourage further experimental studies in which coaches promote autonomy support for athletes intending to increase their adherence to practising sports.

KEYWORDS

autonomy support, basic psychological needs, motivation, intention to be physically active, sport

1. Introduction

Regular physical activity and sports are beneficial for physical health and for the mental health of children and adolescents. However, a large part of the population is becoming less and less active due to changes in lifestyle patterns, the use of transportation, the increasing use of technology, changing cultural values, and urbanization

(World Health Organization, 2018). Despite the possible advantages that can be obtained by practising sports, dropout rates indicate that half of the children and adolescents who start an activity end up quitting during the first 6 months (Molinero et al., 2011); hence the interest in studying variables that help improve the population's intention to practice a physical activity. One of these variables is motivation, which denotes someone's energy and direction as well as the persistence of and purpose behind their behaviors, including their intentions and resulting actions, thus placing itself at the center of the biological, cognitive, and social regulation of the individual (Deci and Ryan, 1985).

In order to understand motivation, Self-determination theory (SDT) (Deci and Ryan, 1985, 2000) is one of the most popular contemporary frameworks that describes the process through which it develops and how it influences human behavior and wellbeing. Deci and Ryan (1991) postulated that the regulation of human behavior could be framed in terms of autonomous, controlled, or lack of motivation. In SDT, autonomous motivation is defined as the participation in activities for the interest and satisfaction derived from the activities themselves (Hagger et al., 2014). This motivation consists of intrinsic (the individual performs an activity because it is fun and attractive), identified (the individual identifies with the value of the activity and has a predisposition to act), and integrated motivation (the individual finds the activity congruent with his/her values and interests). Embedded within SDT, the basic psychological needs are fundamental to increase a more autonomous motivation and for that, positive consequences (Vallerand, 1997). These basic psychological needs are autonomy, competence and relatedness. Autonomy can be defined as one's need to experience a sense of willingness in one's actions. Competence refers to one's need to experience effectiveness in one's interactions with the world. Finally, relatedness refers to a need for connectedness with significant others, satisfaction with the social world, and a feeling of being accepted (Ryan and Deci, 2017).

From this perspective, coaches should consider the importance of supporting the autonomy of their athletes since it can create a context in which athletes feel their decisions are voluntary (autonomy perception). It follows that their behaviors would take on a more intrinsic character at the motivational level (Ryan and Deci, 2017) and according to studies like Merino-Barrero et al. (2019) or Rodrigues et al. (2019) it could predict higher levels of the intention to continue exercising in the future.

This theory has been investigated through different studies in recent decades, including those related to sports, exercise, and physical education. For instance, some studies have attempted to predict the intention to be physically active through different variables such as the interpersonal style of the coach/teacher (Almagro and Conde, 2012; Expósito et al., 2012; Baena-Extremera and Granero-Gallegos, 2015; Fernández-Ozcorta et al., 2015; Moreno-Murcia et al., 2018; Cid et al., 2019; Trigueros-Ramos et al., 2019; Huéscar et al., 2020), the satisfaction of basic psychological needs of autonomy, competence and relatedness (Almagro and Conde, 2012; Fernández-Ozcorta et al., 2015; Franco et al., 2017; Rodrigues et al., 2020) and autonomous motivation (Lim and Wang, 2009; Méndez-Giménez et al., 2012; Cuevas et al., 2014; Franco et al., 2016; Rodrigues et al., 2019; Teixeira et al., 2020). Focusing particularly on the sports field and based on the importance of autonomy support teaching style from coach to athlete (Deci and Ryan, 1987), numerous studies have focused on this variable since it demonstrates high predictive power in relation to the satisfaction of the basic psychological needs (Isoard-Gautheur et al., 2012; Morillo et al., 2018; Pineda-Espejel et al., 2020).

Various studies have analyzed these variables separately since no studies in the bibliography have tested the SDT's complete sequence—support for autonomy, basic psychological needs, and autonomous motivation—using intention to be physically active as the final variable.

For this reason, based on the SDT, this study aimed to test a model in relation to Ecuadorian athletes using structural equations where the predictive power of the perception of the coach's interpersonal style was seen as supporting autonomy in terms of basic personal needs along with autonomous motivation and, finally, autonomous motivation to continue to be physically active in the future. It was deemed very important to assess the intention to be physically active in this age range because practising sports is usually interrupted by the start of higher education since in Ecuador many students do not have access to a public university and have to work to pay for their studies (Almagro et al., 2011). Following this, it was hypothesized that the interpersonal style of a coach that supports autonomy would predict the satisfaction of basic psychological needs, which in turn would predict autonomous motivation and, finally, the intention to be physically active.

2. Materials and methods

2.1. Design

This research corresponds to a cross-sectional explanatory design, meaning that an empirical study is considered alongside an associative strategy, where theoretical models are put together to test their integration into an underlying theory (Ato et al., 2013).

2.2. Participants

In the present study, the sample comprised 301 federated Ecuadorian athletes in the province of Azuay. The sample selection was a non-probabilistic type for the sake of convenience according to the subjects that could be accessed. After discarding the questionnaires that were not fully completed and applying statistical procedures to detect atypical cases and missing values, the final sample comprised 280 male ($n = 153$) and female ($n = 127$) athletes aged between 12 and 20 years, with the mean age being 15.28 (SD = 1.71).

2.3. Measures

2.3.1. Support autonomy

Support for autonomy was assessed using seven items belonging to the "Support for Autonomy Scale" developed by Moreno-Murcia et al. (2020). Participants had to answer questions about the interpersonal style of the coach in practices aimed at supporting autonomy (e.g., "offers different ways to perform a certain task"). The previously used statement was the following: "In my training sessions, my coach . . ." The scale corresponds to a Likert-type scale, with five response options from one (surely not) to five (surely). The internal consistency coefficients showed a value α = 0.75 and Ω = 0.76.

2.3.2. Basic psychological needs

The "Psychological Need Satisfaction in Exercise Scale" (PNSE) developed by Wilson et al. (2006) was validated for the Spanish context by Moreno-Murcia et al. (2011). The PNSE uses 18 items, six of which assess each of the following needs: competence (e.g., "I have the confidence to do the most challenging exercises"), autonomy (e.g., "I believe that I can make decisions regarding my exercise program"), and relatedness (e.g., "I enjoy camaraderie with my classmates because we exercise for the same reason"). The previous sentence started with "In my training . . .," and the responses were collected on a Likert-type scale, whose score ranges from one (false) to six (true). Internal consistency demonstrated a value of α = 0.84, competence Ω = 0.84, autonomy α = 0.76 and Ω = 0.76, and relatedness α = 0.66, and Ω = 0.70. In addition, the Psychological Mediators Index (IMP) was developed by calculating the average of the three factors in a single dimension; the internal consistency was α = 0.79 and Ω = 0.81.

2.3.3. Autonomous motivation

The factors that make up autonomous motivation in the "Behavior Regulation Questionnaire in Sport" (BRQS) developed by Lonsdale et al. (2008) were validated for the Spanish context by Moreno-Murcia et al. (2011). Six factors from four items were used to measure general intrinsic motivation (e.g., "because I find it pleasant"), intrinsic motivation for knowledge (e.g., "because I enjoy learning new techniques"), intrinsic motivation for stimulation (e.g., "because of the pleasure it gives me when I am fully dedicated to this sport"), intrinsic motivation for achievement (e.g., "because it gives me satisfaction when I strive to achieve my goals"), integrated regulation (e.g., "because practising this sport is part of who I am"), and identified regulation (e.g., "because it is a good way to learn things that can be useful in my daily life"). The introductory phrase used was the following: "I participate in this sport . . ." A seven-point Likert scale was used, ranging from one (totally false) to seven (totally true). Following Williams et al. (1996), to analyze the data in the present work we unified the four dimensions of intrinsic motivation along with integrated regulation and identified regulation into a single dimension called autonomous motivation. The reliability of the variables for the athletes was α = 0.61 and Ω = 0.67 for general motivation; α = 0.78 and Ω = 0.77 for intrinsic motivation for knowledge; α = 0.71 and Ω = 0.72 for intrinsic motivation for stimulation; α = 0.75 and Ω = 0.76 for intrinsic motivation for achievement; α = 0.77 and Ω = 0.78 for integrated regulation; α = 0.67 and Ω = 0.69 for identified regulation; and α = 0.84 and Ω = 0.84 for the unified factor of autonomous motivation.

2.3.4. Future intention to be physically active

The questionnaire Intention to be physically active (IPA) was used by Hein et al. (2004) and validated for the Spanish context by Moreno et al. (2007). This tool comprises five items, e.g., "after graduation, I would like to be physically active," that are preceded by a statement, in this case, "Regarding my intention to practice some physical sporting activity . . ." The answers are closed with a Likert-type scale whose score ranges from totally disagree (1) to totally agree (5). The reliability value was α = 0.75 and Ω = 0.77.

2.4. Procedure

This project was presented to the Azuay Sports Federation in Cuenca–Ecuador, from which permission was also requested. Contact was established with the managers, coaches, and monitors responsible for the participating federation through an informative meeting to inform them of the objectives of the project and request their collaboration and the approval of the representatives of the sports clubs. Underage athletes were asked for written authorization from their parents, guardians, or legal representatives, and once the relevant informed consent was obtained, information was given the athletes on how to fill out the questionnaires and resolve all doubts that may arise during the process. The instruments were administered with the researcher present to provide a brief explanation of the objective of the study, and the questionnaires were administered at the beginning of the training sessions in the different sports venues following a prior agreement with the relevant coach and without his/her presence. The anonymity of the answers was asserted. The time required to complete the questionnaire was approximately 15 min, and it varied slightly according to the age of the athletes. The design was approved by the Research Ethics Commission of the University of Murcia, code 3023/2020.

2.5. Data analysis

Following a reliability analysis of all the scales, the Mahalanobis distance was used to detect and eliminate atypical cases or those that did not follow a logical pattern in the set of variables. In addition, the skewness and kurtosis values were analyzed and considered adequate at <2 and <7, respectively (Curran et al., 1996). After eliminating 21 participants who did not meet these requirements, we again proceeded to the reliability analysis of Cronbach's alpha and McDonald's omega of the different scales and finally ended up with a total sample of 280 subjects. The McDonald's omega was calculated following the recommendations of Hayes and Coutts (2020), who consider that this reliability analysis has been more feasible and more widely used in recent years since it works with factor loadings, which makes the calculations more stable and presents a greater level of reliability. The reliability coefficients revealed values for most of the variables above 0.70, a criterion considered acceptable for psychological domain scales (Nunnally, 1978). For the general motivation and regulation identified, the alpha and omega coefficients fell in the range between 0.60 and 0.70, which is also considered acceptable by authors such as Sturmey et al. (2005).

Since this was the first time these instruments were applied to a group of Ecuadorian athletes, a confirmatory factor analysis (CFA) was performed to test the factorial structure of each scale. The findings show that all the rankings exhibited were acceptable with significant factor loadings. Subsequently, the structural equation

TABLE 1 Mean, standard deviation, reliability, and bivariate correlations of the study variables.

Constructs	M	SD	A	K	α	Ω	1	2	3	4
Autonomy style	4.28	0.56	−0.93	0.85	0.75	0.76	–	–	–	–
BPN	4.74	0.60	−0.49	0.16	0.79	0.81	0.384*	–	–	–
Autonomous motivation	6.39	0.58	−1.32	1.49	0.84	0.84	0.826*	0.361*	–	–
IPA	4.56	0.56	−0.95	0.40	0.75	0.77	0.091	0.175*	0.266*	–

*$p < 0.01$; M, media; SD, standard deviation; A, asymmetry; K, kurtosis; α, Cronbach's alpha value; Ω, McDonald's omega value; BPN, basic psychological needs (composite factor); IPA, physical activity intention.

model was used while considering the same dependent and independent variables (Kline, 2011).

As for the analysis, the following absolute and incremental indices were calculated: Comparative Fair Index (CFI), Tucker-Lewis Index (TLI), and the Root Mean Squared Approximation Error (RMSAE), with their respective confidence intervals (90% CI). The following cut-off points were considered acceptable: CFI and TLI ≥0.90, and RMSEA ≤0.80, following various recommendations (Marsh et al., 2004; Hair et al., 2014). To calculate the direct and indirect effects between the constructs, a 95% Confidence Interval (95% CI) was used, with the CI being significant where zero was not included. Subsequently, the composite reliability coefficient (CR) was calculated while considering values greater than 0.70 (Bagozzi and Yi, 1988; Hair et al., 2014) and mean-variance extracted (AVE), which is satisfied if it is >0.50 (Fornell and Larcker, 1981); however, this criterion can be considered very conservative, and slightly lower values can be accepted (Hair et al., 2014). Finally, the measurement invariance between the two samples was reviewed according to gender, meaning that the configure, metric, scale, and strict invariance were evaluated (Byrne, 2016) while the CFI variation was taken as a criterion (ΔCFI < 0.01) (Cheung and Rensvold, 2002). All analyses were carried out using the statistical package SPSS 25.0 and Amos 23 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Preliminary analysis and bivariate correlations

Table 1 shows the bivariate correlations between variables. All the variables were directly and positively correlated with each other ($p < 0.001$) except for the variable "interpersonal style of autonomy support" with the variable "intention of being physically active" ($p = 0.52$).

3.2. Measurement model

Testing the measurement model involved addressing the autonomy-supportive interpersonal style, the satisfaction of basic psychological needs, autonomous motivation (intrinsic motivation, integrated regulation, and identified regulation), and intention to be physically active. Due to the low factorial loads of some of the items that made up the autonomy support scale, and with the intention to present a better fit of the model, the items that were included for the autonomy support factor were all included except 4, 9, 10, and 11. The results showed a good fit for the data [X^2 = 194.326 (126); SRMR = 0.061; RMSEA = 0.044 (90% LO = 0.031, HI = 0.056); TLI = 0.932; CFI = 0.944].

3.3. Structural model

The structural model demonstrated a good fit for the data [X^2 = 189.734 (118); SRMR = 0.058; RMSEA = 0.047 (90% LO = 0.034, HI = 0.059); TLI = 0.911; CFI = 0.932]. For the standardized direct effect (**Figure 1**), positive and significant associations were observed between all the constructs. Specifically, the association between an interpersonal style of autonomy support and the satisfaction of basic psychological needs (β = 0.42), autonomous motivation (β = 0.75), and autonomous motivation and the intention to be physically active (β = 0.35) were all significant, whereas the indirect effect of autonomy support to intention was β = 0.22 and of basic psychological needs to intention β = 0.06.

3.4. Convergent and discriminant validity

Once the confirmatory factorial analysis was carried out, the resulting values of the factors were taken to calculate the convergent validity, thereby fulfilling the latter since all the saturations of the standardized factorial loads yielded values above the 0.50 criterion point. Meanwhile, **Table 2** shows the composite reliability (CR) with values greater than 0.70, bar the value of basic psychological needs (0.461). The average variance extracted (AVE) was also evaluated and values above 0.5 were obtained, although the autonomy support style presented a somewhat lower value (0.354).

3.5. Factorial invariance according to gender

Since the structural model presented a good fit for the data, multigroup confirmatory factor analysis was used to verify its factorial invariance according to gender. First, the configured model (M1) was established and from this basis a series of nested models (M2, M3, and M4) were tested. As can be seen in **Table 3**, the first model (the M1 base model) did not present restrictions based on gender, thereby showing acceptable fit indices, which allowed for the examination of the configural invariance between groups based on gender. The existence of non-significant

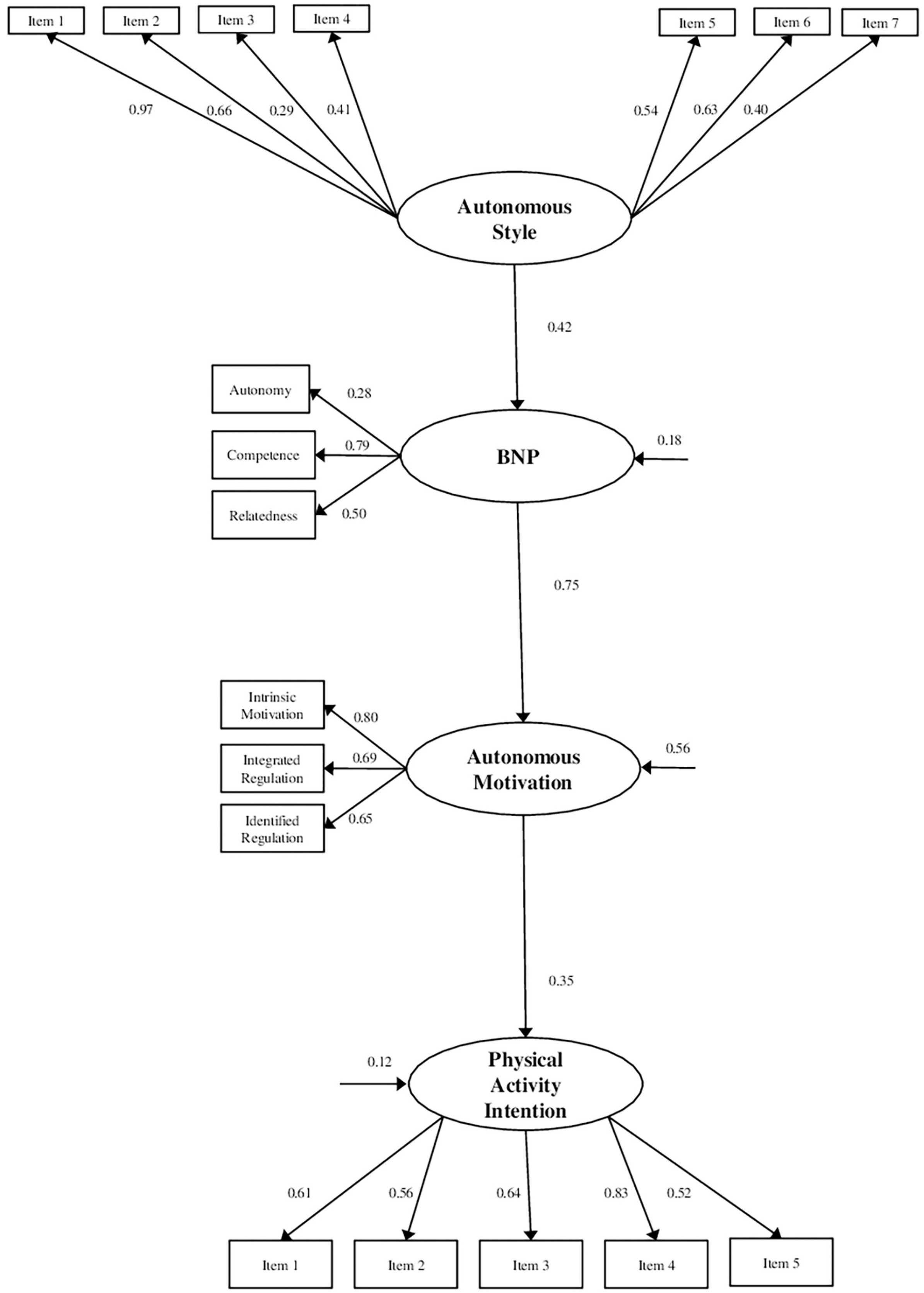

FIGURE 1
Standardized solution of the structural model of autonomy support, autonomy satisfaction, relationship and competence, autonomous motivation, and the intention to be physically active. All parameters are standardized and significant at $p < 0.05$.

TABLE 2 Convergent and discriminant validity of the model.

Constructs	CR	AVE
Autonomy style	0.788	0.354
BPN	0.461	0.523
Autonomous motivation	0.808	0.641
Physical activity intention	0.744	0.520

BPN, basic psychological needs (composite factor); CR, composite reliability; AVE, average variance extract.

differences between the models meant that the constraints could assume invariance across groups. In M2, the factorial weights were restricted to being the same in both groups, and the fit indices were adequate. Therefore, the criterion of metric invariance could be assumed. The findings suggest that the factorial weights were invariant between groups.

In M3, the covariances between the factors were restricted to being the same between the groups, the fit indices of the model were not entirely adequate (ΔCFI > 0.01), differences existed in the covariances between the factors, and the scalar invariance criterion of accuracy could not be assumed. This implies that the strict invariance of the groups, measured through the residual measurement loads (M4), must also be ruled out.

4. Discussion

The objective of this study was to explore the predictive power that autonomy support has on basic psychological needs using a sample of Ecuadorian athletes, some of whom have autonomous motivation and/or autonomous motivation with the intention to continue to be physically active in the future. It was hypothesized that the perception of the coach's autonomy-supportive interpersonal style would act as a positive predictor of the satisfaction of basic psychological needs, which would act as positive predictors of autonomous motivation, while the intention to be physically active would be predicted by the autonomous motivation.

In terms of the first postulate of the model, the results confirm the first part of the hypothesis, thus showing that the autonomy support given by coaches positively predicts the satisfaction of the three basic psychological needs in young Ecuadorian athletes, that is, competence, autonomy, and relatedness. These results have been corroborated in several investigations that have uncovered a positive relationship between autonomy support and the satisfaction of basic psychological needs, such as the case of Adie et al. (2008) in the United Kingdom with 539 participants who practiced different sports and trained an average of 7 h per week; the study by Álvarez et al. (2013) in Spain on 159 Spanish taekwondo athletes; the investigation carried out by González et al. (2015) into 434 Spanish soccer players who belonged to 24 different teams; and the study of López-Walle et al. (2012) in Mexico with 669 athletes from 18 different sports. Therefore, it has been highlighted that the coaches who interacted with their athletes while supporting their autonomy during practice allowed for greater satisfaction of each of the three basic psychological needs, as mentioned by the SDT postulates (Deci and Ryan, 1985, 2000). Huéscar et al. (2020) presented similar findings, indicating the presence of a positive and significant relationship between teacher-induced support for autonomy and the satisfaction of basic psychological needs in sports science students.

On the other hand, and following the sequence of the proposed model, the findings of the present study suggest that basic psychological needs are an essential ingredient for autonomous motivation since athletes who perceive this sequence obtain a greater degree of self-determined motivation. This has been corroborated by different studies from other investigations in the sports and Hispanic-Latino context, where the significant relationship between basic psychological needs and autonomous motivation, self-determined motivation, or intrinsic motivation has been demonstrated. This is the case in the Spain-based studies of Almagro et al. (2011), who analyzed 580 male and female participants who practiced competitive sports, and Balaguer et al. (2008), who studied 301 athletes of different modalities who practiced more than 4 days a week and had been competing for an average of 8 years. Along the same lines, a study was carried out in Mexico by Cantú-Berrueto et al. (2016) with soccer players who had been practicing the discipline for more than two and a half years, while the study by Teixeira et al. (2020) investigated 799 elite swimmers between the ages of 12 and 20 who had an average training experience of 8 years. Finally, in Spain and in the context of physical education, Valero-Valenzuela et al. (2021) carried out a study with a sample of 618 students and obtained results in line with those from the current study. From these results and those of the present study, the contribution of the coach to meeting the basic psychological needs of his/her athletes to achieve optimal autonomous motivation, as mentioned by Deci and Ryan (2000) in their well-known SDT, stands out.

From the third and last postulate of the studied model, it is evident that autonomous motivation is positively related to the intention to be physically active. This relation is of vital importance since in different sports environments motivation may be the most important factor for maintaining fitness in the future (Ryan and Deci, 2007). These statements coincide with the results obtained in various investigations, such as the studies by Almagro et al. (2010) mentioned above; Cid et al. (2019) on Portuguese students who practiced extracurricular sports; Fernández-Ozcorta et al. (2015) on Spanish participants who, as inclusion criteria, had to demonstrate their physical activity; and Lim and Wang (2009) on Singaporean students. Although a great novelty, it is noteworthy that to date no study has predicted the intention of athletes to continue to be physically active, a sequence that has been considered in the present study. If it has been investigated, it is from the opposite point of view, namely, in terms of how the frustration of basic psychological needs predicts the validity of SDT. Indeed, Rodrigues et al. (2019) analyzed athletes who went to gyms and health clubs and found that the frustration of basic psychological needs promoted more controlling motivation and a smaller intention to be physically active. Therefore, it is important to encourage the fulfilment of these three basic psychological needs in order to promote healthy habits and adherence to regular physical activity.

One of the limitations of this research is its cross-correlational nature and the fact that the relationships described do not indicate a causal relationship. Despite this, the study has the following strengths: the consideration of a large sample of federated

TABLE 3 Measurement invariance of the model based on gender.

Model	X^2	gl	Δ X^2	Δ gl	CFI	RMSEA	Δ CFI	Δ RMSEA
Gender								
Man	154.912	126	–	–	0.963	0.039	–	–
Woman	189.625	126	–	–	0.864	0.064	–	–
M1	344.587	252	–	–	0.926	0.036	–	–
M2	355.600	266	11.01	14	0.928	0.035	0.002	0.001
M3	382.734	276	27.13	10	0.914	0.037	0.014	0.002
M4	433.603	297	50.87	21	0.890	0.041	0.024	0.004

M1 = Configure, M2 = Metric, M3 = Scale, and M4 = Strict.

athletes and the high level of reliability obtained from the instruments together with the adequate values of the predictive model. Consequently, the research provides important information concerning the study variables that stimulate the physically active practice of sport, which reduces problems such as obesity and sedentary lifestyles that are so relevant today. Ideally, longitudinal intervention research into coaches with experimental or quasi-experimental designs could be carried out as already described, such as those that have been carried out in the educational and sports fields in relation to teachers (Serrano et al., 2018; Moreno-Murcia et al., 2019). Similarly, interventions that encourage athletes to intend to continue being physically active have been proposed in other studies with different intervention variables (Martínez et al., 2016; Zamorano et al., 2021). Following the postulates of Vallerand (1997), studies have been proposed to find out if athletes, who are encouraged to support autonomy for a certain time and satisfy their basic psychological needs, develop more autonomous motivation and are physically more active than athletes who are not involved in the intervention group. New studies should also be carried out using different methodological designs, random sampling, and different age groups.

5. Conclusion

In conclusion, coaches' support for autonomy is a fundamental aspect of autonomous motivation due to its relationship with basic psychological needs: these could act as mediators that increase autonomous motivation and thus produce an increase in the intention to be physically active. In short, it is important to focus on the training of coaches to provide them with strategies that favor autonomy support so that athletes can satisfy their different psychological needs, which can in turn motivate young athletes to increase their physical activity and commitment to sports in the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the University of Murcia (2871/2020). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

DH-L, AV-V, DM-S, and AG-M: conceptualization, methodology and investigation, formal analysis, data curation, and writing—review and editing. DH-L: writing—original draft preparation. AV-V: visualization. AV-V, DM-S, and AG-M: supervision. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

We thank the international Ph.D. School of the University of Murcia, since this research is part of the Ph.D. program in Physical Activity and Sport Sciences. We appreciate the full support of the Azuay Sports Federation of Ecuador.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adie, J. W., Duda, J. L., and Ntoumanis, N. (2008). Autonomy support, basic need satisfaction and the optimal functioning of adult male and female sport participants: a test of basic needs theory. *Motiv. Emot.* 32, 189–199. doi: 10.1007/s11031-008-9095-z

Almagro, B. J., Sáenz-López, P., and Moreno, J. A. (2010). Prediction of sport adherence through the influence of autonomy-supportive coaching among Spanish adolescent athletes. *J. Sports Sci. Med*. 9, 8–14.

Almagro, B. J., Sáenz-López, P., González-Cutre, D., and Moreno-Murcia, J. A. (2011). Perceived motivational climate, psychological needs and intrinsic motivation as predictors of sport commitment in adolescent athletes. *Rev. Int. Cienc. Deporte* 25, 250–265. 2011.02501 doi: 10.5232/ricyde

Almagro, B., and Conde, C. (2012). Motivational factors as predictors of young basketball players ì intention to be physically active. *Cuad. Psicol. Deporte* 1, 1–4.

Álvarez, O., Estevan, I., Falco, C., and Castillo, I. (2013). Effects of perceived autonomy support on elite taekwondo Spanish athletes. *Rev. Iberoam. Psicol. Ejerc. Deporte* 8, 54–65.

Ato, M., López, J. J., and Benavente, A. (2013). A classification system for research designs in psychology. *An. Psicol.* 29, 1038–1059. doi: 10.6018/analesps.29.3.178511

Baena-Extremera, A., and Granero-Gallegos, A. (2015). Physical education and intention to engage in leisure-time physical activity. *Rev. Electron. Investig. Educ*. 17, 132–144.

Bagozzi, R., and Yi, Y. (1988). On the evaluation of structural equation models. *J. Acad. Mark. Sci.* 16, 74–94. doi: 10.1007/BF02723327

Balaguer, I., Castillo, I., and Duda, J. L. (2008). Autonomy support, needs satisfaction, motivation and well-being in competitive athletes: a test of the self-determination theory. *Rev. Psicol. Deporte* 17, 123–139.

Byrne, B. M. (2016). *Structural equation modeling with AMOS: basic concepts, applications, and programming*, 3rd Edn. Milton Park: Routledge. doi: 10.4324/9781315757421

Cantú-Berrueto, A., Castillo, I., López-Walle, J., Tristán, J., and Balaguer, I. (2016). Coach interpersonal style, basic psychological needs and motivation: a study in Mexican college football players. *Rev. Iberoam. Psicol.* 11, 263–270.

Cheung, G. W., and Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Struct. Equ. Model.* 9, 233–255. doi: 10.1207/S15328007SEM0902_5

Cid, L., Pires, A., Borrego, C., Duarte-Mendes, P., Teixeira, D. S., Moutão, J. M., et al. (2019). Motivational determinants of physical education grades and the intention to practice sport in the future. *PLoS One* 14: e0217218. doi: 10.1371/journal.pone.0217218

Cuevas, R., Contreras, O., Fernández, J. G., and González-Martí, I. (2014). Influence of motivation and physical self-concept on the intention to be physically active. *Rev. Mex. Psicol*. 31, 17–24.

Curran, P., West, S., and Finch, F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychol. Methods* 1, 16–29. doi: 10.3758/s13428-015-0619-7

Deci, E. L., and Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York, NY: Plenum.

Deci, E. L., and Ryan, R. M. (1987). The support of autonomy and the control of behavior. *J. Personal. Soc. Psychol.* 53, 1024–1037. doi: 10.1037/0022-3514.53.6.1024

Deci, E. L., and Ryan, R. M. (1991). "A motivational approach to self: integration in personality," in *Nebraska symposium on motivation*, ed. R. Dienstbier (Lincoln, NE: University of Nebraska Press), 237–288.

Deci, E. L., and Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychol. Inq*. 11, 227–268. doi: 10.1207/S15327965PLI1104_01

Expósito, C., Fernández, E. J., Almagro, B. J., and Sáenz-López, P. (2012). Validation of the scale measure of the intention to be physically active in the university context. *Cuad. Psicol. Deporte* 12, 49–56.

Fernández-Ozcorta, E. J., Almagro, B. J., and Sáenz-López, P. (2015). Predicting intention to remain physically active in university students. *Cuad. Psicol. Deporte* 15:284. doi: 10.4321/S1578-84232015000100026

Fornell, C., and Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *J. Mark. Res*. 18, 39–50. doi: 10.2307/3151312

Franco, E., Coterón, J., and Gómez, V. (2017). Promotion of physical activity in adolescents: role of motivation and self-esteem. *PSIENCIA Rev. Latinoam. Psicol.* 9, 1–15.

Franco, E., Coterón, J., and Pérez-Tejero, J. (2016). Intention to be physically active in physical education students: differences according to the compulsory of the educational stage. *REEFD* 414, 39–51. doi: 10.55166/reefd.v0i414.479

González, L., Castillo, I., García-Merita, M., and Balaguer, I. (2015). Autonomy support, psychological needs satisfaction and well-being: invariance of a structural model in soccer players and dancers. *Rev. Psicol. Deporte* 24, 121–129.

Hagger, M. S., Hardcastle, S. J., Chater, A., Mallett, C., Pal, S., and Chatzisarantis, N. L. (2014). Autonomous and controlled motivational regulations for multiple health-related behaviors: between- and within-participants analyses. *Health Psychol. Behav. Med*. 2, 565–601. doi: 10.1080/21642850.2014.912945

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., and Tatham, R. L. (2014). *Pearson new international edition. In Multivariate Data Analysis*, 7th Edn. Essex: Pearson Education Limited Harlow.

Hayes, A. F., and Coutts, J. J. (2020). Use omega rather than Cronbach's alpha for estimating reliability. But.... *Commun. Methods Meas*. 14, 1–24.

Hein, V., Müür, M., and Koka, A. (2004). Intention to be physically active after school graduation and its relationship to three types of intrinsic motivation. *Eur. Phys. Educ. Rev*. 10, 5–19. doi: 10.1177/1356336X04040618

Huéscar, E. H., Moreno-Murcia, J. A., Cid, L., Monteiro, D., and Rodrigues, F. (2020). Passion or perseverance? The effect of perceived autonomy support and grit on academic performance in college students. *IJERPH* 17:2143. doi: 10.3390/ijerph17062143

Isoard-Gautheur, S., Guillet-Descas, E., and Lemyre, P. N. (2012). A prospective study of the influence of perceived coaching style on burnout propensity in high level young athletes: using a self-determination theory perspective. *Sport Psychol*. 26, 282–298. doi: 10.1123/tsp.26.2.282

Kline, R. B. (2011). *Principles and practice of structural equation modeling*, 3rd Edn. New York, NY: Guilford Press.

Lim, B. C., and Wang, C. J. (2009). Perceived autonomy support, behavioural regulations in physical education and physical activity intention. *Psychol. Sport Exerc.* 10, 52–60.

Lonsdale, C., Hodge, K., and Rose, E. A. (2008). The behavioral regulation in sport questionnaire (BRSQ): instrument development and initial validity evidence. *J. Sport Exerc. Psychol.* 30, 323–355. doi: 10.1123/jsep.30.3.323

López-Walle, J., Balaguer, I., Castillo, I., and Tristán, J. (2012). Autonomy support, basic psychological needs and well-being in Mexican athletes. *Span. J. Psychol* 15, 1283–1292. doi: 10.5209/rev_sjop.2012.v15.n3.39414

Marsh, H. W., Hau, K. T., and Wen, Z. (2004). In search of golden rules: comment on hypothesis testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing. *Struct. Equ. Model*. 11, 320–341. doi: 10.1207/s15328007sem1103_2

Martínez, D., Méndez-Giménez, A., and Valverde, J. J. (2016). Sport education model effects in the social climate classroom, perceived competence and intent to be physically active: an extended study in primary education. *Sport Tk.* 5, 153–166.

Méndez-Giménez, A., Cecchini, J. A., Fernández-Río, F. J., and González, C. (2012). Self-determination and social goals: a structural model for understanding intention to exercise, effort and boredom in physical education. *Aula Abierta*. 40, 51–62.

Merino-Barrero, J. A., Valero-Valenzuela, A., and Belando-Pedreño, N. (2019). Self-determined psychosocial consequences of responsibility promotion in physical education. *Rev. Int. Med. Cienc. Act. Fis. Deporte* 19, 415–430.

Molinero, O., Salguero del Valle, A., and Márquez, S. (2011). Self-determination and exercise adherence: state-of-the-art. *Rev. Int. Cienc. Deporte* 25, 287–304. doi: 10.5232/ricyde2011.02504

Moreno, J. A., Moreno, R., and Cervelló, E. (2007). The physical self-concept as predictor of the intention of being physically active. *Psicol. Salud*. 17, 261–267.

Moreno-Murcia, J. A., Huéscar Hernández, E., Nuñez Alonso, J. L., León, J., Valero Valenzuela, A., and Conte, L. (2019). Protocol quasi-experimental study to promote interpersonal style autonomy support in physical education teachers. *Cuad. psicol. Deporte*. 19, 83–101. doi: 10.6018/cpd.337761

Moreno-Murcia, J. A., Huéscar-Hernández, E., and Ruíz-González, L. (2018). The predictive capacity of autonomy support in physical education classes regarding physical exercise. [Capacidad predictiva del apoyo a la autonomía en clases de educación física sobre el ejercicio físico]. *Rev. Latinoam. Psicol.* 51, 30–37. doi: 10.14349/rlp.2019.v51.n1.4

Moreno-Murcia, J. A., Marzo, J. C., Martínez-Galindo, C., and Conte, L. (2011). Validation of psychological need satisfaction in exercise scale and the behavioural regulation in sport questionnaire to the Spanish context. *Rev. Int. Cien. Dep.* 7, 355–369. doi: 10.5232/ricyde2011.02602

Moreno-Murcia, J., Huéscar, E., Andrés-Fabra, J., and Sánchez-Latorre, F. (2020). Adaptation and validation of autonomy support and controller style's scales in physical education: relationship with feed-back. *Rev. Cienc. Act. Fís.* 21, 1–16. doi: 10.29035/rcaf.21.1.3

Morillo, J. P., Reigal, R. E., and Hernández-Mendo, A. (2018). Motivational orientation, autonomy support and psychological needs in beach handball. *Rev. Int. Med. Cienc. Act. Fís. Deporte* 18, 103–117. doi: 10.15366/rimcafd2018.69.007

Nunnally, J. C. (1978). *Psychometric theory*. New York, NY: McGraw-Hill.

Pineda-Espejel, H. A., Morquecho-Sánchez, R., and Alarcón, E. (2020). Coach interpersonal style, competence, motivation, and precompetitive anxiety in high performance athletes. *Cuad. Psicol. Deporte* 20, 19–24.

Rodrigues, F., Macedo, R., Cid, L., Teixeira, D. S., Marinho, D. A., and Monteiro, D. (2020). Sex differences in relationships between perceived coach-induced motivational climates, basic psychological needs, and behavior regulation among young swimmers. *Percept. Mot. Skills* 127:891911. doi: 10.1177/0031512520926805

Rodrigues, F., Teixeira, D. S., Cid, L., Machado, S., and Monteiro, D. (2019). The role of dark-side of motivation and intention to continue in exercise: a self-determination theory approach. *Scand. J. Psychol.* 60, 585–595. doi: 10.1111/sjop.12582

Ryan, R. M., and Deci, E. L. (2007). "Active human nature: self-determination theory and the promotion and maintenance of sport, exercise, and health," in *Intrinsic motivation and self-determination in exercise and sport*, eds M. S. Hagger and N. L. D. Chatzisarantis (Champaign, IL: Human Kinetics), 1–20.

Ryan, R. M., and Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. New York, NY: Guilford.

Serrano, J. S., Catalán, ÁA., Remacha, M. S., and García-González, L. (2018). The "Bright Side" and "Dark Side" of motivation in physical education: effects of intervention in a unit of athletics. *Rev. Iberoam. Diagn. Evol. Psicol.* 1, 93–107. doi: 10.21865/RIDEP46.1.07

Sturmey, P., Newton, J. T., Cowley, A., Bouras, N., and Holt, G. (2005). The PAS–ADD checklist: independent replication of its psychometric properties in a community sample. *Br. J. Psychiatry*. 186, 319–323.

Teixeira, D. S., Pelletier, L. G., Monteiro, D., Rodrigues, F., Moutão, J., Marinho, D. A., et al. (2020). Motivational patterns in persistent swimmers: a serial mediation analysis. *Eur. J. Sport Sci.* 20, 660–669. doi: 10.1080/17461391.2019.1675768

Trigueros-Ramos, R., Navarro-Gómez, G. N., Aguilar-Parra, J. M., and León-Estrada, I. (2019). Influence of physical education teacher on confidence, fun, motivation and intention to be physically active in adolescence. *Cuad. Psicol. Deporte* 19, 222–232. doi: 10.6018/cpd.347631

Valero-Valenzuela, A., Huescar, E., Núñez, J. L., Conte, L., Léon, J., and Moreno-Murcia, J. A. (2021). Prediction of adolescent physical self-concept through autonomous motivation and basic psychological needs in Spanish physical education students. *Sustainability* 13:11759. doi: 10.3390/su132111759

Vallerand, R. J. (1997). "Toward a hierarchical model of intrinsic and extrinsic motivation," in *Advances in experimental social psychology*, ed. M. Zanna (New York, NY: Academic Press), 271–360. doi: 10.1080/02701367.2000.10608895

Williams, G. C., Grow, M. V., Feedman, R. Z., Ryan, R. M., and Deci, E. L. (1996). Motivational predictors of weight loss and weight-loss maintenance. *J. Pers. Soc. Psychol*. 70, 115–126.

Wilson, P., Rogers, W., Rodgers, W., and Wild, T. C. (2006). The psychological need satisfaction in exercise scale. *J. Sport Exerc. Psychol.* 28, 231–251. doi: 10.1123/jsep.28.3.231

World Health Organization (2018). *Global action plan on physical activity 2018-2030: more active people for a healthier world: at-a-glance. 2019*. Geneva: World Health Organization.

Zamorano, D., Fernández, J. G., and Vállez, J. P. (2021). Design and evaluation of a program for the improvement of the physical fitness in Primary Educatio. *Sport Tk.* 10, 107–112. doi: 10.6018/sportk.461721

frontiers | Frontiers in Psychology

TYPE Hypothesis and Theory
PUBLISHED 28 April 2023
DOI 10.3389/fpsyg.2023.1098394

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

RECEIVED 14 November 2022
ACCEPTED 23 March 2023
PUBLISHED 28 April 2023

CITATION
Flack KD, Stults-Kolehmainen MA, Creasy SA, Khullar S, Boullosa D, Catenacci VA and King N (2023) Altered motivation states for physical activity and 'appetite' for movement as compensatory mechanisms limiting the efficacy of exercise training for weight loss. *Front. Psychol.* 14:1098394.
doi: 10.3389/fpsyg.2023.1098394

Altered motivation states for physical activity and 'appetite' for movement as compensatory mechanisms limiting the efficacy of exercise training for weight loss

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Weight loss is a major motive for engaging in exercise, despite substantial evidence that exercise training results in compensatory responses that inhibit significant weight loss. According to the Laws of Thermodynamics and the CICO (Calories in, Calories out) model, increased exercise-induced energy expenditure (EE), in the absence of any compensatory increase in energy intake, should result in an energy deficit leading to reductions of body mass. However, the expected negative energy balance is met with both volitional and non-volitional (metabolic and behavioral) compensatory responses. A commonly reported compensatory response to exercise is increased food intake (i.e., Calories in) due to increased hunger, increased desire for certain foods, and/or changes in health beliefs. On the other side of the CICO model, exercise training can instigate compensatory reductions in EE that resist the maintenance of an energy deficit. This may be due to decreases in non-exercise activity thermogenesis (NEAT), increases in sedentary behavior, or alterations in sleep. Related to this EE compensation, the motivational states associated with the desire to be active tend to be overlooked when considering compensatory changes in non-exercise activity. For example, exercise-induced alterations in the wanting of physical activity could be a mechanism promoting compensatory reductions in EE. Thus, one's desires, urges or cravings for movement–also known as "motivation states" or "appetence for activity"-are thought to be proximal instigators of movement. Motivation states for activity may be influenced by genetic, metabolic, and psychological drives for activity (and inactivity), and such states are susceptible to fatigue-or reward-induced responses, which may account for reductions in NEAT in response to exercise training. Further, although the current data are limited, recent investigations have demonstrated that motivation states for physical activity are dampened by exercise and increase after periods of sedentarism. Collectively, this evidence points to additional compensatory mechanisms, associated with motivational states, by which impositions in exercise-induced changes in energy balance may be met with resistance, thus resulting in attenuated weight loss.

KEYWORDS

exercise compensation, exercise, physical activity, nonexercise activity thermogenesis, motivation, affectively charged motivation states, appetence, weight loss

Introduction

Individuals classified as overweight or obese represent over 70% of US adults and over 50% of adults worldwide, putting an increasingly large portion of this population at risk for a multitude of comorbidities including cardiovascular disease, diabetes, heart disease, and certain cancers (Williams et al., 2015; Chooi et al., 2019). Obesity treatment has therefore emerged as a prime focus of health care and a top concern among the general public. Recent reports indicate 41.5% of individuals are currently trying to lose weight, with 65% of these individuals using exercise as at least one component of their weight loss strategy (Santos et al., 2017). Unfortunately, weight loss from exercise alone is often less than expected (Thomas et al., 2012, 2015). For instance, an individual may exercise to expend 2,000 kcal per week for 15 weeks, to total 30,000 kcal of exercise energy expenditure, although this rarely produces a body mass loss equivalent to 30,000 kcal during this time. Typically, individuals "compensate" for a portion of exercise energy expenditure in an effort to maintain energy homeostasis, thereby attenuating weight loss (King et al., 2007). Maintaining energy balance can be viewed as an evolutionarily conserved mechanism in place to retain bodily energy stores and preserve reproductive function, a useful survival strategy in times of reduced food availability (Rosenbaum and Leibel, 2010; Wang et al., 2019). Thus, humans may have a drive to compensate for energy expended in exercise even though this response is not advantageous in our current obesogenic environment. This has been highlighted in recent studies demonstrating similar total daily EE among individuals with differing levels of physical activity (Pontzer, 2018; Careau et al., 2021).

The degree to which individuals compensate in response to exercise is still unknown but may vary depending on the exercise stimulus. Some evidence indicates that exercise interventions featuring a greater energy expenditure (EE) evoke a greater compensatory response (Rosenkilde et al., 2012), supported by the observed lack of differences in weight loss between groups exercising at 50, 100 or 150% of public health recommendations (Church et al., 2007) or at 14 or 23 kcal/kg/week (Kraus et al., 2002). This is likely due to greater exercise EE eliciting a greater acute energy deficit and thus a stronger compensatory response to maintain energy homeostasis. In this light, the traditional "calories in, calories out" model, where increasing energy expenditure should result in greater losses in body mass, does not hold. On the other hand, others have demonstrated no differences in energy compensation between groups expending 3,000 or 1,500 kcal per week, or between groups exercising 6 days vs. 2 days per week, with all groups compensating roughly ~1,000 kcal per week (Flack et al., 2018, 2020a). One reason for these contrasting findings may be due to the high degree of inter-individual variability observed in the compensatory response to exercise, which is not fully understood (King et al., 2012).

Equivocal findings may also be explained by the variety of compensatory responses, independently and collectively, working to attenuate an exercise-induced energy deficit, reducing the likelihood of expected weight loss. This concept of energy compensation with exercise was initially recognized over 40 years ago by leading behavioral science and nutrition researchers Len Epstein and Rena Wing who noted, *"Exercise may stimulate the appetite so that persons who exercise increase their eating and do not lose as much weight as expected"* (Epstein and Wing, 1980). This hypothesis has been a focal point of attention among metabolism researchers over the past several decades, with many citing the Law of Thermodynamics of Homeostatic Control which states that an energy deficit induced by exercise will be balanced by an increased drive to eat to maintain energy balance. However, this assumes that energy intake (EI) is the only response available to restore homeostasis. King and colleagues defined specific compensatory responses, including automatic and volitional types versus metabolic and behavioral types, for both sides of the energy balance equation–more commonly for energy intake (EI) but also for energy expenditure (EE) (King et al., 2007). All these factors appear to have a place in the phenomenon of energy compensation in response to exercise, but none have adequately explained weight loss outcomes. It may be that the effect of exercise on weight loss is predicted by a combination of the type, magnitude, and temporal profile of these compensatory responses. These responses are also very specific to an individual, where not only may the magnitude of compensation be different, but the proportion of energy compensated through EE vs. EI may be different between individuals.

Compensation for exercise-induced energy deficits can be categorized, as noted above, into behavioral or metabolic responses, that can be either automatic or volitional (King et al., 2007). An automatic compensatory response can be considered a biological inevitability and obligatory, that is, not under conscious control by the individual. Volitional compensatory responses, on the other hand, are those under conscious control by the individual, requiring deliberate action. Most behavioral responses are volitional, such as changing our eating behaviors to increase EI, although some may be automatic and not under one's conscious control, such as decreases in spontaneous physical activity (SPA), reflecting an unconscious drive for movement (Brand and Ekkekakis, 2018; Stults-Kolehmainen, 2022). Metabolic compensatory responses are processes designed to protect against continued weight loss by reducing metabolic EE (often expressed as kcal/kg body mass). All metabolic compensatory responses are automatic, as an individual cannot deliberately alter metabolic processes to change energy expenditure (such as resting metabolic rate). In this example of altering metabolic energy expenditure, an individual may attempt to prevent losses in lean mass during weight loss by consuming a diet high in protein, which could prevent declines in total resting energy expenditure; however, when adjusting energy expenditure for body weight or lean mass, declines in metabolic energy expenditure still persist (Rosenbaum et al., 2003; Goldsmith et al., 2010). Additional examples of metabolic and behavioral compensatory responses and their classification (automatic vs.

TABLE 1 Metabolic and behavioral compensatory responses as varying by automaticity and volitional behavior*.

	Metabolic	Behavioral
Automatic	RMR	Spontaneous/Incidental activity
	EE of exercise/PA	
Volitional	[None]	EI
		Lifestyle PA

*Adapted from (King et al., 2007).
RMR, resting metabolic rate; EE, energy expenditure; EI, energy intake; PA, physical activity.

volitional) are listed in Table 1. Such metabolic and behavioral compensatory processes that defend against a negative energy balance likely go back to our hunter-gatherer days, when food was scarce, and a large amount of activity-induced EE was an obligatory behavior to get food (Chakravarthy and Booth, 2004). Of highest relevance to this review are the volitional, behavioral compensatory responses (e.g., food intake and decreases in non-exercise physical activity) that tend to be deliberate and driven by motivational cues. Processes of automatic motivation, however, are also of interest. Of course, each of these behavioral responses could manifest in several facets of each behavior. For example, EI is reflected by the volume, energy density, and/or frequency of food consumption, while behavioral EE alterations could be conceptualized as changes in exercise volume or intensity, sleep duration, amount of time participating in sedentary activities, or metabolic alterations that reduce resting and non-resting energy expenditure. For both EI and EE associated compensatory responses, the temporal signaling is of importance. That is, acute bouts of exercise could immediately induce EI and EE compensatory responses, before any changes in tissue stores occur (Flack et al., 2022). In the event of a prolonged, marked negative energy balance, a different set of signals could promote behavioral compensatory responses due to loss of tissue stores (e.g., glycogen, lean mass, and adipose tissue).

Hypothesis – Motivation as a behavioral compensatory mechanism

It is generally accepted that increases in EI present to counter an exercise-induced energy deficit, although less is known regarding how changes in non-exercise, volitional EE present to counter this deficit or the mechanisms behind this response. In the search for underlying mechanisms that may drive energy compensation for exercise EE there has been a re-emerging interest in the study of motivation and how it relates to energy balance. Homeostasis of energy balance, including eating (Ferrario et al., 2016) and physical activity, are related to strong motivational factors (Stults-Kolehmainen et al., 2020; Budnick et al., 2022). These are generally controlled by two different systems, a homeostatic system and a hedonic system (Hussain and Bloom, 2013). Some factors are automatic and unconscious or barely noticeable (Ferrario et al., 2016); others, such as hunger, appetite and cravings, are perceptible and often even impossible to ignore (Hussain and Bloom, 2013). While all of these have been investigated for a considerable amount of time (Blundell and Cooling, 2000; Blundell et al., 2010), there is a new science of understanding them as a class of sensations – affectively-charged motivation states (ACMS) (Kavanagh et al., 2005). ACMS include urges, desires, and wants – basic intermediaries for motivated behaviors, such as eating, but also exercise and movement. Nevertheless, while these factors have been explored extensively on the EI side of the EB equation, they have not been commonly investigated on the EE side, and thus represent what could be an important gap in our understanding of motivation-driven processes influencing compensation. The present hypothesis paper will delve into aspects of the compensatory response to an exercise-induced energy deficit, specifically focusing on how the human body reduces non-exercise energy expenditure through mechanisms related to motivation to conserve energy and restore energy balance. We specifically hypothesize that compensation might be, in part, due to alterations in one's appetence (or appetite) for movement and physical activity (Ferreira et al., 2006), or alternatively sedentarism and sleep, perhaps similar to changes that have been observed in the hedonic desire for highly-palatable food with exercise training.

Discussion

Understanding exercise, physical activity, sedentary behaviors, and the 24-h activity cycle

It is important to note the distinctions between exercise, physical activity (PA), and similar concepts. The classic taxonomy by Caspersen et al. (1985) states a difference between PA and exercise, such that PA is any movement eliciting an EE higher than basal levels, whereas exercise is a form of PA which is purportedly programmed and organized to be repeated over time to achieve specific goals. In other words, exercise interventions are designed to change different facets of physical fitness, which include physical and functional qualities, such as endurance, muscular strength, etc., but also body composition. PA not in the form of exercise is considered non-exercise activity thermogenesis, or NEAT (Levine, 2004). While these differentiations are theoretically clear and simple, few studies target both exercise and the superordinate category of PA in their analysis (Hautala et al., 2012; Tonello et al., 2015; Benítez-Flores et al., 2019). The lower number of studies may be due to conceptual pitfalls and methodological constraints. Nevertheless, some interesting results from these studies suggest that PA and exercise may interact with each other to potentiate or reduce physical fitness adaptations and health outcomes (Coyle et al., 2022). PA stands also in contrast to sedentary behavior or physical inactivity, which is not simply the opposite of PA, but rather they are asynchronous with each other. It is possible to be both very sedentary and very active on the same day (Thompson and Batterham, 2013; Raichlen et al., 2020). The 24-h activity cycle framework has been proposed as a new paradigm to integrate all forms of PA into one conceptual model (Rosenberger et al., 2019). However, it does not fit well with the classic taxonomy by Caspersen et al. (1985) as it only includes the four activities of sleep, sedentary behavior, light intensity physical activity (LIPA), and moderate-to-vigorous physical activity (MVPA), which have independent and interactive effects to simultaneously affect health. In other words, there may be positive and negative synergies among exercise, NEAT, sedentary time, and sleep. For instance, better sleep quality and/or quantity may result in greater PA the next day and greater PA may also result in better sleep (Master et al., 2019). Therefore, it is necessary to monitor the quality and quantity of any form of PA, including exercise, sedentary behaviors, and sleep, to better understand the relative influence of each activity component on health outcomes in bodyweight management interventions.

Models of compensation – CICO, constrained total EE

Most studies on energy compensation with exercise have focused on EI, largely due to the accepted belief that EI is the largest source of compensation when exercising for weight loss (King et al., 2007; Thomas et al., 2012, 2015; Flack et al., 2018, 2020a). Although in the CICO model, the 'calories out', aspect cannot be overlooked, manifesting as decreases in EE in an attempt to negate an exercise-induced negative energy balance. As noted above, mechanisms working to decrease EE can be either physiological (decreases in resting energy expenditure (REE)/metabolic) or behavioral (decreases in PA outside the exercise intervention). These responses fit into the constrained total EE hypothesis speculating that in the presence of increasing levels of PA, total daily EE plateaus (Pontzer, 2015). There are several sources of cross-sectional data that support this hypothesis (Pontzer et al., 2012, 2016; Willis et al., 2022); however, prospective data are limited. In one study by Westerterp et al. (1992) previously sedentary males began training for a half marathon and had marked increases in total daily EE at 8 and 20 weeks; however, these increases in total daily EE tapered at week 40 even with an increase in exercise load. In females, total daily EE increased at week 8 but leveled off at weeks 20 and 40 even with increases in exercise load. However, the constrained model of compensation may not apply to individuals who purposely match additional daily EE with additional EI, such as in an athletic population not attempting to lose body weight (and often attempting to gain body weight). Maintaining energy balance via a high energy flux in this scenario would likely attenuate metabolic compensation (Bell et al., 2004).

Changes in NEAT

What remains lacking in the constrained Total EE model is what specific components of EE are compensating in response to increases in PA. In controlled exercise studies, the EE of exercise is measured and held constant, leaving only resting and non-exercise EE to serve as compensatory variables. Some evidence suggests that REE, adjusted for body composition, may decline with increased aerobic exercise EE (Westerterp et al., 1992; Byrne and Wilmore, 2001); however, not all studies have demonstrated this effect (Donnelly et al., 2013; Creasy et al., 2022b). In addition to REE, a decline in non-exercise EE (or NEAT) is a likely mechanism of EE compensation. Reductions in NEAT can stem from improvements in skeletal muscle efficiency that reduce the energy cost of non-exercise activities (Rosenbaum et al., 2003; Goldsmith et al., 2010). Reductions in NEAT have also been attributed to decreases in non-exercise PA, including spontaneous (incidental) physical activity, such as fidgeting. The importance of the contribution of NEAT to energy balance and weight control was originally highlighted by Levine where NEAT has been proposed as a cause of differences in weight change in response to exercise interventions (Levine et al., 1999; Levine, 2004). It is important to note that Levine's proposal of NEAT is based predominantly on cross-sectional data and hypothetical inferences. However, evidence for a decrease in NEAT comes from a carefully controlled, 7-day exercise intervention study by Stubbs et al. (2002). Participants tended to restore energy balance (EB) at a rate of 0.3–0.6 MJ/d by appearing to progressively reduce daily EE across 7 days. Several other studies suggest that initiating an aerobic exercise program leads to increases in sedentary behavior and decreases in non-exercise physical activity (NEPA) (Morio et al., 1998; Meijer et al., 1999; Di Blasio et al., 2012; Willis et al., 2014). Specifically Meijer et al. (1999) found that non-exercise activity measured with accelerometry was reduced on exercise training days compared to non-training days. In addition, a secondary analysis of the Midwest Exercise Trial 2 (MET-2), Herrmann et al. (2015) found that compensators (i.e., individuals with <5% weight loss) decreased non-exercise physical activity, whereas, non-compensators (i.e., individuals with ≥5% weight loss) increased non-exercise physical activity across a 10-month aerobic exercise intervention. This compensation may contribute to the declines in non-exercise EE noted above, and subsequently attenuate weight loss. Although results have been inconsistent, as indicated in a 2018 meta-analysis demonstrating 15 studies out of 36 reporting declines in NEAT (eight), NEPA (four) or both (three), pointing to the individual variability observed in this compensatory response. This meta-analysis also points to how weight-loss magnitude, energetic restriction degree, exercise dose and participant characteristics may all influence NEAT and/or NEPA (Silva et al., 2018). One explanation for a reduction in NEAT is that fatigue from the exercise intervention caused reciprocal increases in total time spent inactive when the individual would have usually been active (prior to starting the exercise intervention). That is, individuals could consciously or unconsciously perceive rest periods as reward for exercising, and factors, such as muscle soreness and general tiredness, could lower subsequent physical activity (discussed below).

Inter-individual variability in exercise compensatory responses

It is well established that energy compensation for exercise interventions is variable between individuals (King et al., 2008). Compensatory responses, or the lack of response, account for the diversity in weight loss following fixed exercise loads. This could explain why some people are resistant to or susceptible to the theoretical weight loss associated with exercise. A problem with most studies evaluating the effectiveness of exercise on weight loss is that they tend to report the mean data only, which inadvertently masks the inter-individual variability. Expressing only the mean data fails to explore the variability in exercise-induced weight loss, which inherently prevents the opportunity to identify candidates for, and the characterization of, compensatory responses. Recent studies have highlighted the phenotypic responses as 'poor' and 'good' responders. The concept of exploring individual variability in response to fixed feeding or exercise interventions is not original. Claude Bouchard's classic studies identified the variability in weight change in response to over-feeding interventions in twins (Tremblay et al., 1987; Bouchard et al., 1990). Bouchard was also the first to demonstrate large inter-individual variability (i.e., good and poor responders) in changes in maximum oxygen consumption (VO_2max) in response to a fixed-load of exercise training (Bouchard et al., 1990). Levine has also proposed that individual variability in postural allocation (e.g., time spent sitting, standing) influences the predisposition to gain weight (Bouchard et al., 1990). Therefore, compensatory responses, and their associated variability, make some individuals susceptible to weight loss through exercise and render others resistant (Bouchard, 1995; Snyder et al., 1997; Weinsier et al., 2002; Blundell et al., 2003; Stubbs et al., 2004). Little is known regarding the variability in the volitional behavioral compensatory responses centered on decreasing non-exercise PA when engaging in an exercise intervention. This is despite several studies demonstrating decreases in NEAT when engaging in an exercise intervention (Blaak et al., 1992; Levine et al., 1999; Meijer et al., 1999; Westerterp, 2003). Further, this response has not always been observed, necessitating additional investigation behind potential mechanisms that may promote this compensatory response (Flack et al., 2018, 2020a; Martin et al., 2019).

Behavioral compensatory responses

The two most relevant behaviors that contribute to the overall compensatory response to an exercise-induced energy deficit are changes in eating behaviors (influencing EI) and changes in non-exercise activity behaviors (influencing NEAT). Both behaviors are greatly influenced by motivation. Eating is targeted as an important behavioral compensatory response due to its potent contribution to energy balance, whereas physical activity tends to be overlooked. Therefore, while the Laws of Thermodynamics and Homeostasis propose feasible theoretical concepts of energy balance, they take little account of the motivations and psychological factors underpinning compensatory behavior, especially in the realm of NEAT. Indeed, these classic theories were originally based on physiological and metabolic processes associated with systems and states of steady internal, biological conditions (e.g., blood glucose; Newton's 3rd Law - "To every action, there is always an opposite and equal reaction"). By nature of their automated, biological regulation, they tend not to take into account motivational control or individual variability.

A key issue is whether the human regulatory system is capable of selectively determining which, when, and the magnitude, of behavioral responses compensating for the exercise-induced energy deficit. The temporal profile of compensatory responses will inevitably influence weight loss through feedback mechanisms that may render the use of exercise a less efficacious method for weight management. For instance, immediate compensatory responses (i.e., present during the first few weeks), may resist initial weight loss (Flack et al., 2022), while more 'delayed' compensatory responses (i.e., exhibited after several weeks/months), may result in a plateauing of weight loss. This could lead to disappointment, reduced expectation or belief that exercise can result in the desired weight loss, lessened perceived behavior control and, perhaps, exercise drop out (Conroy et al., 2007). These reflective factors are considered "Type 2" processes in dual-process models of behavior (Brand and Ekkekakis, 2018). More pertinent to our hypothesis, however, are automatic "Type 1" processes (e.g., hedonic / appetitive pathways) at play that may work less visibly but with equal or greater force to undermine exercise behavior and lifestyle physical activity. For Type 1 behavioral compensatory responses to be enacted, there needs to be a priming and detection of internal signals (e.g., leptin), associated with any reductions in body weight and tissue composition (Wang et al., 2019). How an individual responds behaviorally to these signals may be in the form of a downstream motivational state (e.g., urges, cravings, impulses), as described in various models, such as the Affective-Reflective Theory of Physical Inactivity (ART) (Brand and Ekkekakis, 2018) or the COM-B System / Behavior Change Wheel (Michie et al., 2011). Alternatively, they can resist and overcome the signal-induced compensatory behavior, via Type 1 (e.g., counter-impulses) and Type 2 motivational control processes (e.g., action planning).

Motivational nudges and brakes

Dual process models of exercise behavior, however, have resurrected the idea from Kurt Lewin about propelling and restraining forces (Brand and Ekkekakis, 2018) – the psychological analog to physical forces explained above. These fall roughly into two categories, internal (or endogenous) factors and external (or exogenous) factors. It is important to acknowledge that behaviors are strongly influenced by external factors or stimuli, sometimes referred to as nudges or cues. Similarly, the endogenously-generated urge or impulse to act on these factors will be moderated by motivational factors or counter-impulses such as restraint, inhibition–processes of self-control (Michie et al., 2011; Carver and Scheier, 2017). It is also worth bearing in mind that these nudges and signals, and associated urges and impulses, related to behavioral initiation, interplay with factors associated with suppressing or halting behaviors. The motivational endpoint might be the result of the preponderance of factors working to promote a behavior balanced against those working against it (Brand and Ekkekakis, 2018). Unfortunately, those in Western societies, but increasingly in non-Western as well, are surrounded by environments that encourage a sedentary lifestyle (e.g., many prompts to stop and watch a video clip), with few cues or nudges to be active.

Indeed, there is an asymmetry of motivational signals to start and stop eating or moving. From behavioral "nudges" (i.e., "go"/want) and "brakes" (i.e., "stop"/do not want) point of view, it is commonly thought that humans are predisposed to promote a positive energy balance and to protect against a negative energy balance (Chakravarthy and Booth, 2004). Table 2 shows the imbalance between the internal cues associated with eating, PA, sedentary activities (e.g., television), and sleep. In relative terms, we have strong impulses or urges to initiate the motivation to eat (e.g., hunger), and weaker internal cues (e.g., fullness) to stop (brake) eating (Hofmann et al., 2012; Stevenson et al., 2015). With PA and exercise, there are relatively weak internal cues or urges to be active (Stults-Kolehmainen et al., 2020), especially in an environment that encourages and enables inactivity. However, there are strong internal cues associated with the urge to stop exercising, for example, from muscle pain or the different facets of fatigue (Hartman et al., 2019). There are large inter-individual differences (Stevenson et al., 2015; Stults-Kolehmainen et al., 2021). Nevertheless, there is an imbalance of impulses and counter-impulses when considering the factors associated with behavioral compensation in response to exercise. Reinforcement for food is so strong because the combination of pleasure from eating is great (positive reinforcement) and strong displeasure (hunger) is concomitantly reduced. With exercise, this pattern of reinforcement is not as universal as food reinforcement, but can be prevalent, especially

TABLE 2 The relative imbalance of impulses and counter-impulses (i.e., internal nudges and brakes/constraints) to either promote or stop eating, physical activity, sedentary, and sleep behaviors (typically observed across the adult population), as varying in strength by hedonic motivation.

	Impulses	Counter-impulses	Pleasure provided (positive reinforcement)	Displeasure removed (negative reinforcement)
Eating	Strong	Weak (fullness)	Strong	Moderate (hunger)
Physical activity (incidental, NEAT)	Weak	Strong	Weak*	Weak*
Exercise	Weak	Strong	Weak*	Weak*
Sedentary activities (e.g., television)	Strong	Weak	Moderate	Weak to moderate
Sleep	Strong	Weak	Moderate	Strong (fatigue)

*PA and exercise are typically thought to provide relatively weak amounts of pleasure and remove relatively small amounts of displeasure, but this is not universal as some individuals experience a high amount of pleasure from exercise.
The strongest impulses and urges should come from activities that result in the provision of higher pleasure combined with removal of displeasure. Sleep and eating, therefore, have the greatest urges, theoretically. Furthermore, some experience high amounts of tension from a lack of exercise that results in negative reinforcement when exercise is engaged [see (Stults-Kolehmainen et al., 2022b) for a broader discussion].

among people dependent on exercise (Stults-Kolehmainen et al., 2020). In this condition, deprivation of activity causes significant tension, which is only relieved with exercise (Marques et al., 2019). When considering the compensatory responses to exercise, this imbalance of relative potency and contributions of internal brake-and urges-signals could also have an impact on the desired method for weight loss.

Role of rewards and motivation in energy compensation

As noted, the compensatory response to an exercise-induced energy deficit is highly variable, potentially due to the 'sensitivity to reward' reflecting a trait where some individuals are more tuned for reward from activities, such as exercise and eating, than others (Davis and Woodside, 2002). Evidence indicates that vigorous exercise and eating behaviors, particularly food restriction, stimulate brain circuitry which are associated with reward and dependence (Bergh and Sodersten, 1996). Indeed, exercise has been shown to increase perceived ratings of pleasantness for a range of highly-palatable foods (Lluch et al., 1998, 2000). Our team has also demonstrated acute exercise increases one's attentional processing toward food (an important component in the development of behavioral reinforcement) and that declines in fat-free mass from an aerobic exercise program predict increases in food reinforcement (Flack et al., 2020b, 2022). These reward-driven food choices, as well as misperceptions about the rate of intake (number of calories consumed) relative to the energy cost of physical activity (energy expended), could also drive compensatory responses, which in turn, result in lower than expected weight loss (Blundell et al., 2003). Processes of motivation have generally been overlooked as compensatory mechanisms explaining changes in non-exercise physical activity, but recent data and theories have implicated motivation in physical activity compensation and sedentary behavior. In King's review, motivation was tangentially discussed as a mechanism influencing NEAT (King et al., 2007). It was posited that the motivational *drive to be inactive* is the key mechanism in place to promote decreases in physical activity outside the exercise intervention. The role of motivation as a compensatory mechanism was also explored in a recent systematic review (Swelam et al., 2022). These authors specifically listed 4 factors as impairing physical activity in the face of exercise training: (1) lack of motivation, (2) drive to be inactive, (3) fear of overexertion, and (4) autonomous motivation. The major theories of motivation (e.g., Self Determination Theory) do not seem able to accommodate the diversity of aforementioned motivational constructs, thus necessitating novel and innovative research questions and theories to better explain the implications of shifting motivation in energy expenditure compensation specific to decreases in NEAT (Ryan and Deci, 2000).

Exercise is highly rewarding for some individuals, and is generally agreeable for most individuals, giving rise to the notion of exercise as a reinforcing behavior controlled by central dopamine signaling and termed "exercise reinforcement" (Cheval et al., 2018; Flack K. et al., 2019). Indeed, exercise has reinforcing properties in that exercise dependency has been demonstrated in both humans (Chan and Grossman, 1988; Chapman and De Castro, 1990; Belke, 1997; Holden, 2001) and rodents (Iversen, 1993; Belke, 1997, 2000; Lett et al., 2000). Recent cross sectional data have demonstrated that adults who find aerobic exercise highly reinforcing are more likely to meet PA guidelines for aerobic exercise while those who find resistance-type exercise more reinforcing are more likely to meet PA guidelines for both muscle-strengthening and aerobic exercise (Flack et al., 2017). Thus, it appears the reinforcing value of exercise is an important determinant in the choice to engage in exercise frequently enough to meet the Physical Activity Guidelines for Americans (Epstein et al., 1999; Barkley et al., 2009).

This has given rise to a growing body of literature demonstrating that exercise reinforcement can be increased through the process of "incentive sensitization," a theory originally proposed to explain drug addiction (Robinson and Berridge, 1993). Incentive Sensitization theory states that behavioral reinforcement is increased through repeated exposures by producing neuroadaptations that increase the craving of the behavior (Salvy et al., 2009). After repeated exposures to a stimulus, a 'sensitization' or hypersensitivity to the motivational effects of the stimulus follows. The result is an increased reinforcing value of the stimulus relative to a competing alternative. In this light, an exercise intervention that exposes individuals, repeatedly, to bouts of exercise can produce increases in exercise reinforcement (Flack et al., 2019a,b, 2021; Ufholz et al., 2019). However, recent evidence by our group indicates changes in exercise reinforcement from pre- to post-exercise intervention are not correlated with the overall compensatory response to that exercise intervention (Flack et al., 2018, 2019a, 2020a, 2021). This could be due to the large individual variability in the compensatory response noted above, where some individuals may increase their exercise reinforcement and have greater motivation to exercise while others do not. Conversely, differences in exercise reinforcement and the desire to be physically active outside the exercise intervention (free-living PA) may be two very different concepts. Furthermore, it is certainly possible to be highly motivated to exercise but also very motivated to rest (i.e., reduced physical activity) after the exercise bout. It is also possible that an athlete will desire to rest more in order to train harder at a later time. These may be likely scenarios if the motivation to exercise is high enough to promote extremely high levels of exercise.

WANT model

A recent conceptual framework, the WANT model (Wants and Aversions for Neuromuscular Tasks), may be better positioned to describe motivational factors as compensatory mechanisms for exercise training (Stults-Kolehmainen et al., 2020). The basic tenet of the WANT model is that humans have "wants" for movement that vary from moment to moment. These desires are loosely coupled and work asymmetrically with desires to rest or be sedentary. For instance, it is possible for the "want for movement" to remain stable and the "want for rest" to increase (or *vice-versa*). In general, the ratio of these two constructs is continually changing but infrequently equal. These "wants" vary in intensity from weak desires to strong urges and cravings for movement, when they are typically felt subjectively and often acted upon (Stults-Kolehmainen et al., 2022a). Collectively, wants, desires, urges and cravings are considered "affectively-charged motivation states" (ACMS), impulses for activity that are often felt as tension in conditions of deprivation or excess (Kavanagh et al., 2005; Stults-Kolehmainen, 2022).

In this way, they vary by previous behaviors - i.e., when sitting for a long time (deprived of activity) urges for movement rise (Stults-Kolehmainen et al., 2021). Likewise, with excessive movement, like maximal exercise, desires to move fall, and urges to stop and rest rise (Stults-Kolehmainen et al., 2021; Taylor et al., 2022). These desires, consequently, seem to flow in processes of satiation and accommodation, similar to desires for other rewarding activities, like eating, drinking, smoking, using drugs, etc. (Redden, 2015). This has prompted some researchers to refer to the desires for movement as "appetence" (Ferreira et al., 2006; Redden, 2015; Robinson et al., 2016; Stults-Kolehmainen, 2022). Similar to these other rewarding activities, appetence for movement increases with restriction and results in mental and physical tension, such as jitteriness and fidgeting, until the desire is consummated, which results in a sharp decrease in appetence (i.e., feel "fulfilled", "satisfied", or "exertiated", and do not want any more) (Stults-Kolehmainen et al., 2022a). Such an appetite is likely propelled by both positive reinforcement (i.e., pleasurable aspects of exercise) and negative reinforcement (i.e., relieving tension from disuse of muscle and / or from the drive to be active) (Stults-Kolehmainen, 2022).

Work in this area has been stymied by a lack of useful measurement tools, but new developments in the measurement of motivation states (CRAVE scale: Cravings for Rest and Volitional Energy Expenditure) have facilitated collection of new data (Stults-Kolehmainen et al., 2021). This scale was developed with 9 studies, demonstrating superior psychometric properties, such as high face, construct and convergent validity, good reliability and intra-class correlations, indicating that the scale measures states and not traits (Stults-Kolehmainen et al., 2021, 2022a; Budnick et al., 2022; Filgueiras et al., 2022). With use of the CRAVE, it was demonstrated that appetence for movement and rest rises and falls continuously in response to a variety of stimuli and situations (Stults-Kolehmainen et al., 2021, 2022a). With a maximal treadmill test, there were large effect sizes observed for increases in the desire to rest and decreases in the desire to move. With both a passive and active sedentary activity, desires to move increased after 45 min and desires to be sedentary decreased (Stults-Kolehmainen et al., 2021, 2022a). CRAVE is also associated with body position, such as laying down, sitting, leaning on something (e.g., a wall), standing, and walking (Budnick et al., 2022). Desires to move and rest also predict intentions to move in the next 30 min. Furthermore, a majority of people have a biorhythm for movement motivation (Budnick et al., 2022). These data stand in contrast to theories that promote the idea that humans are primarily driven to rest and save energy (Cheval and Boisgontier, 2021).

Fatigue and pain: Implications in energy compensation

As suggested above, fatigue and soreness could account for both short-and long-term compensatory responses that reduce EE after acute and chronic bouts of training. Fatigue serves as a feedback response and causes increased inactivity when the individual would have been otherwise active to resist returning to an energy balance (Stubbs et al., 2004). A natural reaction to fatigue is to rest and to choose activities that require minimal energy expenditure (Cheval and Boisgontier, 2021). For example, retiring to bed earlier in the evening could influence the impact of the acute energy deficit created by exercise. In this way, exercise-induced fatigue is an underlying mechanism promoting decreases in non-exercise physical activity (Wlodek and Gonzales, 2003; Cheval and Boisgontier, 2021). Importantly, exercise-induced fatigue is a complex phenomenon with various peripheral and central processes, including metabolite accumulation, depletion of fuel reserves, neuromuscular damage and changes in neurotransmitter levels (Lambert, 2005).

Noakes et al. (2004) were among the first exercise physiologists to propose that fatigue is an emotional state, rather than a physical state, and that the sensation of fatigue is an interpretation of the current level of activity as well as future exercise capacity. If this is the case, we know that emotional and motivational states can be influenced by attention, perception, interpretation, and memory (Cheval and Boisgontier, 2021). Specific exercise experiences are associated with memories of energy and fatigue, causing one to continually estimate their reserves and tolerance levels. In the case that fatigue is assessed as high and tolerance is low, it would result in a greater sense of effort and impaired motivation for movement (Iodice et al., 2017). For instance, Iodice et al. (2017) demonstrated that under conditions of fatigue, people prefer lower-effort behaviors. Prolonged and/or intense fatigue may even lead to sensations of hedonic dread for physical activity (Williams and Bohlen, 2019; Stevens et al., 2020), otherwise known as movement aversion or 'diswant' (Stults-Kolehmainen et al., 2020, 2022b). Such may be the case with athletes experiencing burnout and associated loss of motivation (Kentta and Hassmen, 1998; Poscente and Irvine, 2002; Oldervoll et al., 2003; King et al., 2007; Blaney et al., 2010; Purvis et al., 2010; Van Oosterwijck et al., 2010; Yoon et al., 2013; Legrand et al., 2018). These mental processes can thus be considered important mediators on the compensatory response, directing decision-making to reduce or enhance physical activity levels (St Clair Gibson et al., 2003).

Pain is also an important psychosomatic sensation contributing to compensatory responses. Delayed-onset muscle soreness (DOMS) due to exercise, for example, can produce pain and discomfort associated with muscle tenderness, stiffness, and weakness (Cleary et al., 2005). DOMS interferes with physical activity levels since any movement or palpation may exaggerate the smallest increase in pressure and stimulate the pain receptors, thus reducing muscle function (Smith, 1991). Individuals classified as obese report physical activity and exercise as a painful experience, causing severe soreness and stiffness, and often perceive their bodies as too heavy and incapable of more exercise (Danielsen et al., 2016). Individuals with obesity associate physical activity with pain and anxiety (Mæhlum et al., 2012) that can interfere with physical activity levels (Ginis et al., 2003; Dobkin et al., 2006; Law et al., 2010, 2013). In the worst case scenario, repeated or high-intensity exposure to pain during exercise may even result in kinesiophobia (Glaviano et al., 2019). It is important to note that in highly motivated populations, such as athletes or perhaps those with anorexia nervosa or muscle dysmorphia, sensations of pain and fatigue may be routinely bypassed or disregarded in the effort to maintain very high levels of activity and performance (Marcora and Staiano, 2010). Finally, it should be noted some exercise routines, like Curves, were designed to minimize excessive soreness by limiting eccentric contractions (Kerksick et al., 2009). The concept is that less damaging exercise is better tolerated, more acceptable, and more sustainable. Likewise, short sprint interval training (sSIT) (de Sousa et al., 2018; Boullosa et al., 2022; Filgueiras et al., 2022; Metcalfe et al., 2022) involves very short bouts of exercise (5–6 s) that do not produce painful sensations. In the case of Curves, the degree of compensation is unknown. SSIT, on the other hand, is too short to result in important reductions in body fat, but interestingly, it may result in enhanced desire to move and be active (Filgueiras et al., 2022).

Influence of sleep and sedentary behaviors on energy compensation from exercise

Any discussion about the effects of physical activity and exercise on weight management would be remiss if it did not consider sedentary behaviors and sleep, which account for most of the 24-h activity cycle (Rosenberger et al., 2019). Rest behaviors are not the inverse of physically active ones. In fact, as discussed previously, one may be high in both sedentary and active behaviors on the same day (Thompson and Batterham, 2013). Physical activity, sedentary behavior, and sleep are under control from distinct, but interacting, neurobiological systems (Dishman et al., 2006; Harrington, 2012). According to the WANT model, motivation for movement and sedentary behaviors is asynchronous (Stults-Kolehmainen et al., 2020). One might be motivated to move and sleep or be sedentary at the same time, with the same intensity. There may also be a total absence of desire to move or rest. Their correlation is moderate (r's typically −0.6 to −0.7; Stults-Kolehmainen et al., 2021, 2022a). The key issue is whether exercise training enhances desires to rest, be sedentary or, more specifically, to sleep (e.g., tiredness, sleepiness). This is a different question than if exercise training reduces the desire to move or be active.

The desire to sleep or nap is one of the most common desires humans possess (Hofmann et al., 2012). Sleep, however, is an understudied variable in exercise and weight loss research. Both epidemiological and experimental evidence demonstrate that sleep quantity and quality may influence body weight and energy balance regulation (Garaulet et al., 2011; Markwald et al., 2013; Wirth et al., 2015; Sun et al., 2016; Park et al., 2018; Liu et al., 2019; Sa et al., 2020). Experimental studies have found that reducing sleep duration from 9 h/night to 5 h/night alters metabolic energy expenditure while promoting insulin resistance and weight gain (Jung et al., 2011; Markwald et al., 2013; Eckel et al., 2015). Although most of these studies have focused on how sleep timing and duration may influence EI, there is also evidence that sleep and NEAT may be linked (Lambiase et al., 2013). Thus, understanding how aspects of sleep are influenced during exercise trials is imperative, particularly in exercise studies focused on the impact of the intervention on bodyweight.

Exercise and sleep have a dynamic relationship (Youngstedt and Kline, 2006; Kline, 2014; Ash et al., 2021). It is likely that sleep and exercise are synergistic with better sleep helping to support exercise behavior and engagement in exercise helping to promote better sleep. For instance, Lambiase et al. (2013) found that greater sleep efficiency was associated with greater total daily physical activity and greater moderate to vigorous physical activity (MVPA) the following day. Those who sleep well are also likely more motivated to move and exercise (Hong and Dimsdale, 2003; Baron et al., 2013), perhaps by lessening fatigue and enhancing feelings of energy, arousal, and motivation states to move (Nicholson et al., 1984; Frederick et al., 2021). Thus, the common suggestion of reducing sleep duration when looking to increase total daily EE may be counterproductive because of the negative effects on metabolism, psychological well-being, and motivation (Chennaoui et al., 2015).

To date there is limited evidence on what happens to aspects of sleep when initiating exercise. When an individual who is previously sedentary begins an exercise intervention, the time spent engaging in the exercise must replace time spent engaging in a previous behavior. Because there is only a finite amount of time in day, it is possible that time spent engaging in exercise replaces sleep time apart from other sedentary activities. Interestingly, in the study by Lambiase et al. (2013) lower sleep time was associated with more minutes of MVPA across the week. Creasy et al. (2022a) also found that adherence to MVPA recommendations for weight management (300 min/wk) was associated with lower time in bed and lower sleep duration. Further, in a study that examined the effect of morning vs. evening exercise on bodyweight, morning exercisers woke up earlier in the morning to engage in their exercise, thereby reducing sleep duration (Creasy et al., 2022b). Evening exercisers went to bed earlier and woke up later, thereby, increasing sleep duration. Thus, the time of day of exercise may be a crucial factor in bodyweight management interventions. It is critical that future studies examining the effect of exercise on bodyweight also measure sleep to better understand compensatory mechanisms.

Future studies

Very few studies directly connect the concept of motivation states for movement (e.g., appetence) with energy expenditure and/or compensatory effects (Stults-Kolehmainen et al., 2021). To investigate these potential associations, the following key areas should be considered:

(1) Track the subjective experience of wanting/desiring to move (and be sedentary or sleep) with acute bouts of exercise training at various intensities (e.g., moderate, vigorous), and durations, starting with the public health dosage (150 min/week of MVPA) and then progressively increasing this to 300 min/week, the recommendation associated with greater impact on weight loss/maintenance (Flack et al., 2018, 2020a).
(2) Conduct longer training studies, up to a minimum of 6 months, that evaluate the relationship between motivation states and energy compensation.
(3) Attempt to modulate motivation states with training studies that aim to mitigate fatiguing and painful sensations during or after exercise, perhaps by: (a) lowering intensity at the end of the training session, (b) through proper exercise ramp-up/progression, or (c) minimizing concentric contractions or glycolytic activity. Alternatively, attempt to maximize enjoyment and pleasure, as liking is usually matched with wanting (Stults-Kolehmainen et al., 2020).
(4) Implement controlled exercise training interventions that monitor, at the same time, non-exercise physical activity, sedentary time and sleep.
(5) Explore mechanisms that may mediate processes of motivation and physical activity in response to exercise training, such as orexin /hypocretin, which has been implicated in the regulation of appetite, sleep, and arousal (Sakurai, 2005).

Conclusion

The main premise of the current paper is that humans have an appetite for movement (or rather, "appetence") that may be altered with an exercise training program and the related changes in lifestyle and daily activities. This has long been hypothesized for eating behaviors, though the effects of exercise on appetite for food and hunger are equivocal. At the current time, it is not known how exercise training impacts the desire or want to move and be active. There is some evidence, though conflicting, that exercise training impacts lifestyle physical activity outside of the training program, typically by lowering it, but in some cases enhancing it (Foster-Schubert et al., 2012). It may be the case that these effects have been poorly explored due to difficulties in the detection of these behavioral processes in play and the large inter-individual variability in their response to exercise. New developments in motivational theory (Stults-Kolehmainen et al., 2020, 2021) and instrumentation (Stults-Kolehmainen et al., 2021) may spur greater efforts to investigate these phenomena.

Data availability statement

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

Author contributions

MS-K, NK, and KF developed and conceived the manuscript. MS-K, NK, KF, SC, SK, DB, and VC completed the writing. All authors contributed to the article and approved the submitted version.

Funding

Portions of this work was funded by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) Project 3062–51000-051-00D and National Institutes of Health P30GM127211 of the National Institute of General Medical Sciences. DB was supported by Grant RYC2021-031098-I funded by MCIN/AEI/10.13039/501100011033, by "European Union NextGenerationEU/PRTR," and by a productivity research grant (PQ1D) from CNPq (Brazil).

Acknowledgments

The authors would like to thank Patrick J. O'Connor (University of Georgia), Mark Hartman (University of Rhode Island), and John B. Bartholomew (The University of Texas at Austin) for critical insights that helped to refine the scope of this project. Philip R. Stanforth (The University of Texas at Austin) provided technical assistance.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Ash, G., Jeon, S., Conley, S., Knies, A. K., Yaggi, H. K., Jacoby, D., et al. (2021). Day-to-day relationships between physical activity and sleep characteristics among people with heart failure and insomnia. *Behav. Sleep Med.* 19, 602–614. doi: 10.1080/15402002.2020.1824918

Barkley, J. E., Epstein, L. H., and Roemmich, J. N. (2009). Reinforcing value of interval and continuous physical activity in children. *Physiol. Behav.* 98, 31–36. doi: 10.1016/j.physbeh.2009.04.006

Baron, K. G., Reid, K. J., and Zee, P. C. (2013). Exercise to improve sleep in insomnia: exploration of the bidirectional effects. *J. Clin. Sleep Med.* 9, 819–824. doi: 10.5664/jcsm.2930

Belke, T. W. (1997). Running and responding reinforced by the opportunity to run: effect of reinforcer duration. *J. Exp. Anal. Behav.* 67, 337–351. doi: 10.1901/jeab.1997.67-337

Belke, T. W. (2000). Studies of wheel-running reinforcement: parameters of Herrnstein's (1970) response-strength equation vary with schedule order. *J. Exp. Anal. Behav.* 73, 319–331. doi: 10.1901/jeab.2000.73-319

Bell, C., Day, D. S., Jones, P. P., Christou, D. D., Petitt, D. S., Osterberg, K., et al. (2004). High energy flux mediates the tonically augmented beta-adrenergic support of resting metabolic rate in habitually exercising older adults. *J. Clin. Endocrinol. Metab.* 89, 3573–3578. doi: 10.1210/jc.2003-032146

Benítez-Flores, S., Medeiros, A. R., Voltarelli, F. A., Iglesias-Soler, E., Doma, K., Simões, H. G., et al. (2019). Combined effects of very short "all out" efforts during sprint and resistance training on physical and physiological adaptations after 2 weeks of training. *Eur. J. Appl. Physiol.* 119, 1337–1351. doi: 10.1007/s00421-019-04125-6

Bergh, C., and Sodersten, P. (1996). Anorexia nervosa, self-starvation and the reward of stress. *Nat. Med.* 2, 21–22. doi: 10.1038/nm0196-21

Blaak, E. E., Westerterp, K. R., Bar-Or, O., Wouters, L. J., and Saris, W. H. (1992). Total energy expenditure and spontaneous activity in relation to training in obese boys. *Am. J. Clin. Nutr.* 55, 777–782. doi: 10.1093/ajcn/55.4.777

Blaney, J., Lowe-Strong, A., Rankin, J., Campbell, A., Allen, J., and Gracey, J. (2010). The cancer rehabilitation journey: barriers to and facilitators of exercise among patients with cancer-related fatigue. *Phys. Ther.* 90, 1135–1147. doi: 10.2522/ptj.20090278

Blundell, J. E., and Cooling, J. (2000). Routes to obesity: phenotypes, food choices and activity. *Br. J. Nutr.* 83, S33–S38. doi: 10.1017/s0007114500000933

Blundell, J., de Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluch, A., et al. (2010). Appetite control: methodological aspects of the evaluation of foods. *Obes. Rev.* 11, 251–270. doi: 10.1111/j.1467-789X.2010.00714.x

Blundell, J. E., Stubbs, R. J., Hughes, D. A., Whybrow, S., and King, N. A. (2003). Cross talk between physical activity and appetite control: does physical activity stimulate appetite? *Proc. Nutr. Soc.* 62, 651–661. doi: 10.1079/PNS2003286

Bouchard, C. (1995). Individual differences in the response to regular exercise. *Int. J. Obes. Relat. Metab. Disord.* 19, S5–S8. doi: 10.1097/00005768-200106001-00013

Bouchard, C., Tremblay, A., Després, J. P., Nadeau, A., Lupien, P. J., Thériault, G., et al. (1990). The response to long-term overfeeding in identical twins. *N. Engl. J. Med.* 322, 1477–1482. doi: 10.1056/NEJM199005243222101

Boullosa, D., Dragutinovic, B., Feuerbacher, J. F., Benítez-Flores, S., Coyle, E. F., and Schumann, M. (2022). Effects of short sprint interval training on aerobic and anaerobic indices: A systematic review and meta-analysis. *Scand. J. Med. Sci. Sports* 32, 810–820. doi: 10.1111/sms.14133

Brand, R., and Ekkekakis, P. (2018). Affective–reflective theory of physical inactivity and exercise. *German J. Exerc. Sport Res.* 48, 48–58.

Budnick, C. J., Stults-Kolehmainen, M., Dadina, C., Bartholomew, J. B., Boullosa, D., Ash, G. I., et al. (2022). Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal. *Sportxiv* 2022:217. doi: 10.51224/SRXIV.217

Byrne, H. K., and Wilmore, J. H. (2001). The relationship of mode and intensity of training on resting metabolic rate in women. *Int. J. Sport Nutr. Exerc. Metab.* 11, 1–14. doi: 10.1123/ijsnem.11.1.1

Careau, V., Halsey, L. G., Pontzer, H., Ainslie, P. N., Andersen, L. F., Anderson, L. J., et al. (2021). Energy compensation and adiposity in humans. *Curr. Biol.* 31, 4659–66.e2. doi: 10.1016/j.cub.2021.08.016

Carver, C. S., and Scheier, M. F. (2017). "Chapter one–self-regulatory functions supporting motivated action" in *Advances in Motivation Science*. ed. A. J. Elliot. *4th* ed (Amsterdam, Netherlands: Elsevier), 1–37.

Caspersen, C. J., Powell, K. E., and Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Rep.* 100, 126–131.

Chakravarthy, M. V., and Booth, F. W. (2004). Eating, exercise, and "thrifty" genotypes: connecting the dots toward an evolutionary understanding of modern chronic diseases. *J. Appl. Physiol.* 96, 3–10. doi: 10.1152/japplphysiol.00757.2003

Chan, C. S., and Grossman, H. Y. (1988). Psychological effects of running loss on consistent runners. *Percept. Mot. Skills* 66, 875–883. doi: 10.2466/pms.1988.66.3.875

Chapman, C. L., and De Castro, J. M. (1990). Running addiction: measurement and associated psychological characteristics. *J. Sports Med. Phys. Fitness* 30, 283–290.

Chennaoui, M., Arnal, P. J., Sauvet, F., and Léger, D. (2015). Sleep and exercise: A reciprocal issue? *Sleep Med. Rev.* 20, 59–72. doi: 10.1016/j.smrv.2014.06.008

Cheval, B., and Boisgontier, M. P. (2021). The theory of effort minimization in physical activity. *Exerc. Sport Sci. Rev.* 49, 168–178. doi: 10.1249/JES.0000000000000252

Cheval, B., Radel, R., Neva, J. L., Boyd, L. A., Swinnen, S. P., Sander, D., et al. (2018). Behavioral and neural evidence of the rewarding value of exercise behaviors: A systematic review. *Sports Med.* 48, 1389–1404. doi: 10.1007/s40279-018-0898-0

Chooi, Y. C., Ding, C., and Magkos, F. (2019). The epidemiology of obesity. *Metabolism* 92, 6–10. doi: 10.1016/j.metabol.2018.09.005

Church, T. S., Earnest, C. P., Skinner, J. S., and Blair, S. N. (2007). Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure-A randomized controlled trial. *JAMA* 297, 2081–2091. doi: 10.1001/jama.297.19.2081

Cleary, M. A., Sweeney, L. A., Kendrick, Z. V., and Sitler, M. R. (2005). Dehydration and symptoms of delayed-onset muscle soreness in hyperthermic males. *J. Athl. Train.* 40, 288–297.

Conroy, C., Eastman, A. B., Stanley, C., Vilke, G. M., Vaughan, T., Hoyt, D. B., et al. (2007). Fatal positional asphyxia associated with rollover crashes. *Am J Forensic Med Pathol* 28, 330–332. doi: 10.1097/PAF.0b013e31815b4c47

Coyle, E. F., Burton, H. M., and Satiroglu, R. (2022). Inactivity causes resistance to improvements in metabolism after exercise. *Exerc. Sport Sci. Rev.* 50, 81–88. doi: 10.1249/JES.0000000000000280

Creasy, S. A., Ostendorf, D. M., Blankenship, J. M., Grau, L., Arbet, J., Bessesen, D. H., et al. (2022a). Effect of sleep on weight loss and adherence to diet and physical activity recommendations during an 18-month behavioral weight loss intervention. *Int. J. Obes.* 46, 1510–1517. doi: 10.1038/s41366-022-01141-z

Creasy, S. A., Wayland, L., Panter, S. L., Purcell, S. A., Rosenberg, R., Willis, E. A., et al. (2022b). Effect of morning and evening exercise on energy balance: A pilot study. *Nutrients* 14:816. doi: 10.3390/nu14040816

Danielsen, K. K., Sundgot-Borgen, J., and Rugseth, G. (2016). Severe obesity and the ambivalence of attending physical activity. *Qual. Health Res.* 26, 685–696. doi: 10.1177/1049732315596152

Davis, C., and Woodside, D. B. (2002). Sensitivity to the rewarding effects of food and exercise in the eating disorders. *Compr. Psychiatry* 43, 189–194. doi: 10.1053/comp.2002.32356

de Sousa, A. F. M., Medeiros, A. R., Benitez-Flores, S., Del Rosso, S., Stults-Kolehmainen, M., and Boullosa, D. A. (2018). Improvements in attention and cardiac autonomic modulation after a 2-weeks Sprint interval training program: A Fidelity approach. *Front. Physiol.* 9:241. doi: 10.3389/fphys.2018.00241

di Blasio, A., Ripari, P., Bucci, I., di Donato, F., Izzicupo, P., D'Angelo, E., et al. (2012). Walking training in postmenopause. *Menopause* 19, 23–32. doi: 10.1097/gme.0b013e318223e6b3

Dishman, R. K., Berthoud, H. R., Booth, F. W., Cotman, C. W., Edgerton, V. R., Fleshner, M. R., et al. (2006). Neurobiology of exercise. *Obesity (Silver Spring)* 14, 345–356. doi: 10.1038/oby.2006.46

Dobkin, P. L., Sita, A., and Sewitch, M. J. (2006). Predictors of adherence to treatment in women with fibromyalgia. *Clin. J. Pain* 22, 286–294. doi: 10.1097/01.ajp.0000173016.87612.4b

Donnelly, J. E., Honas, J. J., Smith, B. K., Mayo, M. S., Gibson, C. A., Sullivan, D. K., et al. (2013). Aerobic exercise alone results in clinically significant weight loss for men and women: Midwest exercise trial 2. *Obesity* 21, E219–E228. doi: 10.1002/oby.20145

Eckel, R. H., Depner, C. M., Perreault, L., Markwald, R. R., Smith, M. R., McHill, A. W., et al. (2015). Morning circadian misalignment during short sleep duration impacts insulin sensitivity. *Curr. Biol.* 25, 3004–3010. doi: 10.1016/j.cub.2015.10.011

Epstein, L. H., Kilanowski, C. K., Consalvi, A. R., and Paluch, R. A. (1999). Reinforcing value of physical activity as a determinant of child activity level. *Health Psychol.* 18, 599–603.

Epstein, L. H., and Wing, R. R. (1980). Aerobic exercise and weight. *Addict. Behav.* 5, 371–388. doi: 10.1016/0306-4603(80)90011-8

Ferrario, C. R., Labouèbe, G., Liu, S., Nieh, E. H., Routh, V. H., Xu, S., et al. (2016). Homeostasis meets motivation in the Battle to control food intake. *J. Neurosci.* 36, 11469–11481. doi: 10.1523/JNEUROSCI.2338-16.2016

Ferreira, A., Lamarque, S., Boyer, P., Perez-Diaz, F., Jouvent, R., and Cohen-Salmon, C. (2006). Spontaneous appetence for wheel-running: a model of dependency on physical activity in rat. *Eur. Psychiatry* 21, 580–588. doi: 10.1016/j.eurpsy.2005.02.003

Filgueiras, A., Stults-Kolehmainen, M., Boullosa, D. S., Bartholomew, R., McKee, J. B., Gilson, P. C., et al. (2022). The CRAVE and ARGE scales for motivation states for physical activity and sedentarism. *SportRxiv* 2022:224. doi: 10.51224/SRXIV.224

Flack, K. D., Anderson, R. E. 3rd, McFee, K. F., Kryscio, R., and Rush, C. R. (2022). Exercise increases attentional bias towards food cues in individuals classified as overweight to obese. *Physiol. Behav.* 247:113711. doi: 10.1016/j.physbeh.2022.113711

Flack, K. D., Hays, H. M., and Moreland, J. (2020b). The consequences of exercise-induced weight loss on food reinforcement. A randomized controlled trial. *PLoS One* 15:e0234692. doi: 10.1371/journal.pone.0234692

Flack, K. D., Hays, H. M., and Moreland, J. (2021). Incentive sensitization for exercise reinforcement to increase exercise behaviors. *J. Health Psychol.* 26, 2487–2504. doi: 10.1177/1359105320914073

Flack, K. D., Hays, H. M., Moreland, J., and Long, D. E. (2020a). Exercise for weight loss: further evaluating energy compensation with exercise. *Med. Sci. Sports Exerc.* 52, 2466–2475. doi: 10.1249/MSS.0000000000002376

Flack, K. D., Johnson, L., and Roemmich, J. N. (2017). Aerobic and resistance exercise reinforcement and discomfort tolerance predict meeting activity guidelines. *Physiol. Behav.* 170, 32–36. doi: 10.1016/j.physbeh.2016.11.032

Flack, K., Pankey, C., Ufholz, K., Johnson, L., and Roemmich, J. N. (2019). Genetic variations in the dopamine reward system influence exercise reinforcement and tolerance for exercise intensity. *Behav. Brain Res.* 375:112148. doi: 10.1016/j.bbr.2019.112148

Flack, K. D., Ufholz, K., Johnson, L., Fitzgerald, J. S., and Roemmich, J. N. (2018). Energy compensation in response to aerobic exercise training in overweight adults. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 315, R619–R626. doi: 10.1152/ajpregu.00071.2018

Flack, K. D., Ufholz, K., Johnson, L., and Roemmich, J. N. (2019a). Increasing the reinforcing value of exercise in overweight adults. *Front. Behav. Neurosci.* 13:265. doi: 10.3389/fnbeh.2019.00265

Flack, K. D., Ufholz, K. E., Johnson, L., and Roemmich, J. N. (2019b). Inducing incentive sensitization of exercise reinforcement among adults who do not regularly exercise-A randomized controlled trial. *PLoS One* 14:e0216355. doi: 10.1371/journal.pone.0216355

Foster-Schubert, K. E., Alfano, C. M., Duggan, C. R., Xiao, L., Campbell, K. L., Kong, A., et al. (2012). Effect of diet and exercise, alone or combined, on weight and body composition in overweight-to-obese postmenopausal women. *Obesity (Silver Spring)* 20, 1628–1638. doi: 10.1038/oby.2011.76

Frederick, G. M., O'Connor, P. J., Schmidt, M. D., and Evans, E. M. (2021). Relationships between components of the 24-hour activity cycle and feelings of energy and fatigue in college students: A systematic review. *Ment. Health Phys. Act.* 21:100409. doi: 10.1016/j.mhpa.2021.100409

Garaulet, M., Ortega, F. B., Ruiz, J. R., Rey-López, J. P., Béghin, L., Manios, Y., et al. (2011). Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. *Int. J. Obes.* 35, 1308–1317. doi: 10.1038/ijo.2011.149

Ginis, K. A. M., Latimer, A. E., McKechnie, K., Ditor, D. S., McCartney, N., Hicks, A. L., et al. (2003). Using exercise to enhance subjective well-being among people with spinal cord injury: the mediating influences of stress and pain. *Rehabil. Psychol.* 48, 157–164. doi: 10.1037/0090-5550.48.3.157

Glaviano, N. R., Baellow, A., and Saliba, S. (2019). Elevated fear avoidance affects lower extremity strength and squatting kinematics in women with patellofemoral pain. *Athl., Train. Sports Health Care* 11, 192–200. doi: 10.3928/19425864-20181029-01

Goldsmith, R., Joanisse, D. R., Gallagher, D., Pavlovich, K., Shamoon, E., Leibel, R. L., et al. (2010). Effects of experimental weight perturbation on skeletal muscle work efficiency, fuel utilization, and biochemistry in human subjects. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 298, R79–R88. doi: 10.1152/ajpregu.00053.2009

Harrington, M. E. (2012). Neurobiological studies of fatigue. *Prog. Neurobiol.* 99, 93–105. doi: 10.1016/j.pneurobio.2012.07.004

Hartman, M. E., Ekkekakis, P., Dicks, N. D., and Pettitt, R. W. (2019). Dynamics of pleasure-displeasure at the limit of exercise tolerance: conceptualizing the sense of exertional physical fatigue as an affective response. *J. Exp. Biol.* 222:jeb186585. doi: 10.1242/jeb.186585

Hautala, A., Martinmaki, K., Kiviniemi, A., Kinnunen, H., Virtanen, P., Jaatinen, J., et al. (2012). Effects of habitual physical activity on response to endurance training. *J. Sports Sci.* 30, 563–569. doi: 10.1080/02640414.2012.658080

Herrmann, S. D., Willis, E. A., Honas, J. J., Lee, J., Washburn, R. A., and Donnelly, J. E. (2015). Energy intake, nonexercise physical activity, and weight loss in responders and nonresponders: the Midwest exercise trial 2. *Obesity* 23, 1539–1549. doi: 10.1002/oby.21073

Hofmann, W., Baumeister, R. F., Forster, G., and Vohs, K. D. (2012). Everyday temptations: an experience sampling study of desire, conflict, and self-control. *J. Pers. Soc. Psychol.* 102, 1318–1335. doi: 10.1037/a0026545

Holden, C. (2001). Compulsive behaviors: "behavioral" addictions: do they exist? *Science* 294, 980–982. doi: 10.1126/science.294.5544.980

Hong, S., and Dimsdale, J. E. (2003). Physical activity and perception of energy and fatigue in obstructive sleep apnea. *Med. Sci. Sports Exerc.* 35, 1088–1092. doi: 10.1249/01.MSS.0000074566.94791.24

Hussain, S. S., and Bloom, S. R. (2013). The regulation of food intake by the gut-brain axis: implications for obesity. *Int. J. Obes.* 37, 625–633. doi: 10.1038/ijo.2012.93

Iodice, P., Calluso, C., Barca, L., Bertollo, M., Ripari, P., and Pezzulo, G. (2017). Fatigue increases the perception of future effort during decision making. *Psychol. Sport Exerc.* 33, 150–160. doi: 10.1016/j.psychsport.2017.08.013

Iversen, I. H. (1993). Techniques for establishing schedules with wheel running as reinforcement in rats. *J. Exp. Anal. Behav.* 60, 219–238. doi: 10.1901/jeab.1993.60-219

Jung, C. M., Melanson, E. L., Frydendall, E. J., Perreault, L., Eckel, R. H., and Wright, K. P. (2011). Energy expenditure during sleep, sleep deprivation and sleep following sleep deprivation in adult humans. *J. Physiol.* 589, 235–244. doi: 10.1113/jphysiol.2010.197517

Kavanagh, D. J., Andrade, J., and May, J. (2005). Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol. Rev.* 112, 446–467. doi: 10.1037/0033-295X.112.2.446

Kentta, G., and Hassmen, P. (1998). Overtraining and recovery. A conceptual model. *Sports Med.* 26, 1–16. doi: 10.2165/00007256-199826010-00001

Kerksick, C., Thomas, A., Campbell, B., Taylor, L., Wilborn, C., Marcello, B., et al. (2009). Effects of a popular exercise and weight loss program on weight loss, body composition, energy expenditure and health in obese women. *Nutr. Metab. (Lond.)* 6:23. doi: 10.1186/1743-7075-6-23

King, N. A., Caudwell, P., Hopkins, M., Byrne, N. M., Colley, R., Hills, A. P., et al. (2007). Metabolic and behavioral compensatory responses to exercise interventions: barriers to weight loss. *Obesity (Silver Spring)* 15, 1373–1383. doi: 10.1038/oby.2007.164

King, N. A., Hopkins, M., Caudwell, P., Stubbs, R. J., and Blundell, J. E. (2008). Individual variability following 12 weeks of supervised exercise: identification and characterization of compensation for exercise-induced weight loss. *Int. J. Obes.* 32, 177–184. doi: 10.1038/sj.ijo.0803712

King, N. A., Horner, K., Hills, A. P., Byrne, N. M., Wood, R. E., Bryant, E., et al. (2012). Exercise, appetite and weight management: understanding the compensatory responses in eating behaviour and how they contribute to variability in exercise-induced weight loss. *Br. J. Sports Med.* 46, 315–322. doi: 10.1136/bjsm.2010.082495

Kline, C. E. (2014). The bidirectional relationship between exercise and sleep: implications for exercise adherence and sleep improvement. *Am. J. Lifestyle Med.* 8, 375–379. doi: 10.1177/1559827614544437

Kraus, W. E., Houmard, J. A., Duscha, B. D., Knetzger, K. J., Wharton, M. B., McCartney, J. S., et al. (2002). Effects of the amount and intensity of exercise on plasma lipoproteins. *N. Engl. J. Med.* 347, 1483–1492. doi: 10.1056/NEJMoa020194

Lambert, E. V. (2005). Complex systems model of fatigue: integrative homoeostatic control of peripheral physiological systems during exercise in humans. *Br. J. Sports Med.* 39, 52–62. doi: 10.1136/bjsm.2003.011247

Lambiase, M. J., Gabriel, K. P., Kuller, L. H., and Matthews, K. A. (2013). Temporal relationships between physical activity and sleep in older women. *Med. Sci. Sports Exerc.* 45, 2362–2368. doi: 10.1249/MSS.0b013e31829e4cea

Law, R.-J., Breslin, A., Oliver, E. J., Mawn, L., Markland, D. A., Maddison, P., et al. (2010). Perceptions of the effects of exercise on joint health in rheumatoid arthritis patients. *Rheumatology* 49, 2444–2451. doi: 10.1093/rheumatology/keq299

Law, R.-J., Markland, D. A., Jones, J. G., Maddison, P. J., and Thom, J. M. (2013). Perceptions of issues relating to exercise and joint health in rheumatoid arthritis: A UK-based questionnaire study. *Musculoskeletal Care* 11, 147–158. doi: 10.1002/msc.1037

Legrand, F. D., Race, M., and Herring, M. P. (2018). Acute effects of outdoor and indoor exercise on feelings of energy and fatigue in people with depressive symptoms. *J. Environ. Psychol.* 56, 91–96. doi: 10.1016/j.jenvp.2018.03.005

Lett, B. T., Grant, V. L., Byrne, M. J., and Koh, M. T. (2000). Pairings of a distinctive chamber with the aftereffect of wheel running produce conditioned place preference. *Appetite* 34, 87–94. doi: 10.1006/appe.1999.0274

Levine, J. A. (2004). Nonexercise activity thermogenesis (NEAT): environment and biology. *Am. J. Physiol. Endocrinol. Metab.* 286, E675–E685. doi: 10.1152/ajpendo.00562.2003

Levine, J. A., Eberhardt, N. L., and Jensen, M. D. (1999). Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science* 283, 212–214.

Liu, W., Zhang, R., Tan, A., Ye, B., Zhang, X., Wang, Y., et al. (2019). Long sleep duration predicts a higher risk of obesity in adults: a meta-analysis of prospective cohort studies. *J. Public Health (Oxf.)* 41, e158–e168. doi: 10.1093/pubmed/fdy135

Lluch, A., King, N. A., and Blundell, J. E. (1998). Exercise in dietary restrained women: no effect on energy intake but change in hedonic ratings. *Eur. J. Clin. Nutr.* 52, 300–307. doi: 10.1038/sj.ejcn.1600555

Lluch, A., King, N. A., and Blundell, J. E. (2000). No energy compensation at the meal following exercise in dietary restrained and unrestrained women. *Br. J. Nutr.* 84, 219–225.

Mæhlum, S., Danielsen, K. K., Heggebø, L. K., and Schiøll, J. (2012). The Hjelp24 NIMI Ringerike obesity clinic: an inpatient programme to address morbid obesity in adults. *Br. J. Sports Med.* 46, 91–94. doi: 10.1136/bjsm.2010.071894

Marcora, S. M., and Staiano, W. (2010). The limit to exercise tolerance in humans: mind over muscle? *Eur. J. Appl. Physiol.* 109, 763–770. doi: 10.1007/s00421-010-1418-6

Markwald, R. R., Melanson, E. L., Smith, M. R., Higgins, J., Perreault, L., Eckel, R. H., et al. (2013). Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proc. Natl. Acad. Sci. U. S. A.* 110, 5695–5700. doi: 10.1073/pnas.1216951110

Marques, A., Peralta, M., Sarmento, H., Loureiro, V., Gouveia, E. R., and Gaspar de Matos, M. (2019). Prevalence of risk for exercise dependence: A systematic review. *Sports Med.* 49, 319–330. doi: 10.1007/s40279-018-1011-4

Martin, C. K., Johnson, W. D., Myers, C. A., Apolzan, J. W., Earnest, C. P., Thomas, D. M., et al. (2019). Effect of different doses of supervised exercise on food intake, metabolism, and non-exercise physical activity: the E-MECHANIC randomized controlled trial. *Am. J. Clin. Nutr.* 110, 583–592. doi: 10.1093/ajcn/nqz054

Master, L., Nye, R. T., Lee, S., Nahmod, N. G., Mariani, S., Hale, L., et al. (2019). Bidirectional, daily temporal associations between sleep and physical activity in adolescents. *Sci. Rep.* 9:7732. doi: 10.1038/s41598-019-44059-9

Meijer, E. P., Westerterp, K. R., and Verstappen, F. T. (1999). Effect of exercise training on total daily physical activity in elderly humans. *Eur. J. Appl. Physiol.* 80, 16–21. doi: 10.1007/s004210050552

Metcalfe, R. S., Williams, S., Fernandes, G. S., Astorino, T. A., Stork, M. J., Phillips, S. M., et al. (2022). Affecting effects on affect: the impact of protocol permutations on affective responses to Sprint interval exercise; A systematic review and meta-analysis of pooled individual participant data. *Front. Sports Act. Living* 4:815555. doi: 10.3389/fspor.2022.815555

Michie, S., van Stralen, M. M., and West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement. Sci.* 6:42. doi: 10.1186/1748-5908-6-42

Morio, B., Montaurier, C., Pickering, G., Ritz, P., Fellmann, N., Coudert, J., et al. (1998). Effects of 14 weeks of progressive endurance training on energy expenditure in elderly people. *Br. J. Nutr.* 80, 511–519. doi: 10.1017/S0007114598001603

Nicholson, A. N., Stone, B. M., Borland, R. G., and Spencer, M. B. (1984). Adaptation to irregularity of rest and activity. *Aviat. Space Environ. Med.* 55, 102–112.

Noakes, T. D., St Clair Gibson, A., and Lambert, E. V. (2004). From catastrophe to complexity: a novel model of integrative central neural regulation of effort and fatigue during exercise in humans. *Br. J. Sports Med.* 38, 511–514. doi: 10.1136/bjsm.2003.009860

Oldervoll, L. M. K. S., Knobel, H., and Longe, J. H. (2003). Exercise reduces fatigue in chronic fatigued Hodgkins disease survivors–results from a pilot study. *Eur. J. Cancer* 39, 57–63. doi: 10.1016/s0959-8049(02)00483-5

Park, S. K., Jung, J. Y., Oh, C. M., McIntyre, R. S., and Lee, J. H. (2018). Association between sleep duration, quality and body mass index in the Korean population. *J. Clin. Sleep Med.* 14, 1353–1360. doi: 10.5664/jcsm.7272

Pontzer, H. (2015). Constrained Total energy expenditure and the evolutionary biology of energy balance. *Exerc. Sport Sci. Rev.* 43, 110–116. doi: 10.1249/JES.0000000000000048

Pontzer, H. (2018). Energy constraint as a novel mechanism linking exercise and health. *Physiology (Bethesda)* 33, 384–393.

Pontzer, H., Durazo-Arvizu, R., Dugas, L. R., Plange-Rhule, J., Bovet, P., Forrester, T. E., et al. (2016). Constrained Total energy expenditure and metabolic adaptation to physical activity in adult humans. *Curr. Biol.* 26, 410–417. doi: 10.1016/j.cub.2015.12.046

Pontzer, H., Raichlen, D. A., Wood, B. M., Mabulla, A. Z., Racette, S. B., and Marlowe, F. W. (2012). Hunter-gatherer energetics and human obesity. *PLoS One* 7:e40503. doi: 10.1371/journal.pone.0040503

Poscente, N. R. M., and Irvine, J. M. (2002). Using marketing research methods to evaluate a stage-specific intervention. *Am. J. Health Behav.* 26, 243–251. doi: 10.5993/ajhb.26.4.1

Purvis, D., Gonsalves, S., and Deuster, P. A. (2010). Physiological and psychological fatigue in extreme conditions: overtraining and elite athletes. *PM R* 2, 442–450. doi: 10.1016/j.pmrj.2010.03.025

Raichlen, D. A., Pontzer, H., Zderic, T. W., Harris, J. A., Mabulla, A. Z. P., Hamilton, M. T., et al. (2020). Sitting, squatting, and the evolutionary biology of human inactivity. *Proc. Natl. Acad. Sci. U. S. A.* 117, 7115–7121. doi: 10.1073/pnas.1911868117

Redden, J. P. (2015). "Desire over time: The multifaceted nature of satiation" in *The Psychology of Desire*. eds. W. Hofmann and L. F. Nordgren (New York: The Guilford Press)

Robinson, T. E., and Berridge, K. C. (1993). The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Res. Brain Res. Rev.* 18, 247–291. doi: 10.1016/0165-0173(93)90013-P

Robinson, M. J., Fischer, A. M., Ahuja, A., Lesser, E. N., and Maniates, H. (2016). Roles of "wanting" and "liking" in motivating behavior: gambling, food, and drug addictions. *Curr. Top. Behav. Neurosci.* 27, 105–136. doi: 10.1007/7854_2015_387

Rosenbaum, M., and Leibel, R. L. (2010). Adaptive thermogenesis in humans. *Int. J. Obes.* 34, S47–S55. doi: 10.1038/ijo.2010.184

Rosenbaum, M., Vandenborne, K., Goldsmith, R., Simoneau, J. A., Heymsfield, S., Joanisse, D. R., et al. (2003). Effects of experimental weight perturbation on skeletal muscle work efficiency in human subjects. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 285, R183–R192. doi: 10.1152/ajpregu.00474.2002

Rosenberger, M. E., Fulton, J. E., Buman, M. P., Troiano, R. P., Grandner, M. A., Buchner, D. M., et al. (2019). The 24-hour activity cycle: A new paradigm for physical activity. *Med. Sci. Sports Exerc.* 51, 454–464. doi: 10.1249/MSS.0000000000001811

Rosenkilde, M., Auerbach, P., Reichkendler, M. H., Ploug, T., Stallknecht, B. M., and Sjodin, A. (2012). Body fat loss and compensatory mechanisms in response to different doses of aerobic exercise--a randomized controlled trial in overweight sedentary males. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 303, R571–R579. doi: 10.1152/ajpregu.00141.2012

Ryan, R. M., and Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* 55, 68–78.

Sa, J., Choe, S., Cho, B. Y., Chaput, J. P., Kim, G., Park, C. H., et al. (2020). Relationship between sleep and obesity among U.S. and south Korean college students. *BMC Public Health* 20:96. doi: 10.1186/s12889-020-8182-2

Sakurai, T. (2005). Roles of orexin/hypocretin in regulation of sleep/wakefulness and energy homeostasis. *Sleep Med. Rev.* 9, 231–241. doi: 10.1016/j.smrv.2004.07.007

Salvy, S. J., Roemmich, J. N., Bowker, J. C., Romero, N. D., Stadler, P. J., and Epstein, L. H. (2009). Effect of peers and friends on youth physical activity and motivation to be physically active. *J. Pediatr. Psychol.* 34, 217–225. doi: 10.1093/jpepsy/jsn071

Santos, I., Sniehotta, F. F., Marques, M. M., Carraca, E. V., and Teixeira, P. J. (2017). Prevalence of personal weight control attempts in adults: a systematic review and meta-analysis. *Obes. Rev.* 18, 32–50. doi: 10.1111/obr.12466

Silva, A. M., Judice, P. B., Carraca, E. V., King, N., Teixeira, P. J., and Sardinha, L. B. (2018). What is the effect of diet and/or exercise interventions on behavioural compensation in non-exercise physical activity and related energy expenditure of free-living adults? A systematic review. *Br. J. Nutr.* 119, 1327–1345. doi: 10.1017/S000711451800096X

Smith, L. L. (1991). Acute inflammation: the underlying mechanism in delayed onset muscle soreness? *Med. Sci. Sports Exerc.* 23, 542–551.

Snyder, K. A., Donnelly, J. E., Jabobsen, D. J., Hertner, G., and Jakicic, J. M. (1997). The effects of long-term, moderate intensity, intermittent exercise on aerobic capacity, body composition, blood lipids, insulin and glucose in overweight females. *Int. J. Obes. Relat. Metab. Disord.* 21, 1180–1189. doi: 10.1038/sj.ijo.0800533

St Clair Gibson, A., Baden, D. A., Lambert, M. I., Lambert, E. V., Harley, Y. X. R., Hampson, D., et al. (2003). The conscious perception of the sensation of fatigue. *Sports Med.* 33, 167–176. doi: 10.2165/00007256-200333030-00001

Stevens, C. J., Baldwin, A. S., Bryan, A. D., Conner, M., Rhodes, R. E., and Williams, D. M. (2020). Affective determinants of physical activity: A conceptual framework and narrative review. *Front. Psychol.* 11:568331. doi: 10.3389/fpsyg.2020.568331

Stevenson, R. J., Mahmut, M., and Rooney, K. (2015). Individual differences in the interoceptive states of hunger, fullness and thirst. *Appetite* 95, 44–57. doi: 10.1016/j.appet.2015.06.008

Stubbs, R. J., Hughes, D. A., Johnstone, A. M., Whybrow, S., Horgan, G. W., King, N., et al. (2004). Rate and extent of compensatory changes in energy intake and expenditure in response to altered exercise and diet composition in humans. *Am. J. Phys. Regul. Integr. Comp. Phys.* 286, R350–R358. doi: 10.1152/ajpregu.00196.2003

Stubbs, R. J., Sepp, A., Hughes, D. A., Johnstone, A. M., Horgan, G. W., King, N., et al. (2002). The effect of graded levels of exercise on energy intake and balance in free-living men, consuming their normal diet. *Eur. J. Clin. Nutr.* 56, 129–140. doi: 10.1038/sj.ejcn.1601295

Stults-Kolehmainen, M. (2022). Humans have a basic physical and psychhological need to move the body. *SportRxiv* 2022:236. doi: 10.51224/SRXIV.236

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Boullosa, D., Janata, P., Koo, B. B., et al. (2022b). Urges to move and other motivation states for physical activity in clinical and healthy populations: A scoping review protocol. *Front. Psychol.* 13:901272. doi: 10.3389/fpsyg.2022.901272

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Gilson, T. A., Ash, G. I., McKee, P. C., et al. (2020). Motivation states for physical activity and sedentary behavior: desire, urge, wanting, and craving. *Front. Psychol.* 11:568390. doi: 10.3389/fpsyg.2020.568390

Stults-Kolehmainen, M. A., Blacutt, M., Fogelman, N., Gilson, T. A., Stanforth, P. R., Divin, A. L., et al. (2021). Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front. Psychol.* 12:568286. doi: 10.3389/fpsyg.2021.568286

Stults-Kolehmainen, M. A. G. T., SantaBarbara, N., McKee, P., Sinha, R., Bartholomew, J. B., Boullosa, D., et al. (2022a). Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups. *Front. Sports Act. Living* 5:1033619. doi: 10.3389/fspor.2023.1033619

Sun, W., Yuan, J., Yu, Y., Wang, Z., Shankar, N., Ali, G., et al. (2016). Poor sleep quality associated with obesity in men. *Sleep Breath.* 20, 873–880. doi: 10.1007/s11325-015-1193-z

Swelam, B. A., Verswijveren, S., Salmon, J., Arundell, L., and Ridgers, N. D. (2022). Exploring activity compensation amongst youth and adults: a systematic review. *Int. J. Behav. Nutr. Phys. Act.* 19:25. doi: 10.1186/s12966-022-01264-6

Taylor, I. M., Whiteley, S., and Ferguson, R. A. (2022). Disturbance of desire-goal motivational dynamics during different exercise intensity domains. *Scand. J. Med. Sci. Sports* 32, 798–806. doi: 10.1111/sms.14129

Thomas, D. M., Bouchard, C., Church, T., Slentz, C., Kraus, W. E., Redman, L. M., et al. (2012). Why do individuals not lose more weight from an exercise intervention at a defined dose? An energy balance analysis. *Obes. Rev.* 13, 835–847. doi: 10.1111/j.1467-789X.2012.01012.x

Thomas, D. M., Kyle, T. K., and Stanford, F. C. (2015). The gap between expectations and reality of exercise-induced weight loss is associated with discouragement. *Prev. Med.* 81, 357–360. doi: 10.1016/j.ypmed.2015.10.001

Thompson, D., and Batterham, A. M. (2013). Towards integrated physical activity profiling. *PLoS One* 8:e56427. doi: 10.1371/journal.pone.0056427

Tonello, L., Reichert, F. F., Oliveira-Silva, I., Del Rosso, S., Leicht, A. S., and Boullosa, D. A. (2015). Correlates of heart rate measures with incidental physical activity and cardiorespiratory fitness in overweight female workers. *Front. Physiol.* 6:405. doi: 10.3389/fphys.2015.00405

Tremblay, A., Poehlman, E. T., Nadeau, A., Dussault, J., and Bouchard, C. (1987). Heredity and overfeeding-induced changes in submaximal exercise VO_2. *J. Appl. Physiol.* 62, 539–544. doi: 10.1152/jappl.1987.62.2.539

Ufholz, K., Flack, K. D., Johnson, L., and Roemmich, J. N. (2019). Active videogames to promote traditional active play: increasing the reinforcing value of active play among low-active children. *Games Health J.* 2019:40. doi: 10.1089/g4h.2019.0040

van Oosterwijck, J., Nijs, J., Meeus, M., Lefever, I., Huybrechts, L., Lambrecht, L., et al. (2010). Pain inhibition and postexertional malaise in myalgic encephalomyelitis/chronic fatigue syndrome: an experimental study. *J. Intern. Med.* 268, 265–278. doi: 10.1111/j.1365-2796.2010.02228.x

Wang, A., Luan, H. H., and Medzhitov, R. (2019). An evolutionary perspective on immunometabolism. *Science* 363:6423. doi: 10.1126/science.aar3932

Weinsier, R. L., Hunter, G. R., Desmond, R. A., Byrne, N. M., Zuckerman, P. A., and Darnell, B. E. (2002). Free-living activity energy expenditure in women successful and unsuccessful at maintaining a normal body weight. *Am. J. Clin. Nutr.* 75, 499–504. doi: 10.1093/ajcn/75.3.499

Westerterp, K. R. (2003). Impacts of vigorous and non-vigorous activity on daily energy expenditure. *Proc. Nutr. Soc.* 62, 645–650. doi: 10.1079/PNS2003279

Westerterp, K. R., Meijer, G. A., Janssen, E. M., Saris, W. H., and Ten Hoor, F. (1992). Long-term effect of physical activity on energy balance and body composition. *Br. J. Nutr.* 68, 21–30. doi: 10.1079/bjn19920063

Williams, D. M., and Bohlen, L. C. (2019). "Motivation for exercise: Reflective desire versus hedonic dread" in *APA Handbook of Sport and Exercise Psychology, Volume 2: Exercise Psychology*. eds. M. H. Anshel, S. J. Petruzzello and E. E. Labbé (Washington, DC: American Psychological Association), 363–385.

Williams, E. P., Mesidor, M., Winters, K., Dubbert, P. M., and Wyatt, S. B. (2015). Overweight and obesity: prevalence, consequences, and causes of a growing public health problem. *Curr. Obes. Rep.* 4, 363–370. doi: 10.1007/s13679-015-0169-4

Willis, E. A., Creasy, S. A., Saint-Maurice, P. F., Keadle, S. K., Pontzer, H., Schoeller, D., et al. (2022). Physical activity and Total daily energy expenditure in older US adults: constrained versus additive models. *Med. Sci. Sports Exerc.* 54, 98–105. doi: 10.1249/MSS.0000000000002759

Willis, E. A., Herrmann, S. D., Honas, J. J., Lee, J., Donnelly, J. E., and Washburn, R. A. (2014). Nonexercise energy expenditure and physical activity in the Midwest exercise trial 2. *Med. Sci. Sports Exerc.* 46, 2286–2294. doi: 10.1249/MSS.0000000000000354

Wirth, M. D., Hébert, J. R., Hand, G. A., Youngstedt, S. D., Hurley, T. G., Shook, R. P., et al. (2015). Association between actigraphic sleep metrics and body composition. *Ann. Epidemiol.* 25, 773–778. doi: 10.1016/j.annepidem.2015.05.001

Wlodek, D., and Gonzales, M. (2003). Decreased energy levels can cause and sustain obesity. *J. Theor. Biol.* 225, 33–44. doi: 10.1016/S0022-5193(03)00218-2

Yoon, S., Buckworth, J., Focht, B., and Ko, B. (2013). Feelings of energy, exercise-related self-efficacy, and voluntary exercise participation. *J. Sport Exerc. Psychol.* 35, 612–624. doi: 10.1123/jsep.35.6.612

Youngstedt, S. D., and Kline, C. E. (2006). Epidemiology of exercise and sleep. *Sleep Biol. Rhythms* 4, 215–221. doi: 10.1111/j.1479-8425.2006.00235.x

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 29 August 2023
DOI 10.3389/fpsyg.2023.1106571

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OPEN ACCESS

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RECEIVED 23 November 2022
ACCEPTED 03 August 2023
PUBLISHED 29 August 2023

CITATION
Filgueiras A, Stults-Kolehmainen MA, Boullosa D, Sinha R, Bartholomew JB, McKee P, Gilson TA, Keegan R, Viana A, Bueno FA, Medeiros AR, Militão-de-Leutério SF and Ash GI (2023) The CRAVE and ARGE scales for motivation states for physical activity and sedentarism: Brazilian Portuguese translation and single-item versions.
Front. Psychol. 14:1106571.
doi: 10.3389/fpsyg.2023.1106571

The CRAVE and ARGE scales for motivation states for physical activity and sedentarism: Brazilian Portuguese translation and single-item versions

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Motivation states for physical activity and sedentarism potentially vary from moment to moment. The CRAVE scale (Cravings for Rest and Volitional Energy Expenditure) was developed to assess transient wants and desires to move. Three studies were conducted with the aims of: (1) translating and validating the scale in Brazilian Portuguese, (2) examining changes with exercise, and (3) determining the best single-item for Move and Rest subscales for English and Portuguese. In Study 1, six bilingual speakers translated the scale into Brazilian Portuguese [named *Anseios por Repouso e Gastos com Energia* (ARGE)]. The ARGE had good content validity coefficients across three dimensions (0.89–0.91), as determined by three independent, bilingual referees. 1,168 participants (mean age = 30.6, SD = 12.2) from across Brazil completed an online version of the ARGE. An Exploratory Factor Analysis found two clear, oblique, and inversely related factors (Move and Rest; GFI = 1.00, RMSR = 0.03). Reliability was good (Cronbach α's: 0.93 and 0.92). Two models of the scale (10 vs. 13 items) were compared with Confirmatory Factor Analysis. The previously validated version using 10 scored items (GFI = 1.00, RMSEA = 0.07, RMSR = 0.02) outperformed the version scored with 13 items. State anxiety and exercise behavior had small associations with Move and Rest (−0.20 to 0.26). In Study 2, ARGE Move scores had high correspondence post-session (ICC = 0.83) for 9 women performing short Sprint Interval Training (sSIT; 6 sessions). Large, but non-significant, effects were detected for changes in motivation states with sSIT. In Study 3, IRT analyses found that for the United States sample, "be physically active" and "be still" were the most representative items for Move and Rest, respectively, while for the Brazil sample they were "exert my muscles" and "be a couch potato." Overall, it was found that: (A) the ARGE scale demonstrated good psychometric properties, (B) the original scoring (with 10 items) resulted in the best model, (C) it had small associations with exercise behavior, and (D) the subscales were reduced to single items that varied by country, indicating potential cultural differences in the concept of motivation states for physical activity.

KEYWORDS

affectively charged motivation states, motivation, physical activity, exercise, sedentary behavior, psychometrics, Sprint Interval Training, depression

Introduction

Physical inactivity and sedentarism are problems of worldwide proportions (Guthold et al., 2018), leading to numerous health problems (Lee et al., 2012). In the United States, small improvements have been made but, overall, the percentage of the population meeting activity guidelines is low (Hyde et al., 2021; Ussery et al., 2021). There is also a growing physical inactivity pandemic in Brazil (Jaarsma et al., 2013), which has the highest rate of physical inactivity in Latin America at 47% (Guthold et al., 2018). It also one of five countries in the world where physical inactivity is increasing the fastest (>15% from 2001 to 2016), perhaps due to rapid urbanization (Guthold et al., 2018). Physical inactivity and sedentarism result from many factors, including environmental, social, and intra- and inter-personal factors (Bauman et al., 2012). While cognitive explanations have dominated the literature, there has been a turn to affective/emotion-based theories (Williams et al., 2019; Stevens et al., 2020; Williams, 2023), as well as motivational theory (Michie et al., 2011; Stults-Kolehmainen et al., 2020). Indeed, motivation is one of the strongest predictors of physical inactivity/sedentarism (Mayo et al., 2022). Motivation for physically active and sedentary behaviors, including exercise, has typically been conceptualized in terms of motives, or viewed as a stable trait, often in light of self-determination theory (Kilpatrick et al., 2005; Ryan and Deci, 2007; Stults-Kolehmainen et al., 2013a,b). However, newer models of behavior view motivation as a state that varies from moment to moment (Frijda, 2010; Hofmann and Van Dillen, 2012; Hofmann et al., 2012a,b; Frijda et al., 2014).

The concepts of affect, emotion, and motivation intersect within the theory of affectively-charged motivation states (ACMS; Kavanagh et al., 2005) as it applies to movement and sedentarism (Stults-Kolehmainen et al., 2020; Budnick et al., 2023). In short, humans possess transient desires (or wants) to move and be active, and sometimes these are felt subjectively as tension, such as a "pressing readiness" (Stults-Kolehmainen et al., 2020). According to the WANT model (Wants and Aversions for Neuromuscular Tasks; Stults-Kolehmainen et al., 2020, 2023), strong feelings of wanting to move are characterized as urges or cravings, which can vary from moment to moment. Typically, these have been studied in clinical populations, such as those with exercise addiction, anorexia nervosa, or with conditions, such as akathisia or Restless Legs Syndrome (Khan et al., 2017; Stults-Kolehmainen et al., 2022). However, there is recent evidence that these are common in healthy populations (Stults-Kolehmainen et al., 2023), very similar to a biorhythm (Budnick et al., 2023; Crosley-Lyons et al., 2023), and may be stimulated endogenously (e.g., a drive; Stults-Kolehmainen, 2023) or by an environmental stimulus, such as music (Janata et al., 2012, 2018). Motivation states are influenced by recently completed activity behaviors (Stults-Kolehmainen et al., 2021a) and current activities (e.g., sitting, standing, walking; Budnick et al., 2023). Moreover, motivation states predict intentions to be active in the next 30 min in a free-living setting (Budnick et al., 2023) as well as affective responses during subsequent physical activity (Do et al., 2022). Until recently, the study of motivation states for physical activity, such as desires, wants, urges, and cravings, has been stymied by a lack of instrumentation to measure these phenomena (Williams and Bohlen, 2019).

Some progress was made in the area of measurement of ACMS with the creation of the CRAVE scale (Cravings for Rest and Volitional Energy Expenditure; Stults-Kolehmainen et al., 2021a). This 13-item instrument measures wants and desires to both move (i.e., be active) and rest (i.e., be sedentary), 10 of which are scored (5 each for move and rest subscales), while 3 are fillers. Stults-Kolehmainen et al. (2021a) conducted a series of 5 studies to validate the scale, concluding that it had good psychometric properties, including good reliability and greater stability across a single laboratory session compared with increments over 6 months. The data also revealed good discriminant and convergent validity when compared with measurements of energy and fatigue. The instrument, however, needs further development. Psychological assessments developed in North American undergraduate samples (i.e., WEIRD populations–Western, Educated, Industrialized, Rich, and Democratic), such as CRAVE, are often not applicable to the larger human population (Henrich et al., 2010). Major deficits include: (a) lack of cross-cultural adaptation and translations, (b) few data corresponding CRAVE to exercise behavior, (c) shorter versions (e.g., 2 items) that can be used in-task (i.e., during bouts of vigorous exercise), and (d) comparisons of these shorter versions with the original scale.

The present study has 5 general aims, with data collected from 3 studies.

Aim 1—To translate the CRAVE scale into Brazilian Portuguese and determine adequacy of this translation (i.e., with content validity coefficients; Study 1).

Aim 2—To establish psychometrics of the new, adapted scale (i.e., descriptives and cut offs, reliability, test/retest reliability, exploratory and confirmatory factor analyses, convergent and discriminant validity; Studies 1 and 2).

Aim 3—To compare the validated 10-item scoring scheme of the CRAVE scale to a full 13-item scoring scheme (Study 1).

Aim 4—To determine if the translated scale is associated with exercise behavior (Study 1).

Aim 5—To shorten both the CRAVE scale (original American version) and the new translated scale to single-item versions (Study 3).

Study 1

Introduction

Exercise and sport participation, as well as interest for specific physical activities, varies across the globe (Hulteen et al., 2017). According to the Social Ecological Model (Spence and Lee, 2003), health behaviors, such as physical activity and sedentarism, vary by many factors, including culture. Furthermore, discrete psychological factors, such as social support for physical activity, are additionally known to differ between countries and cultures (Bauman et al., 2012). At the current time, however, there is a lack of data on cultural differences in psychological, cognitive, and affective variables impacting PA in low- and middle-income countries, such as in Latin America (Bauman et al., 2012). Previous research (Stults-Kolehmainen et al., 2020) suggested that Brazil may be a good place to start, due to numerous cultural and linguistic differences between the United States and Brazil (Pires et al., 2013; Filgueiras, 2016; Seemiller et al., 2019). Moreover, to our knowledge, there has never been a cross-cultural comparison between Brazil and the United States for motivation for physical activity, exercise, or sedentarism.

Bauman et al. (2012) concluded that this dearth of information is due to the lack of psychological instruments adapted to different cultures and contexts. However, adaptation of an instrument, such as CRAVE, is not a matter of simply translating the scale with automated translation software. This process requires understanding cultural aspects of each of the constructs involved in the instrument in addition to the translation of words. According to Markus (2016), motivation is a "culturally constructed phenomenon," with large differences between North America and non-Western countries. Motivation constructs, such as desires, wants, urges, and cravings, have imprecise translations in Brazilian Portuguese, but might be best translated as "desejos"/"vontades" (desires), quereres (wants), impulsos (urges), necessisdades, compulsões, ânsias (cravings), or anseios (longings). Portuguese also contains motivational constructs that are rarely used or may not exist in English. Common in Brazilian culture, for instance, is the idea of intense longings for someone or something ("saudades"; Neto and Mullet, 2014), a concept perhaps less expressed or understood in North American society.

Given the arguments above, it is important to adapt the CRAVE scale to promote motivation research and practice in Brazil. Therefore, the primary purpose of Study 1 is to translate and validate the scale in Brazilian Portuguese. We hypothesized that the CRAVE scale would maintain the same factor structure in Portuguese (two factors for Move and Rest). This study also affords the opportunity to collect additional psychometric information for the CRAVE scale to address unresolved issues. For instance, some evidence exists (Stults-Kolehmainen et al., 2021a; Study 4) that the scale has better psychometric properties when scored with all 13 items (6 for Move and 7 for Rest). Therefore, a secondary purpose of this study is to analyze alternative models to determine if the 10-item scored scale exhibits advantages over the 13-item scale. A further aim is generate new data for convergent and discriminant validation of the scale (Clark and Watson, 1995; Clark and Watson, 2019; Stults-Kolehmainen et al., 2021a) by comparing motivation states with a mental health factor (i.e., state anxiety), as well as exercise behavior, both of which have not been attempted in previous studies. We hypothesized that there would be a positive association between exercise constructs and the desire to move and a negative association with the desire to rest.

Materials and methods

Participants

Volunteers in this study were 1,168 adult participants (71.6% female) with an age range between 18 and 82 years ($M = 30.6$; $SD = 12.2$). They were dispersed across the country: Southeast region = 868 (74.3%), South = 168 (14.4%), Northeast = 66 (5.7%), Midwest = 58 (5.0%), and North = 8 (0.6%). All volunteers agreed to participate by digitally checking the option of agreement right after reading the Consent Terms. Data were collected between March and June of 2020.

Procedures for cross-cultural adaptation

CRAVE cross-cultural adaptation followed the International Test Commission (ITC) guidelines (Beaton et al., 2000; International Test Commission, 2017) for translating and adapting tests. This was to minimize semantic misinterpretations and misunderstandings and to provide the optimal adaptation for Brazilian culture (Vignola and Tucci, 2014). First, two Brazilian-Portuguese native speakers that were fluent in English translated all items from English to Brazilian-Portuguese. A panel of five specialists formed by the authors developed a synthesis of the two versions to create the first translated version. Instructions were amended to reflect states (e.g., estar, ficar) and not traits (e.g., ser). This translated version was back-translated to English by a native English-speaker fluent in Brazilian-Portuguese. The back-translated version was sent to the main author of the original CRAVE for review. Additional modifications were made for clarity, precision, simplicity, and alignment with the WANT model. The panel of specialists then evaluated and incorporated all suggestions leading to the final Brazilian-translated version of CRAVE. The scale was renamed from CRAVE to "Anseios por Repouso e Gastos com Energia" (i.e., ARGE). See Supplementary material 1 for the scale.

The final Brazilian version of CRAVE was sent to four bilingual experts in motivation and physical activity (i.e., three psychologists and one kinesiologist) to be assessed using the Content Validity Coefficient (CVC; Hernández-Nieto, 2002; Filgueiras et al., 2015). The CVC retrieves a score ranging from 0.0 and 1.0 that comprises the amount of validity the variable holds. If the CVC is above 0.80, then the variable is considered adequate. The experts rated each CRAVE-adapted item in three categories CRAVE-adapted item in three categories (i.e., clarity of the item, adequacy of the item for the construct, and quality of the translation) using a 5-point Likert-type scale (1—poor, 5—excellent). *Clarity of the item* indicates how much an item is understandable for the broad Brazilian population. *Fit for the construct* (adequacy of the item for the construct) entails how much the translated version kept the original content when compared to original and back-translated versions. *The quality of the translated version* assesses to which extent the translation was adequate in a linguistic point of view, not necessarily in a constructive perspective. They also rated scale instructions and rating categories. Based on their responses, each Brazilian-adapted CRAVE item had three CVC scores, and the overall CRAVE had one CVC. All CVC scores were above 0.80, which showed that the Brazilian-version of the CRAVE was adequate and well-adapted.

Procedures for human data collection

The research proposal was submitted to the Rio de Janeiro State University Ethics Committee, obtaining approval through consubstantiated report #2.990.087, which was part of a larger project looking at exercise and health factors during the COVID-19 crisis (Blacutt et al., 2021; Stults-Kolehmainen et al., 2021b; Filgueiras and Stults-Kolehmainen, 2022). After approval, we recruited participants using the main researchers' (AF and MSK) social media, Rio de Janeiro State University's social media, and the local press. We asked volunteers to spread the recruitment advertisement as well, which led to a snow-ball method of recruitment increasing the total number of participants. Among those who viewed the link provided in our recruitment advertisement, 89 individuals (approximately 7.6%) did not agree with the Consent Terms and were redirected to a *thank you* webpage, thus not participating.

We used the Google Forms platform for data collection and the Open Science Framework (OSF) as a database repository. The questionnaires were adapted to the Google Docs format. The first form page consisted of a sociodemographic questionnaire (including: age, education level, height, weight, and self-reported number of days of exercise during last week). The second page was comprised of the state subscale of the Brazilian-adapted version of the Spielberg State and Trait Anxiety (STAI) questionnaire (Spielberger et al., 1971; Fioravanti-Bastos et al., 2011). Page three provided the 13 Brazilian-adapted items of CRAVE in the same order of presentation as the original instrument (Stults-Kolehmainen et al., 2021a). Page four provided the Brazilian-adapted version of the Godin-Shephard Leisure-Time Physical Activity Questionnaire (GSLTPAQ; Godin, 2011; São-João et al., 2013). Finally, the fifth page was a *thank you* notification.

We built our database in Microsoft Excel, after exporting these data from Google Docs and processing some variables based on participants' responses. Height and weight were used to calculate body mass index (BMI), whereas three metabolic equivalent of task (MET) values were calculated based on the participants' answers regarding items 1, 2, and 3 of the GSLTPAQ (respectively, strenuous, moderate, and mild).

Instruments

Sociodemographic questionnaire

A demographic questionnaire collected age (in years), gender, education (i.e., elementary school, high school, college/graduate degree, or post-graduate certificate or diploma), self-reported weight (in kilograms), height (in centimeters), and self-reported number of days of exercise in the past week before answering the research.

Spielberg state and trait anxiety questionnaire

This instrument comprises two subscales, one that refers to how generally a person feels–assessing trait anxiety, whereas the other entails how the person is feeling *right now* or *at this moment*–measuring state anxiety. This study used the state subscale, which comprises 20 items. Items depict emotional statements, which participants rated using a 4-point Likert-type scale ranging from "1—not at all" to "4—very much so." Examples are "1—I feel calm" and "12—I feel nervous" (Spielberger et al., 1971). The Brazilian-adapted version was utilized in this study (Fioravanti-Bastos et al., 2011).

Cravings for rest and volitional energy expenditure (CRAVE)

This questionnaire measures motivation states to move and be sedentary. It entails 13-items divided into two dimensions: Move and Rest—5 items each—and three filler items not considered in the scoring scheme. Examples from the Move factor items are, "I want/desire to move my body" and "I want/desire to expend some energy." Examples from the Rest factor are, "I want/desire to do nothing active" and "I want/desire to be a couch potato." Whereas one example from the filler items is, "I want/desire to burn some calories." Participants rated the statements on an 11-category rating scale from "0—not at all" to "10—more than ever" according to their motivation to either move or be sedentary *right now* or *at this very moment*. The scale has good psychometric properties (Stults-Kolehmainen et al., 2021a). Reliability of the scale is high (McDonald's ω for both Move and Rest = 0.97). CRAVE reliably measures state-like properties of motivation and has good test–retest reliability. Across-session (i.e., over 1 h) interclass correlations (ICC) for Rest (ICC = 0.69–0.88) and Move (ICC = 0.72–0.95) are greater than those measured across 2-years' time (Rest: ICC = 0.49; Move: ICC = 0.53). Respondents report large changes in CRAVE with maximal aerobic fitness testing, with Move decreasing (Cohen's d_{av} = 1.05) and Rest increasing (Cohen's d_{av} = 0.82). It has small to moderate associations with psychosomatic sensations, such as energy, fatigue, and tiredness. The process of translation was described above.

Godin-Shephard leisure-time physical activity questionnaire (GSLTPAQ)

We used the Brazilian-adapted version of GSLTPAQ (São-João et al., 2013). This measure is a 4-item instrument to which participants answered how many times in a 7-day period they engaged in mild/light, moderate, or strenuous exercise practices *for more than 15 min* (Godin, 2011). Item one takes into account strenuous exercise (e.g., running, jogging, hockey, football, soccer, etc.). Item two entails moderate exercise (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, etc.). Item three queries about mild/light exercise (e.g., yoga, archery, fishing from a riverbank, bowling, etc.), and item 4 asks how many days within a 7-day period, the participant engages in exercise or physical activity that accelerates their heart-rate. To determine exercise volume, we calculated the Leisure Score Index (Godin, 2011), which is the number of exercise bouts reported in items 1, 2 and 3 multiplied by 9, 5 and 3 (METs, or metabolic equivalent of task values for strenuous, moderate, and light exercise), respectively (Amireault and Godin, 2015). For example, a participant who only engages in mild exercise four times in a week has a Leisure Score Index (LSI) of "4 × 3 = 12."

Statistical analysis

For descriptive statistics, we calculated arithmetic means, standard deviations (SD), skewness, and kurtosis. The last two indices were adopted to assess normality; we considered the data to be normal whenever both skewness and kurtosis statistics remained between −2.0 and +2.0.

To ensure that this study's sample was representative of Brazilians, we followed the guidelines from the normative resolution (#031/2022) of the Brazilian Federal Council of Psychology (CFP, 2022) that requires either at least 150 participants from three of the five regions in Brazil or a total 1,000 participants. Due to the nature of online recruitment and snowball sampling method, we decided to follow the second rule and collected data on at least 1,000 participants.

Standardized norms based on percentiles were calculated for the two CRAVE factors: Move and Rest. Interpretation of data was as follows: below percentile 10—low wants/cravings, between percentiles 10 and 25—wants/cravings below average, between percentiles 25 and 75—average wants/cravings, between percentiles 75 and 90—wants/cravings above average, and above percentile 90—high wants/cravings.

We adopted Baumgartner (2009) guidelines to develop the normative data (percentile norms) based on percentile ranks. Generally, ROC curve and cut off thresholds are adopted to develop normative cut offs, particularly in the case of clinical diagnosis, which is not the case for ARGE. Accordingly, Crawford et al. (2011) showed that ROC-based cut off norms and percentile norms are equivalent among 10 of the most cited self-reported mood assessment measures, which enables us to utilize percentile ranks to calculate our norms.

We developed a product–moment correlation matrix with demographic variables, scores for the STAI-State, CRAVE Move and Rest (both the 10-item and 13-item scoring), MET mild/light, moderate and strenuous, BMI, and self-reported number of days of exercise in the past week for convergent validity purposes. Additionally, we calculated internal consistency using three indices: Cronbach's alpha, Guttman's Lambda (Trizano-Hermosilla and Alvarado, 2016), and Mislevy and Bock's (1990) reliability index. All reliability indices with values above 0.70 were considered adequate.

Regarding the factor analysis, we first divided the sample into two subsamples with the same number of participants using the randomization tool of Microsoft Excel. Thus, a sample of 1,168 participants yielded two subsamples of 584 participants each. With the first sample we conducted the exploratory factor analysis (EFA), whereas we performed the confirmatory factor analysis (CFA) with the second sample.

Due to the nature of our CRAVE data (i.e., an ordinal, Likert-type rating scale), we followed the recommendations from Timmerman and Lorenzo-Seva (2011) to conduct the EFA using the polychoric correlation matrix with the optimal implementation of Parallel Analysis (PA) as the procedure for determining the number of dimensions, the Unweighted Least Squares (ULS) for factor extraction, and Promax rotation to achieve factor simplicity. To assess the adequacy of the correlation matrix we adopted the Bartlett test—expecting a significance of $p < 0.05$—and the Kaiser–Meyer–Olkin (KMO) test that should retrieve a result above 0.80. Explained variance of factors, items' factor loadings, and fit statistics [i.e., goodness-of-fit (GFI) and Root Mean Square of Residuals (RMSR)] followed the recommendations of Kelley (1935) and Lorenzo-Seva (2003). We designated an item to a factor if the factor loading was above 0.30, whereas the GFI expected should be above 0.90 and the RMSR below 0.04 (Kelley, 1935; Lorenzo-Seva, 2003).

We conducted the CFA using Jöreskog and Moustaki (2001) recommendations for ordinal variables; we used Unweighted Least Squares (ULS) as the method of estimation, leaving all parameters on default. We tested two models: the 13-item version of CRAVE and the 10-item model based on the structure found by Stults-Kolehmainen et al. (2021a). We evaluated the models via five fit indices, two error indices, and two information criteria for model comparison. Fit indices were goodness-of-fit (GFI), the adjusted goodness-of-fit (AGFI), the normed fit index (NFI), the parsimony normed fit index (PNFI), and the comparative fit index (CFI). The first two are fit indices to compare empirical data and the hypothesized model; the other two verify the fit between the normed hypothesis and the empirical data. Finally, the CFI evaluated the comparison between the null-hypothesis and the tested model in regard to the empirical data. All fit indices were expected to be above 0.90 (Lorenzo-Seva, 2003). Error indices were the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR); both should be below 0.05. Finally, we used the Aikake Information Criterion (AIC) and the Consistent AIC (CAIC) as information statistics to establish the best model; the lowest values correspond with the best model (Jöreskog and Moustaki, 2001).

Descriptive statistics, normative data, and correlations were performed using R-packages *psych* and *corrplot*. We used the application Factor 9.2 (Lorenzo-Seva and Ferrando, 2013) to perform the EFA and LISREL 8.80 (Jöreskog and Sörbom, 1996) for the CFA.

Results

Descriptive statistics, skewness, and kurtosis are presented for the whole sample ($N = 1{,}168$; 71.5% female) in Table 1. All CVC scores were above 0.80, which showed that the Brazilian-adapted version of CRAVE was adequate and well-adapted. Normative data (i.e., percentiles, cut-offs) are provided in Supplementary material 2. After randomly separating the Exploratory Factor Analysis (EFA) and the Confirmatory Factor Analysis (CFA) samples into two subsamples of 584 participants each, we found in the EFA sample (71.8% female) an average age of 30.84 years (SD = 12.63), an average BMI of 25.27 (SD = 5.12), and an average of 2.16 days of exercise per week (SD = 2.18). The CFA sample (71.2% female) had an average age of 30.27 years (SD = 11.78), an average BMI of 25.24 (SD = 5.40), and an average of 2.31 days of exercise per week (SD = 2.30). The Leisure Score Index (LSI) for the entire sample was 47.49, indicating that this group was, on average, sufficiently active (Amireault and Godin, 2015).

To ensure statistically non-significant differences between the CFA and EFA samples, we conducted t-tests on three basic sample characteristics: age, BMI, and exercise frequency. Results of the t-test for age revealed no significance [$t(583) = 0.83$; $p = 0.41$; Cohen's $d = 0.05$; power = 0.54]. Similar results were retrieved for BMI [$t(583) = 0.12$; $p = 0.91$; Cohen's $d = 0.01$; power = 0.91] and for days of exercise per week [$t(583) = 1.05$; $p = 0.29$; Cohen's $d = 0.07$; power = 0.55].

Reliability metrics of CRAVE (ARGE) factors were calculated separately. The Move subscale yielded a Mislevy and Bock (1990) reliability estimate of 0.94, a Cronbach's alpha of $\alpha = 0.93$ and a Guttman's Lambda of $\lambda = 0.92$; whereas the Rest subscale retrieved a Mislevy and Bock (1990) reliability estimate of 0.92, a Cronbach's alpha of $\alpha = 0.92$ and a Guttman's Lambda of $\lambda = 0.92$. These results suggest good reliability for both CRAVE subscales.

TABLE 1 Descriptive statistics for the entire Brazilian sample (N = 1,168) in Studies 1 and 3, including mean, standard deviation (SD), skewness, and kurtosis.

Variable	Mean	SD	Skewness	Kurtosis
ARGE (CRAVE in Portuguese)				
Move—10 items	29.82	14.58	−0.316	−1.053
Move—13 items	35.64	17.25	−0.330	−0.991
Rest—10 items	21.52	14.64	0.282	−1.128
Rest—13 items	33.18	20.10	0.134	−1.190
MET exercise scores*				
Light or Mild	11.95	18.06	0.356	−1.250
Moderate	9.54	10.56	0.841	−0.404
Strenuous	26.00	22.56	1.363	0.654
Leisure Score Index (LSI)**	47.49	39.22	0.984	−0.267
Exercise frequency/week	2.23	2.24	0.584	−0.925
BMI	25.26	5.26	0.966	1.370
State anxiety	53.55	12.04	−0.279	−0.629

*Frequency of activity per week for light, moderate, or strenuous MET intensities × 3, 5, or 9, respectively. **Sum of MET exercise scores.

TABLE 2 Descriptive statistics and factor loadings for Move and Rest subscale items in the exploratory factor analysis (EFA) for the 13-item version of the ARGE (Brazilian-adapted version of CRAVE scale; Study 1).

Item	Descriptive statistics				Factor loading	
	Mean	SD	Skewness	Kurtosis	Rest	Move
Rest						
11. me deitar.	5.60	3.58	−0.196	−1.411	**0.932**	0.093
12. descansar meu corpo.	5.80	3.42	−0.243	−1.272	**0.916**	0.209
7. ficar quieto.	5.79	3.32	−0.260	−1.244	**0.756**	−0.007
8. não levantar do sofá.	4.13	3.70	0.376	−1.378	**0.750**	−0.132
10. ficar sem me movimentar.	3.63	3.49	0.562	−1.075	**0.643**	−0.240
4. só ficar sentado.	3.96	3.47	0.453	−1.191	**0.616**	−0.210
3. fazer nenhuma atividade.	3.78	3.49	0.533	−1.142	**0.557**	−0.173
Move						
2. estar fisicamente ativo.	6.42	3.30	−0.477	−1.135	0.087	**0.917**
5. queimar calorias.	5.89	3.64	−0.339	−1.367	0.046	**0.772**
1. mexer meu corpo.	5.19	3.30	0.006	−1.313	0.009	**0.735**
9. exercitar meus músculos.	5.92	3.40	−0.379	−1.243	−0.010	**0.885**
6. gastar um pouco de energia.	5.88	3.39	−0.340	−1.274	−0.023	**0.828**
13. me movimentar.	6.07	3.19	−0.377	−1.145	−0.101	**0.792**

Highlighted in bold are factor loadings with values above 0.3. Items are in order by loadings on the Rest factor.

Exploratory factor analysis (EFA)

The EFA results yielded as the best solution a 2-factor structure with a moderate, negative, and significant correlation between dimensions (r = −0.63). Table 2 depicts descriptive statistics and factor loadings of the 13-item Brazilian-adapted version of CRAVE. Regarding the correlation matrix adequacy, the Bartlett test retrieved a significant result [5808.6 (df = 78; p < 0.001)], and the Kaiser–Meyer–Olkin statistic was considered good (KMO = 0.93). The bidimensional structure explained 70.36% of the cumulative variance, whereas only the two first factors showed eigenvalues above 1.0 (more precisely, 7.37 and 1.78, respectively). The goodness-of-fit index presented a good fit of the correlation matrix to the hypothesized bidimensional structure (GFI = 1.00), and the Root Mean Square of Residuals was within the expected amount of measurement error (RMSR = 0.028).

Confirmatory factor analysis (CFA)

We tested two models in the CFA based on the 13-item scored version of CRAVE that was adapted to Brazil and the 10-item scored version suggested by Stults-Kolehmainen et al. (2021a) as the best solution to measure movement and sedentarism motivation states. Table 3 depicts selected fit indices and error statistics. Based on the

TABLE 3 Fit indices, error statistics, and Aikake information criteria retrieved by the confirmatory factor analysis (CFA) for both the 10- and 13-item scoring schemes of the ARGE (Brazilian-adapted CRAVE scale; Study 1).

Statistics	Model	
	10 items	13 items
Fit index		
GFI	1.00	0.99
AGFI	1.00	0.99
NFI	1.00	1.00
PNFI	0.76	0.82
CFI	1.00	1.00
Error estimate		
RMSEA	0.07	0.11
SRMSR	0.02	0.04
Information criterion		
AIC	168.94	552.56
CAIC	281.71	697.55

lowest AIC and CAIC, the 10-item model is the best solution for the Brazilian-adapted version of CRAVE as well. The 13-item version did not hold error below Kelley (1935) criterion, whereas the 10-item version did—additional evidence that suggests the latter version provides the best scoring structure.

The 13-item model presented a significant chi-square [$\chi^2(64)=498.56$; $p<0.001$]. The path coefficient between dimensions retrieved a moderate, negative association ($\beta=-0.61$). Relationships between items and the Move factor varied between $\beta=0.65$ (item 5—Move) and $\beta=0.92$ (item 13—Move), whereas those items with Rest presented path coefficients between $\beta=0.73$ (item 12—Rest) and $\beta=0.85$ (item 8—Rest).

The 10-item model yielded a significant chi-square [$\chi^2(64)=126.94$; $p<0.001$], though this statistic showed a lower value than for the 13-item model. The relationship between factors in this model retrieved a slightly higher negative association than the other model ($\beta=-0.65$). Path coefficients between items and the Move factor varied between $\beta=0.79$ (item 1—Move) and $\beta=0.91$ (items 9 and 13—Move), whereas regarding Rest, path coefficients varied between $\beta=0.74$ (item 3—Rest) and $\beta=0.84$ (items 8 and 10—Rest).

Evidence of validity

We calculated the product–moment correlation between the 10- and 13-item subscale scores of CRAVE (i.e., Move and Rest), along with other variables that may relate to wants and urges to be active or sedentary. Those variables were:

a. self-reported number of days the participant engaged in exercise in the last week (frequency of exercise),
b. the frequency of light or mild, moderate and strenuous intensity activities [determined by metabolic equivalent of task (MET)] as measured by the Godin-Shephard Leisure-time Exercise Questionnaire, plus the composite score, called the Leisure Score Index (LSI),
c. body mass index (BMI), and
d. state anxiety as measured by the State–Trait Anxiety Inventory (STAI).

BMI was the only variable not associated with wants to move or be sedentary. Nevertheless, the 5-item Rest subscale showed a small, but significant negative correlation with BMI. The frequency of exercise was positively associated with urges to move, whereas it negatively correlated with wants to be sedentary. To different degrees, light, moderate, strenuous, and total exercise (in METS) correlated positively with wants to move and negatively with urges to rest, following the same pattern of frequency of exercise. State anxiety was negatively associated with wants to move; however, this relationship was small ($r=-0.10$). Furthermore, the urge to be sedentary was correlated with state anxiety to a larger extent ($r=0.26$). See Figure 1.

Discussion

The ARGE, the translated version of the CRAVE scale, appears to have good psychometric properties and is thus valid for testing in Brazilian Portuguese. The scale had good content validity, as rated by multiple independent raters. It also had good reliability. Factor analyses provided a two-factor solution, as found in previous studies (Stults-Kolehmainen et al., 2021a). Additionally, CFA analysis verified the original 10-item scoring scheme as opposed to a new 13-item scoring. As with previous studies, BMI was not associated with desire to move, but had a very small association with desire to be sedentary. Though correlations were small, the 10- and 13-items versions of the ARGE had nearly identical associations between Move and Rest subscales with state anxiety as well as light-to-strenuous exercise behavior. Nonetheless, exercise-related variables related weakly with motivation states. This seems to contrast with results from Stults-Kolehmainen et al. (2021a), who found that stage-of-change for exercise has a very clear relation with the desire to move and rest, though this last construct is more closely related to habit.

This study has some notable limitations. First, the "Past week" version of the scale was not utilized as in previous studies (Stults-Kolehmainen et al., 2021a). Furthermore, our assessments were conducted during the COVID-19 quarantine, a time of high societal stress (Blacutt et al., 2021; Stults-Kolehmainen et al., 2021b; Filgueiras and Stults-Kolehmainen, 2022). However, CRAVE was only weakly associated with mental health factors, like state anxiety; therefore, this should not have been an undue problem. The exercise measure we used, the Godin-Shepard Leisure-Time Physical Activity Questionnaire, is highly utilized and is related to physical fitness, but has limited correspondence with objectives measures of physical activity, such as accelerometry ($r=0.45$; Miller et al., 1994). Therefore, future studies should compare the ARGE to objective measures of energy expenditure. Despite some limitations, there were several notable strengths, including: (a) a large sample from across Brazil, and (b) content validity with additional, independent raters. Overall, the psychometrics for this new version were as strong or better as those demonstrated in the original validation paper (Stults-Kolehmainen et al., 2021a). Therefore, the adapted scale is suitable for additional cross-cultural, longitudinal, and exercise training studies involving Brazilian samples.

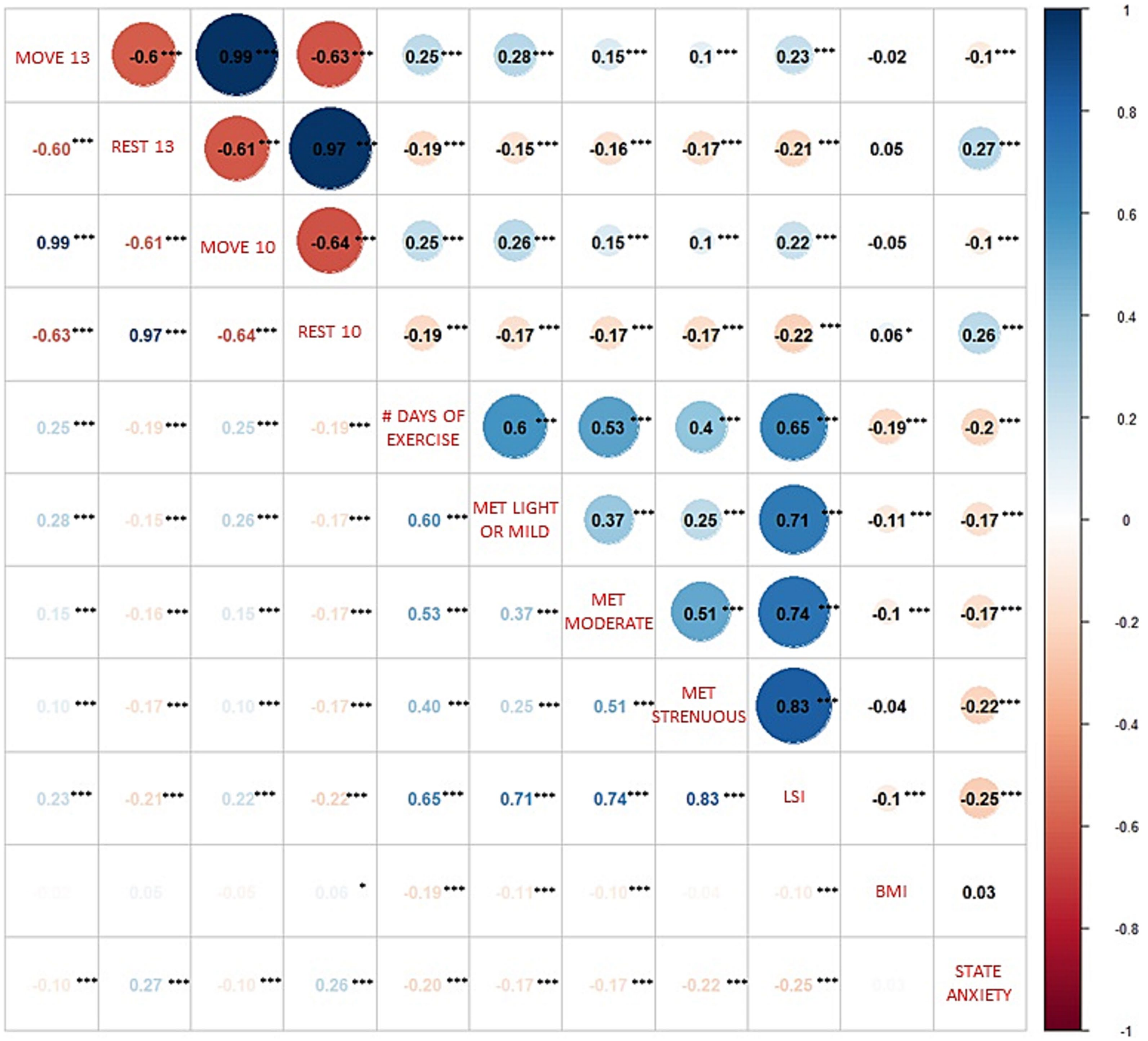

FIGURE 1
Correlation matrix (heat map) of CRAVE Move and Rest subscales with additional variables (i.e., exercise, BMI, state anxiety) to evaluate evidence of convergent and discriminant validity (Study 1)*†. *MET Light or Mild = number of times over the last 7 days completing at least 15 min of light or mild intensity leisure time exercise. MET Moderate = number of times over the last 7 days completing at least 15 min of moderate intensity leisure time exercise. MET Strenuous = number of times over the last 7 days completing at least 15 min of vigorous intensity leisure time exercise. † LSI = Leisure Score Index (sum of MET scores).

Study 2

Introduction

As part of the psychometric validation process, it is important to gather prospective data. For psychological states, it would be expected that data would vary to a high degree from day to day (even moment to moment), but these should correspond more closely over a shorter period (e.g., 30 min) than a longer period (e.g., across an entire day). Motivation states should also change in response to a physical stimulus, or a deprivation of stimuli (Stults-Kolehmainen et al., 2020). In our previous studies (Stults-Kolehmainen et al., 2021a), we found that the CRAVE scale captured motivational states rather than traits, as determined by intra-class correlations (ICCs) in a sample of >100 individuals assessed twice in a laboratory session, repeating every 6 months for over 2 years. The anticipated pattern of longitudinal responses was also demonstrated in a sample of undergraduate students who took CRAVE three times during prolonged sitting (i.e., a 50-min lecture period). In this study (Stults-Kolehmainen et al., 2021a), students' desire to move increased and desire to rest decreased just before class ended. Similar results were found in focus groups of 17 students from the same Midwestern state (Stults-Kolehmainen et al., 2023). Moreover, after these interviews not only did Move scores increase (and Rest scores decrease) as expected, but the variance across participants decreased as well suggesting higher correspondence after similarly structured activities compared to before. With a sample from the Southwest of the United States, we found robust decreases in CRAVE-Move with a maximal treadmill stress test along with concomitant increases in CRAVE-Rest (Stults-Kolehmainen et al., 2021a). Furthermore, in this same study Move and Rest pre-testing were inversely associated ($r = -0.37$), and this relationship was stronger post-exercise ($r = -0.64$). With the new, Portuguese version (ARGE), similar responses would be expected.

Substantial attention has been given to interval training in recent years, with bouts of aerobic activity ranging from a few seconds to a minute (de Sousa et al., 2018). Short Sprint Interval Training (sSIT) consists of high-intensity aerobic exercise engaged for <10 s. Unlike our previous investigation, which used a maximal exercise stimulus designed to rapidly drain energy systems (Stults-Kolehmainen et al., 2021a), sSIT training does not exhaust anaerobic or aerobic metabolism—as demonstrated with minimal lactate accumulation (Flores et al., 2018). Consequently, while the exercise intensity is supramaximal during the very short sprinting bouts, it does not result in excessive fatigue and pain. This is important as lactate accumulation has been associated with reduced motivation to move and continue exercise (Taylor et al., 2022). This may discourage physical activity for some people. However, there is still a robust improvement in affective and cognitive responses, such as enhanced psychological attention (de Sousa et al., 2018; Gerber et al., 2018). Gerber et al. (2018) found that affective and motivational responses were the same for Sprint Interval Training (SIT) and continuous aerobic exercise, though they did not observe changes in motivation states—instead measuring changes in more stable constructs of intrinsic and extrinsic motivation. However, a recent meta-analysis found that shorter sprints are associated with more positive affective responses (Metcalfe et al., 2022).

The primary purpose of this study is to examine the instrument's validity with changes in motivation states in response to exercise stimuli. Due to their highly transitory nature, as well as responsiveness to numerous stimuli and previous behaviors (Budnick et al., 2023), we hypothesized that motivation states measured before exercise sessions (intra-individual) will have low correspondence. However, responses following sprint sessions should have greater correspondence. We also predict that motivation states will change with exercise. However, we do not have a specific hypothesis for how motivation will change pre- to post-sprints because the nature of the exercise is quite different from our previous trials, and less research has been completed with this type of training.

Materials and methods

Participants

This study is part of a larger clinical trial investigating the use of Short Sprint Interval Training (sSIT) training for depression; consequently, this was a sample of convenience. The sample consisted of nine women clinically diagnosed with depression, with a mean age of 37.9 ± 11.9 and a mean BMI of $28.2 \pm 4.5 \text{kg/m}^2$, who were recruited through pamphlets and posters in local psychiatric care establishments and through dissemination in digital media. The inclusion criteria were: having a diagnosis of moderate or severe depression as determined by the Brazilian Portuguese version of the Mini International Neuropsychiatric Interview (MINI) assessment—administered by a psychiatrist (Amorim, 2000; Wu et al., 2020), being sedentary, and signing the Free Informed Consent Form. These participants also completed the 21-item Hamilton Depression Scale (HAM-D21; Hamilton, 1967; Carneiro et al., 2015). The HAM-D21 is the most widely used clinician-administered depression assessment scale. The scale contains 21 items pertaining to symptoms of depression experienced over the past week to be applied as a structured interview. The participants' average and standard deviation at baseline was 24.6 ± 8.2.

Exclusion criteria were: being pregnant, having diseases or conditions that interfere with cardiovascular responses (e.g., having a pacemaker, severe stenosis, heart failure, among others), taking medications that interfere with cardiovascular responses, presenting with any absolute contraindication to perform the cardiorespiratory test or high-intensity physical exercise, and performing physical exercise on a regular basis. Menstrual cycle was not queried or controlled.

Procedures

The volunteers underwent six sessions of approximately 10 min of the short Sprint Interval Training (sSIT) protocol, on a cycle ergometer, consisting of 4–12 maximal sprints each lasting 5 s, with an active rest interval of ≥30 s at 50 W. Training sessions were completed three times a week, all in the morning hours, with a 48-h rest between sessions. Sessions were held at the Maria Aparecida Pedrossian University Hospital (HUMAP) of the Federal University of Mato Grosso do Sul (UFMS). There were 2 min of warm-up followed by the sprint protocol and then 2 min of cool-down at 50 rpm and 50 W load. To perform the maximal sprints, an overload corresponding to 5% of body weight was added (Gillen et al., 2016; Flores et al., 2018). In the first week, the free and informed consent form was signed, and the initial assessment and familiarization took place. In the second and third weeks, the 5 s sSIT training bouts were performed in a linear, periodized fashion.

Instrumentation

Motivation states for physical activity and sedentary behavior were assessed using the 13-item Brazilian version of the CRAVE scale (Stults-Kolehmainen et al., 2021a), called the ARGE (Anseios por Repouso e Gastos de Energia), with construct validity and psychometric properties described in Study 1. The volunteers completed the ARGE scale 5 min before and 5 min after each SIT session. The 10-item scoring scheme was utilized, per the psychometrics above.

Statistical analysis

Two repeated measures ANOVAs were run with Time (Pre, Post) and Sprint session (i.e., 3–4, 4–6, 6–8, 10–12, 6–8 [again]) as within-subjects factors for both Move (Mover) and Rest (Descansar) subscales. To examine intra-rater reliability, intra-class correlations (ICCs) were calculated with a two-way mixed effects model (using absolute agreement) according to guidelines from Koo and Li (2016). This model represents the reliability of specific raters in the experiment, and the ICC's cannot be generalized to other raters or studies. While the use of interrater reliability analysis (in this case, intra-rater) is a less common approach, it is most appropriate for the current investigation. ICCs were calculated for all data and data without session 1, which exhibited some correlations that differed substantially from the rest of the sessions.

Results

Changes in Move and Rest

Composite scores of Move and Rest had varying degrees of association by pre- and post-measurement, with the strongest and only significant association being between Rest and Move post-sprints ($r = -0.84$). See Figure 2. Prior to sprinting, Move scores visually seem to be higher than Rest scores. Furthermore, Move scores visually appear to have increased after all sprints while Rest scores appear to have decreased after all sprints.

For Move, however, we could not reject the null hypothesis for Time ($p = 0.28$, $\eta^2 = 0.16$), Sprint ($p = 0.65$, $\eta^2 = 0.09$), or Time X Sprint ($p = 0.28$, $\eta^2 = 0.03$). Likewise, for Rest we could not reject the null hypothesis for Time ($p = 0.14$, $\eta^2 = 0.29$), Sprint ($p = 0.59$, $\eta^2 = 0.10$), or Time X Sprint ($p = 0.75$, $\eta^2 = 0.05$). Mauchly's test of sphericity indicates that this assumption was violated so we used the Greenhouse–Geisser correction when appropriate. See Figures 3A,B.

Intra-rater reliability

Intra-class correlations (ICCs) were small for Move pre-sprints (0.33 and 0.39 for all sessions and session 2–5, respectively), but strengthened to 0.83/0.84 post-sprints. Likewise, ICCs for Rest strengthened from very low (0.01 and 0.10) to moderate (0.68 and 0.67) from pre- to post-training. ICCs for pre- to post-scores for both Move and Rest were low to moderate. See Table 4.

Discussion

In this small, pilot study of depressed women engaging in short Sprint Interval Training (sSIT), we found that the Brazilian version of the CRAVE scale (ARGE) was stable for Move and Rest measurements taken after exercise training sessions but not for measurements taken before each session's sprints. This was demonstrated with intra-class correlations (ICCs), indicators of correspondence within groups, which were stronger for both Move and Rest after individual sprint training sessions than before sprint sessions. This is in line with the theoretical basis of motivation states (i.e., the WANT model)–that they are transient and can vary greatly from moment to moment, hour to hour, and day to day. However, there should be greater correspondence between these states after a standardized stimulus exposure in a highly controlled laboratory environment, even when repeated multiple times. This provides further evidence that CRAVE/ARGE reflects a state more so than a trait, as we have demonstrated in previous studies (Stults-Kolehmainen et al., 2021a). These data also serve to provide extra validation for the CRAVE/ARGE scales.

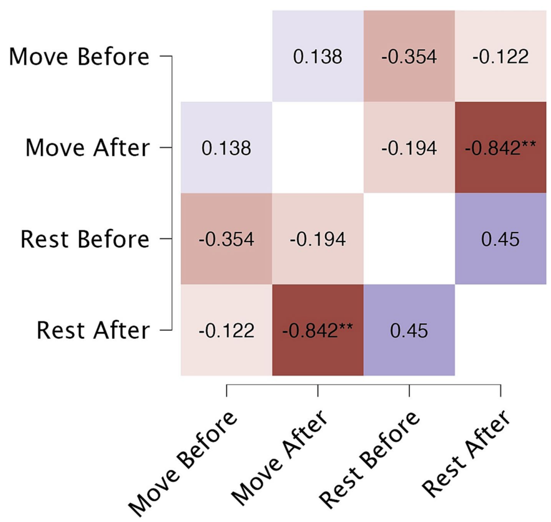

FIGURE 2
Pearson's *r* heatmap (Study 2). Averaged across all levels of sprint, Move and Rest post-sprint observations were negatively correlated ($r = -0.84$, $p < 0.01$).

While not significant, with visual inspection of the data it is apparent that Move increased from pre- to post-sprints, and Rest decreased. This study was greatly underpowered (i.e., very small sample size); therefore, there were no significant results for the effects of time (pre vs. post), session, or the interaction of these factors. However, effect sizes were medium (for across sessions) and large (for pre-post sprint session), indicating that with a greater number of similar participants, it is likely that the null hypotheses would have been rejected (Richardson, 2011). If these trends were to hold with a larger sample size, one might interpret the data in a few different ways: (a) depressed women were reinforced to move with each sSIT training session, (b) sSIT training results in psychological responses that differ from other training methods, or (c) both. Interestingly, our previous work with high intensity weight training found that highly stressed, but not depressed, individuals had blunted affective responses compared to lower stressed individuals, including less pain (Stults-Kolehmainen et al., 2016). Previous studies have shown that sSIT results in improved hedonic tone, similar to other forms of exercise (Gerber et al., 2018), less pain, and perhaps greater "liking" or enjoyment of movement (Metcalfe et al., 2022). Our previous data have demonstrated that short Sprint Interval Training (sSIT) typically results in improved psychological attention (de Sousa et al., 2018). Thus, it is also possible that participants were able to attend to internal sensations (i.e., interoception) better at the end of training sessions compared to pre-session, which is important because both endogenous and exogenous factors likely contribute to motivation states for movement and sedentarism (Stults-Kolehmainen et al., 2022).

This was a pilot study with only nine women attending six sessions of training; thus, few conclusions could be drawn, and several limitations were evident. First, with the small sample size and short intervention, we were not able to examine any chronic or enduring changes from baseline to post-intervention (e.g., in depression status). Moreover, there was no comparison group with non-depressed individuals and no measure of physical activity behavior to ascertain the participants' degree of psychomotor retardation. Future research should expand the sample and training period. There were sufficient data to determine consistency of the measures before and after sSIT sessions. Unfortunately, there were no measures during inter-sprint recovery periods or for the recovery period after sSIT training. There were few explanatory variables collected to assist with understanding the clinical implications of improved desire to move with training sessions. For instance, if people want to continue to move more with a sSIT training session, should we encourage them to do so? Motivation states may vary by setting, whether laboratory-based or real-world (e.g., anticipating upcoming physical activity, naturally occurring, changing patterns of physical activity), which may impact the "want to" move vs. the "have to" move. Future research should explore this as well as control for menstrual status, which is known to have an impact on affective and possibly motivational outcomes (Garcia et al., 2022).

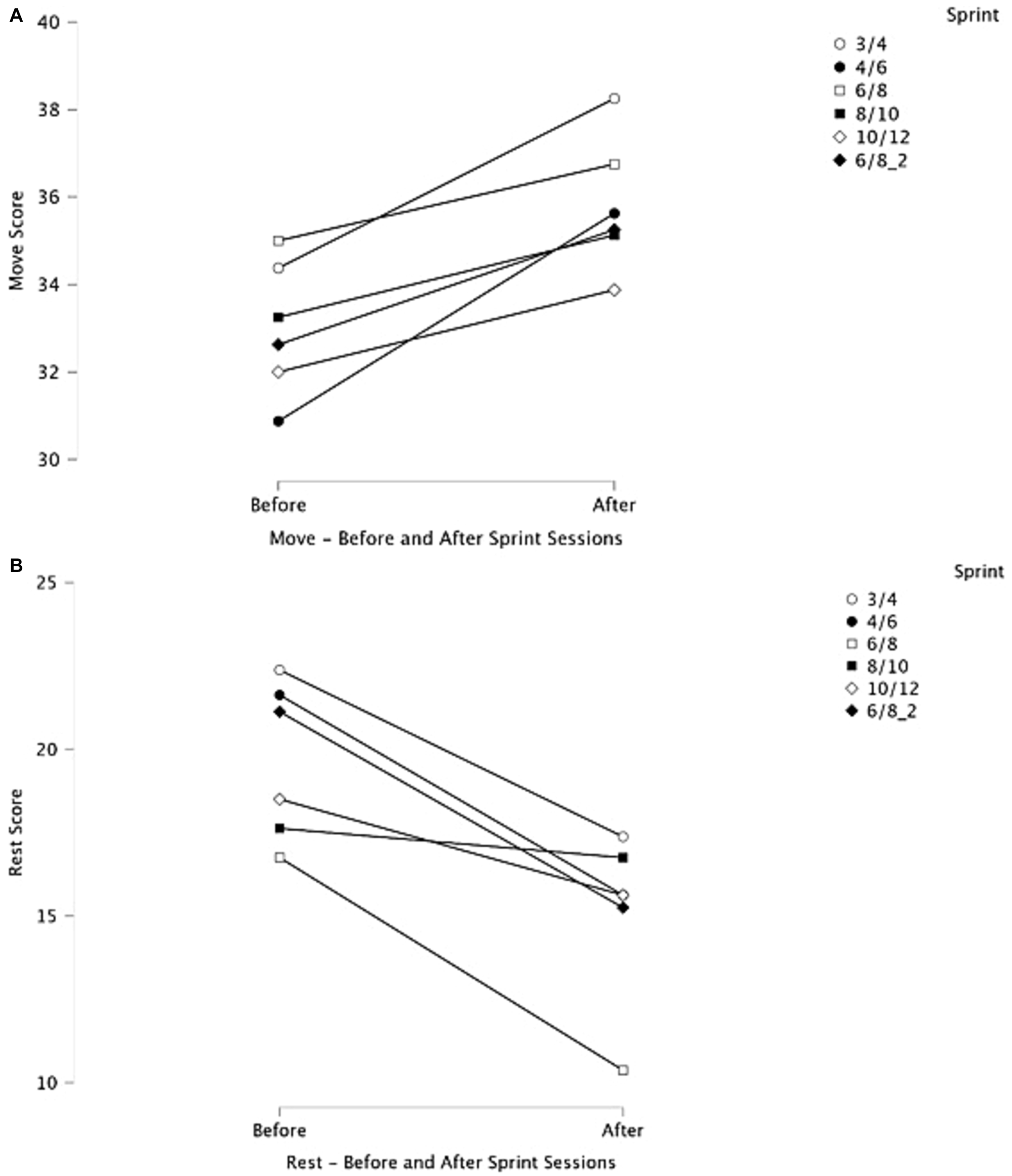

FIGURE 3
(A,B) Changes in Move and Rest across six sessions of sSIT exercise training for nine women (Study 2). Lines represent each exercise training session (i.e., session with 3 or 4 sprints; 4 or 6 sprints, etc.).

Study 3

Introduction

The CRAVE scale, while psychometrically robust, contains 13 items that take about 90 s to complete. This hinders use of the scale during task (e.g., while exercising) and in ecological momentary assessment (EMA) studies. Taylor et al. (2022) used an unvalidated single-item motivation states measure during vigorous exercise, finding that exercise intensity over lactate threshold resulted in rapid increases in the desire to stop exercising. Do et al. (2022), Ponnada et al. (2022), and Crosley-Lyons et al. (2023) have developed and utilized single-item measure for EMA studies, which are still ongoing validation. Multiple other single-item scales exist as well, all unvalidated (discussed by Stults-Kolehmainen et al., 2021a). Lack of valid instrumentation is the prominent hindrance in the investigation of motivation states for movement, physical activity, and sedentarism (Williams and Bohlen, 2019). Therefore, the objective of this study is to validate single-item versions for both the CRAVE and ARGE instruments (Move and Rest subscales).

TABLE 4 Two-way mixed effects model using absolute agreement (Study 2).

Outcome		ICC	95% confidence interval	F	*p*	Stability interpretation*
Move Pre	All sessions	0.39	0.11–0.77	4.473	0.001	Low
	Sessions 2–5	0.33	0.04–0.74	3.257	0.012	Low
Move Post	All sessions	0.83	0.64–0.96	31.270	<0.001	High
	Sessions 2–5	0.84	0.65–0.96	26.084	<0.001	High
Rest Pre	All sessions	0.01	−0.12–0.39	1.057	0.411	Low
	Sessions 2–5	0.10	−0.112 to 0.545	1.488	0.212	Low
Rest Post	All sessions	0.68	0.41–0.91	14.296	<0.001	Moderate
	Sessions 2–5	0.67	0.390 to 0.906	12.116	<0.001	Moderate
Move Pre to Post	All sessions	0.22	−1.46–0.81	1.317	0.353	Low
	Sessions 2–5	0.50	−0.226 to 0.873	2.940	0.089	Moderate
Rest Pre to Post	All sessions	0.46	−0.54–0.86	2.183	0.145	Low
	Sessions 2–5	0.16	−0.462 to 0.732	1.424	0.326	Low

*Based on Koo and Li (2016).
Analysis for: (a) all six short Sprint Interval Training (sSIT) sessions, and (b) with session 1 removed from analysis.

Materials and methods

Participants

The sample of this study was constituted by the same participants from Study 1 (above) and two American samples described by Stults-Kolehmainen et al. (2021a) (see Data availability section). We opted to use the *right now* databases of both the American and Brazilian CRAVE scales, using the 10-item scoring scheme.

Procedures

We asked permission of Stults-Kolehmainen et al. (2021a) to use the American databases of the CRAVE scale—available in an open repository. We then conducted statistical analyses on both the Brazilian and American databases. We needed to equate items to make internal comparisons using Item Response Theory (IRT). To do that, we opted for a vertical "equating" (Cook and Eignor, 1991) merging all databases into a single spreadsheet according to the recommendations from Baker (1992) and Wright (1993). Analyses were conducted using the equated database. We analyzed Move and Rest factors separately.

Statistical analysis

To determine the best single item to represent the Move and Rest subscales in the Brazilian and American versions, we opted to use the item information curve (IIC) based on the Graded Response Model (GRM), an IRT model for ordinal polytomous items developed by Samejima (1969). The level of information is the opposite of the level of error, which means that the item that provides more information is also the item with less measurement errors. Equating both American and Brazilian databases into the same dataset allowed comparison between IICs based on GRM (Baker, 1992).

Due to potential differences of IIC, we decided to further investigate whether items functioned similarly or not for the Brazilian and American datasets. Thus, we conducted a differential item functioning (DIF) analysis comparing the three datasets. To allow comparisons, we calculated chi-square statistics and Aikake and Bayesian information criteria (AIC and BIC, respectively) for each item. This way, we might provide evidence to support whether different weights and likelihoods of endorsement between countries were present.

Results

We used the item information curve (IIC) to investigate which item from each CRAVE subscale (i.e., 5 items each for Move and Rest) best represented the latent trait (i.e., had higher levels of information). We employed the same method to both the Brazilian and the American databases yielding one item for each subscale for both countries. Figure 4A depicts IIC for each CRAVE/ARGE Move subscale item displayed by country, whereas Figure 4B presents the same graph for Rest items.

Our results suggested that item 9 in the Brazilian version of the Move subscale ("exercitar meus músculos/exert my muscles") and item 8 of the Rest subscale from the same country ("não levantar do sofá/be a couch potato") presented the highest levels of information. Whereas Move item 2 ("estar fisicamente ativo/be physically active") and Rest item 7 ("ficar quieto/be still") for the American CRAVE version were the most informative items. This means that the single-item Brazilian version of CRAVE should consider items 9 and 8 to represent Move and Rest subscales, respectively, whereas items 2 and 7 of the American CRAVE correspond to the single-item version of the Move and Rest subscales, respectively. Due to the difference of item information between countries, we decided to further investigate these distinctions using the differential item functioning (DIF) analysis. Table 5 summarizes the DIF results comparing the Brazilian and American samples.

Results from DIF showed that, at least according to AIC and chi-square statistics, all items from the Move subscale functioned differently between Americans in the first sample (USA 1) and Brazilians, whereas item 6 had similar item functioning when comparing Brazilians and Americans from the second sample. It was easier for Brazilians to endorse items 6, 9, and 13, whereas Americans from samples 1 and 2 scored significantly higher on items 1 and 2. However, if we consider the positive BIC, item 6 did not function

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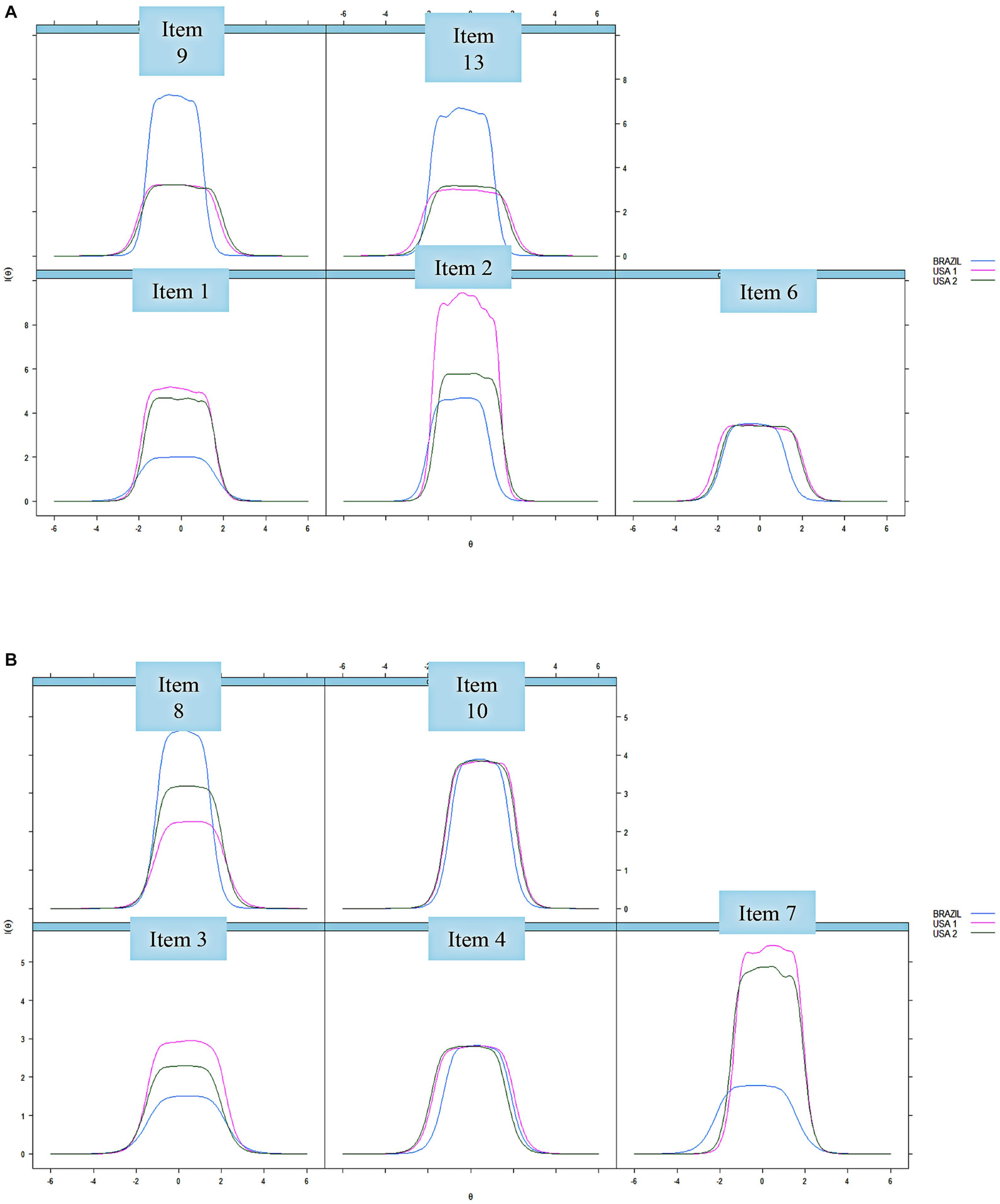

FIGURE 4
(A,B) Items from the CRAVE and ARGE scales, analyzed with the Item Information Curve (IIC) and plotted by country (Study 3). The *X* axis is the latent trait (omega) and the *Y* axis is the level of information.

differently in Brazil in comparison to the United States in either sample, which means it is inconclusive whether item 6 shows DIF or not; however, it tends to function similarly across countries.

Among items from the Rest subscale, items 4 and 10 presented non-significant functioning between Brazil and USA 1, whereas the second American sample (USA 2) only yielded non-significant statistics in item 4, which suggests that item 4 is equivalent in both countries, but item 10 might not be; it is inconclusive. Nevertheless, items 3 and 7 were easier for Americans to endorse, whereas item 8 was scored higher among Brazilians. This way, we provided evidence to support different weights and likelihood of endorsement between countries.

TABLE 5 Brazilian and American versions of Move and Rest CRAVE items with chi-square statistics and Aikake and Bayesian information criteria (AIC and BIC, respectively) for the Brazilian and the two American samples (USA 1 and USA 2; Study 3).

Scale item[1,2]	Statistics (DIF)				
	χ^2	df	*p*	AIC	BIC
Brazil vs. USA 1st sample					
Move					
1. mexer meu corpo/move my body	31.60	1	< 0.001	−29.60	−24.24
2. estar fisicamente ativo/be physically active	14.51	1	<0.001	−12.51	−7.15
6. gastar um pouco de energia/expend some energy	3.11	1	0.007	−1.11	4.25
9. exercitar meus músculos/exert my muscles	16.86	1	<0.001	−14.90	−9.50
13. me movimentar/move around	16.90	1	<0.001	−14.90	−9.54
Rest					
3. fazer nenhuma atividade/do nothing active	13.85	1	<0.001	−11.85	−6.49
4. só ficar sentado/just sit down	0.15	1	0.699	1.85	7.21
7. ficar quieto/be still	35.19	1	<0.001	−33.19	−27.83
8. não levantar do sofá/be a couch potato	11.89	1	<0.001	−9.89	−4.53
10. ficar sem me movimentar/be motionless	0.61	1	0.434	1.39	6.75
Brazil vs. USA 2nd sample					
Move					
1. mexer meu corpo/move my body	24.95	1	<0.001	−22.95	−17.57
2. estar fisicamente ativo/be physically active	1.90	1	0.169	0.10	5.49
6. gastar um pouco de energia/expend some energy	0.53	1	0.528	1.47	6.85
9. exercitar meus músculos/exert my muscles	20.23	1	<0.001	−18.23	−12.84
13. me movimentar/move around	16.89	1	<0.001	−14.89	−9.51
Rest					
3. fazer nenhuma atividade/do nothing active	5.28	1	0.022	−3.28	2.11
4. só ficar sentado/just sit down	0.17	1	0.676	1.83	7.21
7. ficar quieto/be still	32.41	1	<0.001	−30.41	−25.03
8. não levantar do sofá/be a couch potato	2.94	1	0.086	−0.94	4.44
10. ficar sem me movimentar/be motionless	2.56	1	0.110	−0.56	4.82
USA 1st vs. USA 2nd sample					
Move					
1. move my body	0.35	1	0.569	1.68	6.41
2. be physically active	4.55	1	0.033	−2.55	2.18
6. expend some energy	0.79	1	0.374	1.21	5.94
9. exert my muscles	0.07	1	0.789	1.93	6.66
13. move around	0.01	1	0.983	2.00	6.73
Rest					
3. do nothing active	1.61	1	0.205	0.39	5.12
4. just sit down	0.45	1	0.505	1.56	6.29
7. be still	0.15	1	0.697	1.85	6.58
8. be a couch potato	2.29	1	0.130	−0.29	4.44
10. be motionless	0.44	1	0.510	1.57	6.30

[1]There are 13 items in the scales, but only 10 are scored (5 for each subscale). Filler items are not included in this analysis.
[2]Highlighted in bold letter are the items that showed no differential item functioning (DIF).

We found a DIF between the two American samples. Item 2 ("be physically active") retrieved a significant *p*-value (0.033) and a large enough AIC and BIC to enable different item functioning between samples USA 1 and 2. According to our results, sample USA 1 was less likely to endorse item 2 than sample USA 2. Regardless, with the exception of item 2, other Move and Rest items showed equivalent item functioning between the American samples, which was expected.

Discussion

The current study utilized an Item Response Theory model to reduce the 10-item CRAVE and ARGE scales (5 items each for Move and Rest) into single items for each subscale. We found that the ARGE (Brazilian version of CRAVE) was best represented by ("exercitar meus músculos/exert my muscles") for Move and ("não levantar do sofá/be a couch potato") for Rest subscales. On the contrary, the best items in the North American version (original CRAVE) were ("be physically active") and ("be still") for Move and Rest, respectively. The concept of "being still," or a lack of motion, as representative of sedentary activities and rest seems to make sense as it is the physical condition common to sitting, laying down, watching television (typically), etc. It is also relevant in light of psychological phenomena, like freezing (e.g., in the face of threat, or in highly specific situations common to sport, like the moment before a gun fires to start a race), which are states of inactivity and behavioral inhibition but not physical or mental rest, *per se* (Stults-Kolehmainen and Sinha, 2014; Roelofs, 2017). Indeed, an entire special issue in *Philosophical Transactions* was dedicated to the topic of stillness, stopping motion, and "not moving" (Noorani, 2017; Noorani and Carpenter, 2017; Roelofs, 2017). Noorani and Carpenter (2017) concludes that, "…the maintenance of stillness is not simply a matter of doing nothing: it requires as much if not more active and accurate control as creating the movements themselves." This phenomenon was deemed "neglected" but is highly relevant for the control of motivated action of movement and sedentary behavior. Interestingly, the most representative item for Brazilian Portuguese was "não levantar do sofá ("be a couch potato"), which may reflect the general idea of being "stuck" or highly fatigued and less akin to indolence or laziness, key themes discovered in a recent qualitative study (Stults-Kolehmainen et al., 2023). Adaptations of other psychological instruments from English to Brazilian Portuguese have found similar linguistic and cultural challenges (Vignola and Tucci, 2014), and may be due to problems with the translation, back translation, or other deeper factors.

Using the information curve based on the graded response model to decide the best (most informative) item to use as a single-item instrument is relatively novel and innovative (Böhnke and Lutz, 2014; Sekely et al., 2018; Wang et al., 2022). This technique is also prone to loss of other types of information and some of the nuances and details regarding individual differences in either Move or Rest or even both, which can limit the use and interpretation of CRAVE as a measurement instrument. Using differential item functioning (DIF) analysis, we found that all but two of the 10 items differed between Brazilian and North American samples, signifying potential cultural differences, or perhaps differences along some other random factor. For instance, the Brazilian samples were also approximately a decade older than the American samples (30.8 and 30.3 years vs. 20.9 and 20.3 years). Thus, we cannot ignore the potential influence of age, but in our previous work we determined that motivation to exercise (and not move, *per se*) varied little across this period of life (Stults-Kolehmainen et al., 2013a). The IIC provides insights into item quality and its ability to differentiate individuals based on the measured latent trait (Baker, 1992). IICs vary across independent samples (Samejima, 1969), making them more sensitive to detecting differences in comparison to the Classical Test Theory (Baker, 1992). As our instrument measures volatile motivational states, discrepancies in IIC results are likely (Lord, 1975). However, despite slight differences in IICs between the two United States samples, the overall pattern remained, demonstrating strong evidence of item reliability. It might also be considered that a different single item could be a better representation of motivation states to be active or sedentary than any of the items developed as part of the CRAVE scale, such as the "feel like" item from the Dunton laboratory (Do et al., 2022; Ponnada et al., 2022; Crosley-Lyons et al., 2023). Our general assessment, however, is that the single-item subscales found from this IRT analysis are valid and should be utilized in future studies, as outlined in the general discussion below.

General discussion

The present study makes several incremental advancements in the measurement of affectively-charged motivation states (ACMS) for physical activity and sedentarism (Stults-Kolehmainen et al., 2020). First, we conducted the first translation and cultural adaptation of the CRAVE scale (Stults-Kolehmainen et al., 2021a), in this case into Brazilian Portuguese, creating the ARGE scale. This instrument was found to have good psychometric properties, similar to the original CRAVE scale or better. Importantly, these analyses verified the factor structure of the CRAVE scale in a new population from a different country and in another language. We used these data to compare 10- and 13-item scoring schemes of the CRAVE/ARGE scales, finding that the originally validated 10-item scoring had the best psychometric properties. This is ideal as it substantiates two 5-item subscales (i.e., Move and Rest) that range from 0 to 50 points each, which simplifies interpretation. The data were associated in the predicted manner with metrics from the Godin-Shepard Leisure Time Physical Activity Questionnaire—the first time motivation states data have been compared to exercise behavior. Prospective data from a trial involving short Sprint Interval Training (sSIT) determined that the ARGE reflects a state more than a trait. We also found some large effects in motivation states pre- to post-sprint sessions, which were not significant due to the small sample size in Study 2. Using Item Response Theory, we were able to reduce the scale down to two items (1 for Move and Rest) for the original CRAVE and new ARGE scales. Differences in these items revealed some potential cultural differences between the United States and Brazil for motivation for physical activity and sedentarism, one of the first reports to note such variation.

The psychometrics of the new ARGE, while highly similar to the psychometrics from the original CRAVE scale, had some apparent small differences. For instance, in our previous investigations (Stults-Kolehmainen et al., 2021a), Move and Rest factors are correlated moderately and inversely (r's = −0.71 and −0.78, in two different studies). In the current study, we found a two-factor solution that was less strongly related (r = −0.63). Previous investigations provided both quantitative and qualitative evidence suggestive of stronger relationships between exercise behavior and motivation states to move and rest (Stults-Kolehmainen et al., 2021a, 2023). In this study, however, there were small associations with leisure-time exercise indicators from the Godin-Shephard Questionnaire. It may be the case that these state measures do not correspond well with exercise measures quantified over a period of 7+ days. We did not include the Past-Week version of the CRAVE scale in these studies, which may have corresponded better with exercise behavior. Also, CRAVE and ARGE relate to movement and physical activity more generally, and not exercise specifically. The ARGE had negligible associations with BMI (as we previously found; Stults-Kolehmainen et al., 2021a) and state anxiety, perhaps because the stress response can result in multifarious and contrasting movement outcomes, such as fight, flight, freeze, and faint (Stults-Kolehmainen and Sinha, 2014). Further evidence is needed from the CRAVE and ARGE scales to evaluate construct, convergent, and discriminant validity. We developed the single-item measure to help researchers and practitioners to collect data longitudinally and to assess motivational states within subjects, not between. However, we acknowledge that this constitutes a limitation in this article and future research is needed to tap into this issue and develop further percentile norms for the single-item measures. The use of the ARGE, as well as the single-item measures for both the CRAVE and ARGE subscales, is unconditional as long as the proper reference from this study is provided.

Future research

Our previous manuscripts have extensively suggested future research possibilities (Stults-Kolehmainen et al., 2020, 2021a, 2022, 2023; Budnick et al., 2023; Flack et al., 2023). Primarily based on limitations that were discussed above for each study, future research could focus on the following 10 areas of need:

1. Tracking motivation states against stronger measures of exercise and PA, including accelerometry, as well as against levels of aerobic and muscular fitness, which has never been documented.
2. Investigating more robust cross-cultural comparisons, including translation of CRAVE into Spanish and other languages.
3. Assessing correspondence of CRAVE and/or ARGE scales with other exercise and sport motivation questionnaires.
4. Associations with other mental health states, psychological feeling states, like arousal and pleasure/displeasure, and "state mindfulness for physical activity" (Cox et al., 2015; Stults-Kolehmainen et al., 2015; Budnick et al., 2023).
5. Associations with metabolic parameters, such as continuous measures of blood glucose.
6. Implementing studies using the single-item subscales during task (e.g., during vigorous exercise; Taylor et al., 2022) and recovery. Determining changes in ACMS with high intensity interval training (HIIT) vs. vigorous and/or moderate intensity aerobic training.
7. Determining if it is appropriate and useful to utilize CRAVE/ARGE normative data for exercise prescription—similar to affect-based exercise prescriptions (Ekkekakis et al., 2004).
8. Using environmental cues, including short, motivational messages, perhaps from fitness wearables, about physical activity tailored for diverse populations to promotes desires to move and be active, a process that has previously been successful in Brazil (Hoehner et al., 2008; Heath et al., 2012).
9. Just in time adaptive interventions (JITAI; Hardeman et al., 2019) to provide just the right amount of support for people when they are experiencing "CRAVE moments"—transient times of wanting to move.
10. Understanding the physiological, affective, and cognitive components of the "CRAVE moment"—high craving as delineated in Supplementary material 2 that might be close to the "mental hijacking" described by Hofmann and Van Dillen (2012) in their Dynamical Model of Desire.

Conclusion

We conducted three studies to improve psychometrics for the measurement of affectively-charged motivation states (ACMS) for physical activity and sedentary behaviors. In Study 1, we adapted the CRAVE scale (Stults-Kolehmainen et al., 2021a) into Brazilian Portuguese to facilitate examination of cross-cultural influences. The revised scale, named the ARGE, appears to have good psychometric properties. Importantly, the basic factor structure replicated with this new population and language, which is important evidence that the basic constructs measured by the CRAVE scale are valid. These data also provide evidence that the original 13-item scale should be used with 10 items scored (5 each for Move and Rest subscales) and 3 unscored fillers. Motivation states had small, but significant associations with indices of exercise behavior; Move predicted more exercise and Rest predicted less. In Study 2, we found stability of Move and Rest after bouts of short Sprint Interval Training (sSIT), but not before, providing additional evidence that this facet of motivation is a state, and not a trait, and is influenced by numerous inputs. We also observed large effects for changes in motivation states from pre- to post-exercise, but these were not significant due to the small sample size. Finally, in Study 3, we developed single-item subscales for Move and Rest that varied by country, which provides some additional evidence that motivation is a culturally influenced concept. Future studies should use the single-item scales to examine changes in the desire or urge to move and rest during exercise. Additional work is also needed to examine other facets of the WANT model (Stults-Kolehmainen et al., 2020), such as aversions (i.e., dread) to move and be active and how they interact with approach motivation for the same activities.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/ga538/; https://figshare.com/authors/Matthew_Stults_kolehmainen/794794, https://doi.org/10.6084/m9.figshare.13322600.v1; https://doi.org/10.6084/m9.figshare.13322642.v1. Other data is available with reasonable request to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Rio de Janeiro State University Ethics Committee-consubstantiated report #2.990.087. The patients/participants provided their written informed consent to participate in this study.

Author contributions

Study 1 was conceived and designed by AF and MS-K. Translation was conducted by AF, AV, FB, AM, and MS-K. Data were collected by AF. Analyses were conducted by AF. Study 1 was equally written by AF and MS-K. Study 2 was conceived and designed by DB. Data were collected by SM-d-L. Analyses were conducted by PM. Study 2 was written by MS-K, DB, SM-d-L, and FB, in that order. Study 3 was conceived and designed by AF and MS-K. Data were collected by TG and AF. Analyses were conducted by AF. Study 3 was equally written by AF and MS-K. The manuscript was evaluated and refined by MS-K, AF, DB, RS, JB, GA, PM, AV, RK, FB, AM, TG, and SM-d-L, in that order. All authors reviewed, provided critical feedback, and approved the final manuscript.

Funding

GA was supported by a fellowship from the Office of Academic Affiliations at the United States Veterans Health Administration, a Robert E. Leet and Clara Guthrie Patterson Trust Mentored Research Award, Bank of America, N.A., Trustee, American Heart Association Grant #852679 (GA, 2021–2024), and the National Institute of Diabetes, Digestive, and Kidney Diseases of the National Institutes of Health under a mentored research scientist development award (K01DK129441).

Acknowledgments

A special gratitude goes to Alexandra Turner (Simsbury, Connecticut) for her language expertise. The authors also wish to thank Khristdman Cavalcanti (João Pessoa, Brazil) for translation assistance. Bruno Galvão and Rodrigo Pieri (both of University of Santa Ursula, Rio de Janeiro, Brazil) and Pedro Pires (Federal University of Rio de Janeiro, Rio de Janeiro, Brazil) were the scale raters. Additional thanks is due to Jessica Alves (Federal University of Mato Grosso do Sul, Campo Grande, Brazil), Miguel Blacutt (University of Notre Dame, Notre Dame, IN, United States), and Stephen Taerum (Connecticut Agricultural Experiment Station, New Haven, CT, United States). The use of the full, 13-item ARGE, as well as the single-item CRAVE and ARGE measures, is unconditional as long as the proper reference is provided. The ARGE is available at: https://www.researchgate.net/publication/365797582_Brazilian_translation_of_the_CRAVE_scale_ARGE_Anseios_por_Repouso_e_Gastos_de_Energia.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1106571/full#supplementary-material

References

Amireault, S., and Godin, G. (2015). The Godin-Shephard leisure-time physical activity questionnaire: Validity evidence supporting its use for classifying healthy adults into active and insufficiently active categories. *Percept. Mot. Skills* 120, 604–622. doi: 10.2466/03.27.pms.120v19x7

Amorim, P. (2000). Mini international neuropsychiatric interview (Mini): validação de entrevista breve para diagnóstico de transtornos mentais. *Rev. Bras. Psiquiatr.* 22, 106–115. doi: 10.1590/S1516-44462000000300003

Baker, F. B. (1992). Equating tests under the graded response model. *Appl. Psychol. Measur.* 16, 87–96. doi: 10.1177/014662169201600111

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., Martin, B. W., et al. (2012). Correlates of physical activity: Why are some people physically active and others not? *Lancet* 380, 258–271. doi: 10.1016/S0140-6736(12)60735-1

Baumgartner, T. A. (2009). Tutorial: Calculating percentile rank and percentile norms using SPSS. *Meas. Phys. Educ. Exerc. Sci.* 13, 227–233. doi: 10.1080/10913670903262769

Beaton, D. E., Bombardier, C., Guillemin, F., and Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine* 25, 3186–3191. doi: 10.1097/00007632-200012150-00014

Blacutt, M., Filgueiras, A., and Stults-Kolehmainen, M. (2021). Prevalence and incidence of stress, depression, and anxiety symptoms among Brazilians in quarantine across the early phases of the COVID-19 crisis. medRxiv [Preprint].

Böhnke, J. R., and Lutz, W. (2014). Using item and test information to optimize targeted assessments of psychological distress. *Assessment* 21, 679–693. doi: 10.1177/1073191114529152

Budnick, C. J., Stults-Kolehmainen, M., Dadina, C., Bartholomew, J. B., Boullosa, D., Ash, G. I., et al. (2023). Motivation states to move, be physically active and sedentary vary like circadian rhythms and are associated with affect and arousal. *Front. Sports Act. Living* 5:1094288. doi: 10.3389/fspor.2023.1094288

Carneiro, A. M., Fernandes, F., and Moreno, R. A. (2015). Hamilton depression rating scale and Montgomery-Asberg depression rating scale in depressed and bipolar I patients: psychometric properties in a Brazilian sample. *Health Qual. Life Outcomes* 13:42. doi: 10.1186/S12955-015-0235-3

CFP (2022). *Resolução Do Exercício Profissional (Normative Resolution) 31/2022* Brasilia, Brazil: Conselho Federal De Psicologia (Federal Council of Psychology).

Clark, L. A., and Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychol. Assess.* 7, 309–319. doi: 10.1037/1040-3590.7.3.309

Clark, L. A., and Watson, D. (2019). Constructing validity: New developments in creating objective measuring instruments. *Psychol. Assess.* 31, 1412–1427. doi: 10.1037/Pas0000626

Cook, L. L., and Eignor, D. R. (1991). IRT equating methods. *Educ. Meas. Issues Pract.* 10, 37–45. doi: 10.1111/j.1745-3992.1991.tb00207.x

Cox, A., Ullrich-French, S., and French, B. (2015). Validity evidence for the state mindfulness scale for physical activity. *Meas. Phys. Educ. Exerc. Sci.* 20, 1–12. doi: 10.1080/1091367x.2015.1089404

Crawford, J., Cayley, C., Lovibond, P. F., Wilson, P. H., and Hartley, C. (2011). Percentile norms and accompanying interval estimates from an Australian general adult population sample for self-report mood scales (BAI, BDI, CRSD, CES-D, DASS,

DASS-21, STAI-X, STAI-Y, SRDS, AND SRAS). *Aust. Psychol.* 46, 3–14. doi: 10.1111/j.1742-9544.2010.00003.x

Crosley-Lyons, R., Do, B., Hewus, M., and Dunton, G. F. (2023). An ecological momentary assessment study of affectively-charged motivational states and physical activity. *Psychol. Sport Exerc.* 67:102423. doi: 10.1016/j.psychsport.2023.102423

De Sousa, A. F. M., Medeiros, A. R., Benitez-Flores, S., Del Rosso, S., Stults-Kolehmainen, M., and Boullosa, D. A. (2018). Improvements in attention and cardiac autonomic modulation after a 2-weeks sprint interval training program: a Fidelity approach. *Front. Physiol.* 9:e00241. doi: 10.3389/Fphys.2018.00241

Do, B., Rhodes, R. E., Kanning, M., Hewus, M., and Dunton, G. F. (2022). Examining whether affectively-charged motivations predict subsequent affective response during physical activity: an ecological momentary assessment study. *Front. Sports Act. Living* 4:e029144. doi: 10.3389/Fspor.2022.1029144

Ekkekakis, P., Hall, E. E., and Petruzzello, S. J. (2004). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: rationale and a case for affect-based exercise prescription. *Prev. Med.* 38, 149–159. doi: 10.1016/j.ypmed.2003.09.038

Filgueiras, A. (2016). Translation and cross-cultural adaptation of the sport imagery questionnaire to Brazilian Portuguese. *Brazil J sport Psychol* 6, 72–84. doi: 10.31501/rbpe.v6i2.7012

Filgueiras, A., Galvão, B. D. O., Pires, P., Fioravanti-Bastos, A. C. M., Hora, G. P. R., Santana, C. M. T., et al. (2015). Tradução e adaptação semântica do Questionário de Controle Atencional para o Contexto Brasileiro. *Estud Psicol* 32, 173–185. doi: 10.1590/0103-166x2015000200003

Filgueiras, A., and Stults-Kolehmainen, M. (2022). Risk factors for potential mental illness among Brazilians in quarantine due to COVID-19. *Psychol. Rep.* 125, 723–741. doi: 10.1177/0033294120976628

Fioravanti-Bastos, A. C. M., Cheniaux, E., and Landeira-Fernandez, J. (2011). Development and validation of a short-form version of the Brazilian state-trait anxiety inventory. *Psicol Reflex. Crit* 24, 485–494. doi: 10.1590/S0102-79722011000300009

Flack, K. D., Stults-Kolehmainen, M. A., Creasy, S. A., Khullar, S., Boullosa, D., Catenacci, V. A., et al. (2023). Altered motivation states for physical activity and "appetite" for movement as compensatory mechanisms limiting the efficacy of exercise training for weight loss. *Front. Psychol.* 14:1098394. doi: 10.3389/fpsyg.2023.1098394

Flores, S. B., De Sousa, A. F. M., Totó, E. C. D. C., Rosa, T. S., Del Rosso, S., Foster, C., et al. (2018). Shorter sprints elicit greater cardiorespiratory and mechanical responses with less fatigue during time-matched sprint interval training (SIT) sessions. *Kinesiology* 50, 137–148. doi: 10.26582/k.50.2.13

Frijda, N. H. (2010). Impulsive action and motivation. *Biol. Psychol.* 84, 570–579. doi: 10.1016/j.biopsycho.2010.01.005

Frijda, N. H., Ridderinkhof, K. R., and Rietveld, E. (2014). Impulsive action: Emotional impulses and their control. *Front. Psychol.* 5:e00518. doi: 10.3389/Fpsyg.2014.00518

Garcia, L., Asano, R. Y., Silveira, R., Hackney, A. C., Takito, M. Y., Kilpatrick, M. W., et al. (2022). Psychophysiological responses to self-selected exercise intensity over the menstrual cycle: a randomized crossover phase trial. *Res. Q. Exerc. Sport*, 1–9. doi: 10.1080/02701367.2022.2036316

Gerber, M., Minghetti, A., Beck, J., Zahner, L., and Donath, L. (2018). Sprint interval training and continuous aerobic exercise training have similar effects on exercise motivation and affective responses to exercise in patients with major depressive disorders: a randomized controlled trial. *Front. Psych.* 9:694. doi: 10.3389/Fpsyt.2018.00694

Gillen, J. B., Martin, B. J., Macinnis, M. J., Skelly, L. E., Tarnopolsky, M. A., and Gibala, M. J. (2016). Twelve weeks of sprint interval training improves indices of cardiometabolic health similar to traditional endurance training despite a five-fold lower exercise volume and time commitment. *PLoS One* 11:E0154075. doi: 10.1371/journal.pone.0154075

Godin, G. (2011). The Godin-Shephard leisure-time physical activity questionnaire. *Health Fitness J. Canada* 4, 18–22. doi: 10.14288/hfjc.v4i1.82

Guthold, R., Stevens, G. A., Riley, L. M., and Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1 9 million participants. *Lancet Glob. Health* 6, E1077–E1086. doi: 10.1016/S2214-109x(18)30357-7

Hamilton, M. (1967). Development of a psychiatric rating scale for primary depression. *Brit. Soc. Clin. Psychol.* 6, 278–296. doi: 10.1111/j.2044-8260.1967.tb00530.x

Hardeman, W., Houghton, J., Lane, K., Jones, A., and Naughton, F. (2019). A systematic review of just-in-time adaptive interventions (JITAIS) to promote physical activity. *Int. J. Behav. Nutr. Phys. Act.* 16:31. doi: 10.1186/S12966-019-0792-7

Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., et al. (2012). Evidence-based intervention in physical activity: lessons from around the world. *Lancet* 380, 272–281. doi: 10.1016/S0140-6736(12)60816-2

Henrich, J., Heine, S. J., and Norenzayan, A. (2010). Most people are not WEIRD. *Nature* 466:29. doi: 10.1038/466029a

Hernández-Nieto, R. (2002). *Contribuciones Al Análisis Estadístico*. Mérida, Venezuela: Universidad De Los Andes/Iesinfo.

Hoehner, C. M., Soares, J., Parra Perez, D., Ribeiro, I. C., Joshu, C. E., Pratt, M., et al. (2008). Physical activity interventions in Latin America: a systematic review. *Am. J. Prev. Med.* 34:E4. doi: 10.1016/j.amepre.2007.11.016

Hofmann, W., Baumeister, R. F., Forster, G., and Vohs, K. D. (2012a). Everyday temptations: an experience sampling study of desire, conflict, and self-control. *J. Pers. Soc. Psychol.* 102, 1318–1335. doi: 10.1037/A0026545

Hofmann, W., and Van Dillen, L. (2012). Desire: the new hot spot in self-control research. *Curr. Dir. Psychol. Sci.* 21, 317–322. doi: 10.1177/0963721412453587

Hofmann, W., Vohs, K. D., and Baumeister, R. F. (2012b). What people desire, feel conflicted about, and try to resist in everyday life. *Psychol. Sci.* 23, 582–588. doi: 10.1177/0956797612437426

Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., et al. (2017). Global participation in sport and leisure-time physical activities: a systematic review and meta-analysis. *Prev. Med.* 95, 14–25. doi: 10.1016/j.ypmed.2016.11.027

Hyde, E. T., Whitfield, G. P., Omura, J. D., Fulton, J. E., and Carlson, S. A. (2021). Trends in meeting the physical activity guidelines: muscle-strengthening alone and combined with aerobic activity, United States, 1998–2018. *J. Phys. Act. Health* 18, S37–S44. doi: 10.1123/Jpah.2021-0077

International Test Commission (2017). *The ITC guidelines for translating and adapting tests*. 2nd Edn.

Jaarsma, T., Strömberg, A., Ben Gal, T., Cameron, J., Driscoll, A., Duengen, H.-D., et al. (2013). Comparison of self-care behaviors of heart failure patients in 15 countries worldwide. *Patient Educ. Couns.* 92, 114–120. doi: 10.1016/j.pec.2013.02.017

Janata, P., Peterson, J., Ngan, C., Keum, B., Whiteside, H., and Ran, S. (2018). Psychological and musical factors underlying engagement with unfamiliar music. *Music. Percept.* 36, 175–200. doi: 10.1525/Mp.2018.36.2.175

Janata, P., Tomic, S. T., and Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *J. Exp. Psychol. Gen.* 141, 54–75. doi: 10.1037/A0024208

Jöreskog, K. G., and Moustaki, I. (2001). Factor analysis of ordinal variables: a comparison of three approaches. *Multivar. Behav. Res.* 36, 347–387. doi: 10.1207/S15327906347-387

Jöreskog, K. G., and Sörbom, D. (1996). *LISREL 8: User's Reference Guide* Scientific Software International.

Kavanagh, D. J., Andrade, J., and May, J. (2005). Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. *Psychol. Rev.* 112, 446–467. doi: 10.1037/0033-295x.112.2.446

Kelley, T. L. (1935). *Essential traits of mental life: The purposes and principles underlying the selection and measurement of independent mental factors together with computational tables*. Cambridge: Harvard University Press.

Khan, F. H., Ahlberg, C. D., Chow, C. A., Shah, D. R., and Koo, B. B. (2017). Iron, dopamine, genetics, and hormones in the pathophysiology of restless legs syndrome. *J. Neurol.* 264, 1634–1641. doi: 10.1007/S00415-017-8431-1

Kilpatrick, M., Hebert, E., and Bartholomew, J. (2005). College students' motivation for physical activity: differentiating men's and women's motives for sport participation and exercise. *J. Am. Coll. Health* 54, 87–94. doi: 10.3200/Jach.54.2.87-94

Koo, T. K., and Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr. Med.* 15, 155–163. doi: 10.1016/j.jcm.2016.02.012

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., et al. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 380, 219–229. doi: 10.1016/S0140-6736(12)61031-9

Lord, F. M. (1975). The 'Ability' scale in item characteristic curve theory. *Psychometrika* 40, 205–217. doi: 10.1007/BF02291567

Lorenzo-Seva, U. (2003). A factor simplicity index. *Psychometrika* 68, 49–60. doi: 10.1007/Bf02296652

Lorenzo-Seva, U., and Ferrando, P. J. (2013). Factor 9.2: A comprehensive program for fitting exploratory and semiconfirmatory factor analysis and IRT models. *Appl. Psychol. Measur.* 37, 497–498. doi: 10.1177/0146621613487794

Markus, H. R. (2016). What moves people to action? culture and motivation. *Curr. Opin. Psychol.* 8, 161–166. doi: 10.1016/j.copsyc.2015.10.028

Mayo, X., Iglesias-Soler, E., Liguori, G., Copeland, R. J., Clavel, I., Del Villar, F., et al. (2022). A modifiable factors-based model for detecting inactive individuals: are the European assessment tools fit for purpose? *Eur. J. Public Health* 32, 894–899. doi: 10.1093/eurpub/ckac116

Metcalfe, R. S., Williams, S., Fernandes, G. S., Astorino, T. A., Stork, M. J., Phillips, S. M., et al. (2022). Affecting effects on affect: The impact of protocol permutations on affective responses to sprint interval exercise; a systematic review and meta-analysis of pooled individual participant data. *Front. Sports Act. Living* 4:815555. doi: 10.3389/Fspor.2022.815555

Michie, S., Van Stralen, M. M., and West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement. Sci.* 6:42. doi: 10.1186/1748-5908-6-42

Miller, D. J., Freedson, P. S., and Kline, G. M. (1994). Comparison of activity levels using the Caltrac accelerometer and five questionnaires. *Med. Sci. Sports Exerc.* 26, 376–382.

Mislevy, R. J., and Bock, R. D. (1990). *BILOG 3: item analysis and test scoring with binary logistic models*. Mooresville: Scientific Software.

Neto, F., and Mullet, E. (2014). A prototype analysis of the Portuguese concept of Saudade. *J. Cross Cult. Psychol.* 45, 660–670. doi: 10.1177/0022022113518370

Noorani, I. (2017). Towards a unifying mechanism for cancelling movements. *Philos. Trans. R. Soc. B Biol. Sci.* 372:20160191. doi: 10.1098/Rstb.2016.0191

Noorani, I., and Carpenter, R. (2017). Not moving: the fundamental but neglected motor function. *Philos. Trans. R. Soc. B Biol. Sci.* 372:20160190. doi: 10.1098/Rstb.2016.0190

Pires, P., Filgueiras, A., Ribas, R., and Santana, C. (2013). Positive and negative affect schedule: psychometric properties for the Brazilian Portuguese version. *Span. J. Psychol.* 16:E58. doi: 10.1017/sjp.2013.60

Ponnada, A., Wang, S., Chu, D., Do, B., Dunton, G., and Intille, S. (2022). Intensive longitudinal data collection using microinteraction ecological momentary assessment: pilot and preliminary results. *Form. Res.* 6:E32772. doi: 10.2196/32772

Richardson, J. T. E. (2011). Eta squared and partial eta squared as measures of effect size in educational research. *Educ. Res. Rev.* 6, 135–147. doi: 10.1016/j.edurev.2010.12.001

Roelofs, K. (2017). Freeze for action: neurobiological mechanisms in animal and human freezing. *Philos. Trans. R. Soc. Biol. Sci.* 372:20160206. doi: 10.1098/Rstb.2016.0206

Ryan, R. M., and Deci, E. L. (2007). "Active human nature: self-determination theory and the promotion and maintenance of sport, exercise and health" in *Intrinsic motivation and self-determination in exercise and sport*. eds. M. S. Haggar and N. L. D. Chatzisarantis (Human Kinetics: Champaign, Il)

Samejima, F. (1969). Estimation of latent ability using a response pattern of graded scores. *Psychometr Monogr Suppl* 34, 1–97. doi: 10.1007/BF03372160

São-João, T. M., Rodrigues, R. C. M., Gallani, M. C. B. J., Miura, C. T. D. P., Domingues, G. D. B. L., and Godin, G. (2013). Adaptação cultural da versão brasileira do Godin-Shephard Leisure-Time Physical Activity Questionnaire. *Rev. Saude Publica* 47, 479–487. doi: 10.1590/S0034-8910.2013047003947

Seemiller, C., Grace, M., Dal Bo Campagnolo, P., Da Rosa, M., Alves, I., and Severo De Borba, G. (2019). How generation Z college students prefer to learn: a comparison of us and Brazil students. *J. Educ. Res. Pract.* 9:25. doi: 10.5590/jerap.2019.09.1.25

Sekely, A., Taylor, G. J., and Bagby, R. M. (2018). Developing a short version of the Toronto structured interview for alexithymia using item response theory. *Psychiatry Res.* 266, 218–227. doi: 10.1016/j.psychres.2018.03.002

Spence, J. C., and Lee, R. E. (2003). Toward a comprehensive model of physical activity. *Psychol. Sport Exerc.* 4, 7–24. doi: 10.1016/S1469-0292(02)00014-6

Spielberger, C. D., Gonzalez-Reigosa, F., Martinez-Urrutia, A., Natalicio, L. F., and Natalicio, D. S. (1971). The state-trait anxiety inventory. *Revista Interamericana De Psicología/Interamerican Journal Of Psychology* 5, 145–158. doi: 10.30849/rip/ijp.v5i3%20&%204.620

Stevens, C. J., Baldwin, A. S., Bryan, A. D., Conner, M., Rhodes, R. E., and Williams, D. M. (2020). Affective determinants of physical activity: a conceptual framework and narrative review. *Front. Psychol.* 11:568331. doi: 10.3389/Fpsyg.2020.568331

Stults-Kolehmainen, M. A. (2023). Humans have a basic physical and psychological need to move the body: physical activity as a primary drive. *Front. Psychol.* 14:1134049. doi: 10.3389/fpsyg.2023.1134049

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Boullosa, D., Janata, P., Koo, B. B., et al. (2022). Urges to move and other motivation states for physical activity in clinical and healthy populations: a scoping review protocol. *Front. Psychol.* 13:901271. doi: 10.3389/Fpsyg.2022.901272

Stults-Kolehmainen, M. A., Blacutt, M., Bartholomew, J. B., Gilson, T. A., Ash, G. I., Mckee, P. C., et al. (2020). Motivation states for physical activity and sedentary behavior: desire, urge, wanting and craving. *Front. Psychol.* 11:568390. doi: 10.3389/Fpsyg.2020.568390

Stults-Kolehmainen, M. A., Blacutt, M., Fogelman, N., Gilson, T. A., Stanforth, P. R., Divin, A. L., et al. (2021a). Measurement of motivation states for physical activity and sedentary behavior: development and validation of the CRAVE scale. *Front. Psychol.* 12:568286. doi: 10.3389/Fpsyg.2021.568286

Stults-Kolehmainen, M. A., Ciccolo, J. T., Bartholomew, J. B., Seifert, J., and Portman, R. S. (2013a). Age and gender-related changes in exercise motivation among highly active individuals. *Athlet Insight* 5, 45–63.

Stults-Kolehmainen, M. A., Filgueiras, A., and Blacutt, M. (2021b). Factors linked to changes in mental health outcomes among Brazilians in quarantine due to COVID-19. medRxiv [Preprint].

Stults-Kolehmainen, M. A., Gilson, T. A., and Abolt, C. J. (2013b). Feelings of acceptance and intimacy among teammates predict motivation in intercollegiate sport. *J. Sport Behav.* 36, 306–327.

Stults-Kolehmainen, M. A., Gilson, T. A., SantaBarbara, N., McKee, P. C., Sinha, R., Bartholomew, J. B., et al. (2023). Qualitative and quantitative evidence of motivation states for physical activity, exercise and being sedentary from university student focus groups. *Front Sports Active Living* 5:1033619. doi: 10.3389/fspor.2023.1033619

Stults-Kolehmainen, M. A., Lu, T., Ciccolo, J. T., Bartholomew, J. B., Brotnow, L., and Sinha, R. (2016). Higher chronic psychological stress is associated with blunted affective responses to strenuous resistance exercise: RPE, pleasure, pain. *Psychol. Sport Exerc.* 22, 27–36. doi: 10.1016/j.psychsport.2015.05.004

Stults-Kolehmainen, M., Malcolm, L. R., Diloreto, J., Gunnet-Shoval, K., and Rathbun, E. I. (2015). Psychological interventions for weight management: a primer for the allied health professional. *ACSMs Health Fit J* 19, 16–22. doi: 10.1249/Fit.0000000000000150

Stults-Kolehmainen, M. A., and Sinha, R. (2014). The effects of stress on physical activity and exercise. *Sports Med.* 44, 81–121. doi: 10.1007/S40279-013-0090-5

Taylor, I. M., Whiteley, S., and Ferguson, R. A. (2022). Disturbance of desire-goal motivational dynamics during different exercise intensity domains. *Scand. J. Med. Sci. Sports* 32, 798–806. doi: 10.1111/Sms.14129

Timmerman, M. E., and Lorenzo-Seva, U. (2011). Dimensionality assessment of ordered polytomous items with parallel analysis. *Psychol. Methods* 16:209. doi: 10.1037/A0023353

Trizano-Hermosilla, I., and Alvarado, J. M. (2016). Best alternatives to Cronbach's alpha reliability in realistic conditions: congeneric and asymmetrical measurements. *Front. Psychol.* 7:e00769. doi: 10.3389/Fpsyg.2016.00769

Ussery, E. N., Whitfield, G. P., Fulton, J. E., Galuska, D. A., Matthews, C. E., Katzmarzyk, P. T., et al. (2021). Trends in self-reported sitting time by physical activity levels among US adults, NHANES 2007/2008–2017/2018. *J. Phys. Act. Health* 18, S74–S83. doi: 10.1123/Jpah.2021-0221

Vignola, R. C. B., and Tucci, A. M. (2014). Adaptation and validation of the depression, anxiety and stress scale (DASS) to Brazilian Portuguese. *J. Affect. Disord.* 155, 104–109. doi: 10.1016/j.jad.2013.10.031

Wang, X., Cai, Y., and Tu, D. (2022). The application of item response theory in developing and validating a shortened version of the Rotterdam emotional intelligence scale. *Curr. Psychol.* doi: 10.1007/S12144-022-03329-Y

Williams, D. M. (2023). A meta-theoretical framework for organizing and integrating theory and research on motivation for health-related behavior. *Front. Psychol.* 14:1130813. doi: 10.3389/Fpsyg.2023.1130813

Williams, D. M., and Bohlen, L. C. (2019). "Motivation for exercise: reflective desire versus hedonic dread" in *APA Handbook of Sport and Exercise Psychology, Volume 2: Exercise Psychology* (Washington: American Psychological Association)

Williams, D. M., Rhodes, R. E., and Conner, M. T. (2019). Conceptualizing and intervening on affective determinants of health behaviour. *Psychol. Health* 34, 1267–1281. doi: 10.1080/08870446.2019.1675659

Wright, B. (1993). Equitable test equating. *Rasch Meas. Trans.* 7, 298–299.

Wu, Y., Levis, B., Sun, Y., Krishnan, A., He, C., Riehm, K. E., et al. (2020). Probability of major depression diagnostic classification based on the SCID, CIDI and MINI diagnostic interviews controlling for hospital anxiety and depression scale – depression subscale scores: an individual participant data meta-analysis of 73 primary studies. *J. Psychosom. Res.* 129:109892. doi: 10.1016/j.jpsychores.2019.109892