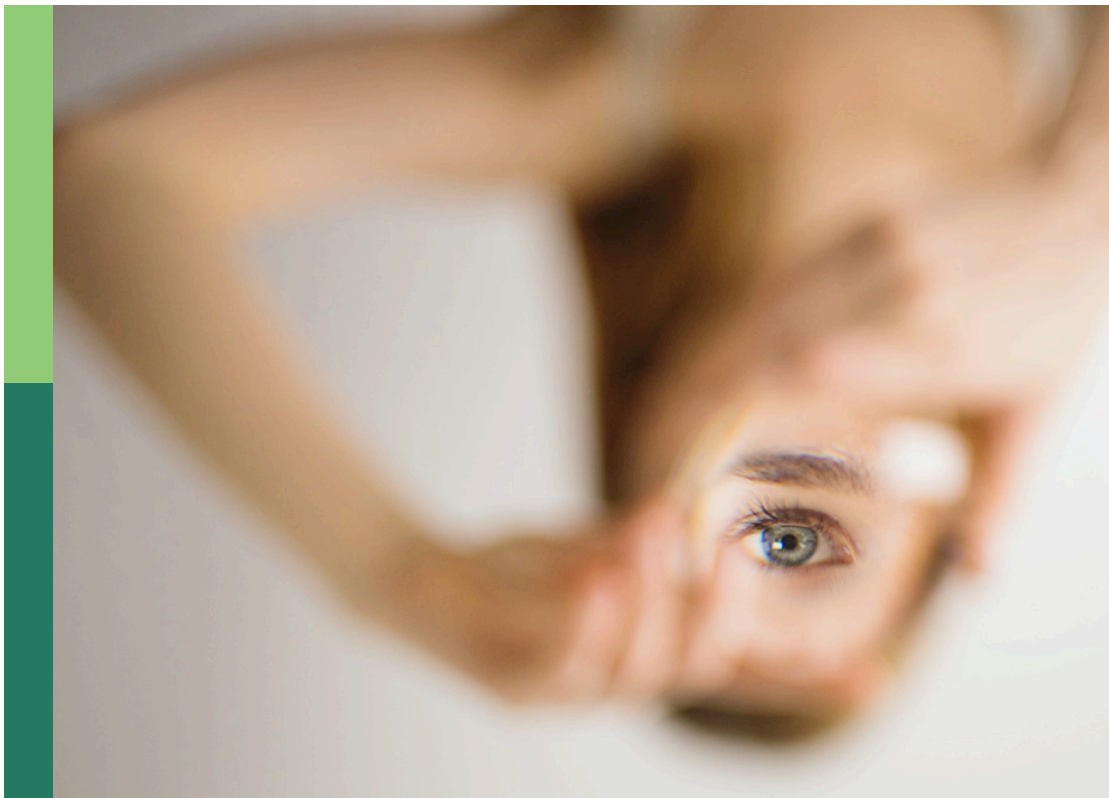
frontiers | Research Topics

Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports

Edited by
Chong Chen, Yasuhiro Mochizuki and Filipe Manuel Clemente

Published in
Frontiers in Psychology
Frontiers in Public Health
Frontiers in Psychiatry



ISSN 1664-8714
ISBN 978-2-8325-4663-5
DOI 10.3389/978-2-8325-4663-5

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports

Topic editors

Chong Chen — Yamaguchi University Graduate School of Medicine, Japan

Yasuhiro Mochizuki — Waseda University, Japan

Filipe Manuel Clemente — Polytechnic Institute of Viana do Castelo, Portugal

Citation

Chen, C., Mochizuki, Y., Clemente, F. M., eds. (2024). *Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-4663-5

Table of contents

frontiers | Frontiers in Psychology

TYPE Editorial
PUBLISHED 13 March 2024
DOI 10.3389/fpsyg.2024.1383947

OPEN ACCESS

EDITED AND REVIEWED BY
Guy Cheron,
Université Libre de Bruxelles, Belgium

*CORRESPONDENCE
Chong Chen
✉ cchen@yamaguchi-u.ac.jp

RECEIVED 08 February 2024
ACCEPTED 27 February 2024
PUBLISHED 13 March 2024

CITATION
Chen C, Mochizuki Y and Clemente FM (2024) Editorial: Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports.
Front. Psychol. 15:1383947.
doi: 10.3389/fpsyg.2024.1383947

Editorial: Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports

Chong Chen[1]*, Yasuhiro Mochizuki[2] and Filipe Manuel Clemente[3,4,5]

[1]Division of Neuropsychiatry, Department of Neuroscience, Yamaguchi University Graduate School of Medicine, Ube, Japan, [2]Center for Data Science, Waseda University, Tokyo, Japan, [3]Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, Viana do Castelo, Portugal, [4]Gdansk University of Physical Education and Sport, Gdańsk, Poland, [5]Sport Physical Activity and Health Research and Innovation Center, Viana do Castelo, Portugal

KEYWORDS

aerobic exercise, resistance training, strength training, fitness, executive functions, emotional wellbeing, mental health, polymorphism

Editorial on the Research Topic
Advances in the understanding of the affective and cognitive effects of physical activity, exercise, and sports

Recent research underscores the positive impact of physical activities, exercises, and sports on enhancing cognitive and emotional wellbeing. Improvements have been noted in areas such as attention (De Greeff et al., 2018), executive functions (Hoffmann et al., 2021; Huang et al., 2022), the process of memory and learning (Wanner et al., 2020; Hoffmann et al., 2021), creativity (Rominger et al., 2022; Chen, 2024), the ability to withstand stress (Arida and Teixeira-Machado, 2021; Toth et al., 2023), and mental health (Chen et al., 2017; Chen and Nakagawa, 2023a). Regular participation in physical activities has been linked to a lower incidence of major neurological and psychiatric conditions, including dementia (Chen and Nakagawa, 2023b), major depressive disorders (Harvey et al., 2018), and anxiety disorders (Svensson et al., 2021).

Despite these well-documented benefits, recent research points to unresolved queries (Chen et al., 2022), notably the determination of the optimal type, intensity, and duration of physical activities that maximize benefits across different demographic groups. This gap calls for a deeper dive into individual differences that have been somewhat neglected in past studies. Furthermore, there is an urgent call for the development of detailed strategies to encourage physical activity, a domain still in need of refinement. This Research Topic, through its 18 articles, seeks to address these critical questions, aiming to deepen our knowledge of the cognitive and emotional advantages offered by physical activity.

A focal point of this Research Topic is the investigation into how different aspects of exercise, including its frequency, duration, intensity, and type, influence its effectiveness. One notable contribution is from Lin and Gao, who conducted a meta-analysis of nine randomized controlled trials among college students. Their findings indicate that physical activity interventions significantly reduce anxiety symptoms, demonstrating an effect size of −0.55 in terms of standard mean difference. This analysis highlights that the benefits of exercise on anxiety might be influenced by the exercise's nature, with aerobic exercise

and yoga showing effectiveness, whereas resistance training did not yield significant improvements. Furthermore, interventions were notably effective when conducted at least three times weekly, lasting longer than 8 weeks, and at moderate to high intensities. This data aligns with the theory that more vigorous exercise could offer greater mental health and cognitive benefits (Nakagawa et al., 2020), a notion further supported by a study from Gilbert et al. This latter study, although not finding significant cognitive benefits from a single 60-min games-based physical education lesson over a regular academic lesson in adolescents, did observe enhanced working memory in those who engaged in more moderate-to-vigorous physical activity.

These insights, however, bring to light the practical challenges in applying them within clinical settings. Patients with depressive disorders—who often experience concurrent anxiety symptoms (Chen, 2022) and cognitive deficits (Chen et al., 2015)—may have lower physical capabilities and motivation. This dilemma has led to the development of lower-intensity exercise therapies aimed at enhancing participation and satisfaction among patients (Sakai et al., 2021). A potentially optimal approach may involve initiating treatment at lower intensities and incrementally increasing them as patients' physical fitness and motivation improve.

Further expanding on these findings, Liu T. et al.'s cross-sectional survey involving over 67,000 school-age children and adolescents demonstrates that even minimal engagement in sports, as infrequent as 1–3 times a month, can enhance subjective wellbeing. This finding is echoed in the work of Bian and Xiang, who, through a longitudinal study of 10,000 adults, observed that regular participation in sports and exercise clubs, even on a weekly or monthly basis, correlates with a reduced likelihood of depressive symptoms 4 years later. These studies suggest that the threshold of physical activity required for preventing future mental health issues may be lower than what is needed to address existing psychiatric symptoms, as demonstrated in the meta-analysis by Lin and Gao.

Additionally, Liu G. et al. sought to determine the optimal exercise duration for academic performance among ∼18,000 Chinese junior high school students. Their research revealed an inverted-U shaped correlation between weekend physical activity and academic achievement, with a noted sex difference in the optimal duration of exercise-−2 h for males and 1 h for females. The inverted-U shape finding aligns with another recent study by Shimura et al. (2023), which examined the association between the total duration of weekly physical activity and mental health outcomes. Moreover, the gender-differentiated impact in the above study is further explored by Wu et al., who found significant associations between physical activity levels and depressive symptoms in males but not in females.

Jin et al.'s study enriches this Research Topic by comparing visual attention among basketball players, swimmers, and non-athletes, revealing that basketball players exhibit superior visual tracking accuracy. This highlights the advantages of open-skill sports, which require constant adaptation to changing environments, in enhancing visual attention and underscores the broader cognitive benefits of specific types of physical activities.

The Research Topic also delves into the specific benefits of physical activity across various populations and disciplines. For instance, Wochyński et al. demonstrated improved physical fitness and cognitive functions in Polish male cadet pilots following 6 months of cadet aviation practice. Moreover, Alhumaid and Said highlighted the positive correlation between physical activity and self-esteem levels in Saudi individuals with physical disabilities.

However, not all studies showcased physical activity's universal benefits. Morava et al. indicated that acute stress's impact on cognitive flexibility might not be alleviated by a single session of vigorous cycling, contrasting with previous evidence that, under stress-free conditions, vigorous cycling may enhance cognitive flexibility (Aga et al., 2021). Moreover, Burns et al. suggested the importance of considering covariates when assessing physical activity's effects on mental health.

The Research Topic also addresses athlete performance enhancement strategies, with Selmi et al. emphasizing mood monitoring in soccer players and Aras et al. investigating the efficacy of mindfulness practices in aiding recovery among female basketball players, albeit without significant findings.

Together, these articles offer a comprehensive perspective on the multifaceted influence of physical activity, suggesting the importance of tailored exercise regimens to optimize affective and cognitive outcomes across diverse populations and settings.

Building on the diverse insights provided by these studies, the Research Topic delves into understanding the factors that influence physical activity behaviors, adding a crucial layer to the narrative. Ma et al. explore how exercise intention and the feelings induced by exercise, such as relaxation, correlate with actual exercise behaviors, noting the moderating role of personality openness in strengthening this relationship. This observation highlights the critical need to consider the emotional responses or mood shifts triggered by exercise when prescribing exercise interventions. Beyond the Exercise-induced Feeling Inventory (Gauvin and Rejeski, 1993) utilized by the researchers, recent concise measures like the Chen-HAgiwara Mood Test (CHAMT, Chen et al., 2024) emerge as promising alternatives. The CHAMT, grounded in the two-dimensional valence-arousal theory of affect and utilizing visual analog scales for a more intuitive assessment than traditional Likert scales, represents a forward-thinking approach to capture the psychological impacts of physical activity (Aga et al., 2021; Matsumoto et al., 2022; Kawashima et al., 2024).

Furthermore, Sheng et al. identify exercise self-efficacy and peer support as key drivers of physical activity levels, while Zhang et al. highlight the pivotal role of the family environment in encouraging physical activity, introducing a novel scale for its assessment. Emphasizing exercise as a family activity, this latter study is in line with the proposal that communal exercise can enhancing bonding, improve adherence to exercise routines and boost overall family wellbeing (Chen, 2017; Koga et al., 2023). This approach promotes incorporating physical activity into family life, underlining its potential to not In addition, Martins et al., in their meta-analysis, highlight the positive correlation between pet ownership and increased physical activity (with an effect size of Cohen's d being 0.55), and Bayraktar et al. suggest genetic factors, such as the rs1800496 polymorphism in the ANKK1 gene, may influence competitive sports involvement.

These studies collectively underscore the complexity of exercise behavior, emphasizing the interplay of psychological, social,

environmental, and genetic factors in promoting physical activity. This comprehensive approach not only enriches our understanding of the multifaceted role of physical activity in enhancing mental health, cognitive functions, and academic performance but also highlights the importance of individualized approaches to exercise prescription, catering to the diverse needs and influences affecting different populations.

Author contributions

CC: Writing – original draft, Writing – review & editing. YM: Writing – review & editing. FC: Writing – review & editing.

Funding

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

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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

References

Aga, K., Inamura, M., Chen, C., Hagiwara, K., Yamashita, R., Hirotsu, M., et al. (2021). The effect of acute aerobic exercise on divergent and convergent thinking and its influence by mood. *Brain Sci.* 11, 546. doi: 10.3390/brainsci11050546

Arida, R. M., and Teixeira-Machado, L. (2021). The contribution of physical exercise to brain resilience. *Front. Behav. Neurosci.* 279, 626769. doi: 10.3389/fnbeh.2020.626769

Chen, C. (2017). *Plato's Insight: How Physical Exercise Boosts Mental Excellence*. London: Brain & Life Publishing.

Chen, C. (2022). Recent advances in the study of the comorbidity of depressive and anxiety disorders. *Adv. Clini. Exp. Med.* 31, 355–358. doi: 10.17219/acem/147441

Chen, C. (2024). Exploring the impact of acute physical activity on creative thinking: a comprehensive narrative review with a focus on activity type and intensity. *Discover Psychol.* 4, 1–19. doi: 10.1007/s44202-024-00114-9

Chen, C., Hagiwara, K., and Nakagawa, S. (2024). Introducing the Chen-HAgiwara Mood Test (CHAMT): a novel, brief scale developed in Japanese populations for assessing mood variations. *Asian J. Psychiatr.* 91, 103941. doi: 10.1016/j.ajp.2024.103941

Chen, C., and Nakagawa, S. (2023a). Recent advances in the study of the neurobiological mechanisms behind the effects of physical activity on mood, resilience and emotional disorders. *Adv. Clini. Exp. Med.* 32, 937–42. doi: 10.17219/acem/171565

Chen, C., and Nakagawa, S. (2023b). Physical activity for cognitive health promotion: an overview of the underlying neurobiological mechanisms. *Ageing Res. Rev.* 86, 101868. doi: 10.1016/j.arr.2023.101868

Chen, C., Nakagawa, S., An, Y., Ito, K., Kitaichi, Y., and Kusumi, I. (2017). The exercise-glucocorticoid paradox: how exercise is beneficial to cognition, mood, and the brain while increasing glucocorticoid levels. *Front. Neuroendocrinol.* 44, 83–102. doi: 10.1016/j.yfrne.2016.12.001

Chen, C., Takahashi, T., Nakagawa, S., Inoue, T., and Kusumi, I. (2015). Reinforcement learning in depression: a review of computational research. *Neurosci. Biobehav. Rev.* 55, 247–267. doi: 10.1016/j.neubiorev.2015.05.005

Chen, C., Yau, S. Y., Clemente, F. M., and Ishihara, T. (2022). Editorial: The effects of physical activity and exercise on cognitive and affective wellbeing. *Front. Behav. Neurosci.*, 16, 1047758. doi: 10.3389/fnbeh.2022.1047758

De Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., and Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *J. Sci. Med. Sport* 21, 501–507. doi: 10.1016/j.jsams.2017.09.595

Gauvin, L., and Rejeski, W. J. (1993). The exercise-induced feeling inventory: Development and initial validation. *J. Sport Exerc. Psychol.* 15, 403–423. doi: 10.1123/jsep.15.4.403

Harvey, S. B., Øverland, S., Hatch, S. L., Wessely, S., Mykletun, A., and Hotopf, M. (2018). Exercise and the prevention of depression: results of the HUNT cohort study. *Am. J. Psychiatry*, 175, 28–36. doi: 10.1176/appi.ajp.2017.16111223

Hoffmann, C. M., Petrov, M. E., and Lee, R. E. (2021). Aerobic physical activity to improve memory and executive function in sedentary adults without cognitive impairment: a systematic review and meta-analysis. *Prevent. Med. Rep.* 23, 101496. doi: 10.1016/j.pmedr.2021.101496

Huang, T. Y., Chen, F. T., Li, R. H., Hillman, C. H., Cline, T. L., Chu, C. H., et al. (2022). Effects of acute resistance exercise on executive function: a systematic review of the moderating role of intensity and executive function domain. *Sports Med.-Open* 8, 1–13. doi: 10.1186/s40798-022-00527-7

Kawashima, C., Chen, C., Hagiwara, K., Mizumoto, T., Watarai, M., Koga, T., et al. (2024). Evaluating the impact of a short bout of stair-climbing on creative thinking in a between-subjects pretest posttest comparison study. *Sci. Rep.* 14, 176. doi: 10.1038/s41598-023-50282-2

Koga, T., Okubo, R., Chen, C., Hagiwara, K., Mizumoto, T., Nakagawa, S., et al. (2023). Associations of parent-child exercise with family relations and parental mental health during the COVID-19 pandemic. *J. Affect. Disord.* 324, 551–558. doi: 10.1016/j.jad.2023.01.001

Matsumoto, K., Chen, C., Hagiwara, K., Shimizu, N., Hirotsu, M., Oda, Y., et al. (2022). The effect of brief stair-climbing on divergent and convergent thinking. *Front. Behav. Neurosci.* 15, 834097. doi: 10.3389/fnbeh.2021.834097

Nakagawa, T., Koan, I., Chen, C., Matsubara, T., Hagiwara, K., Lei, H., et al. (2020). Regular moderate-to vigorous-intensity physical activity rather than walking is associated with enhanced cognitive functions and mental health in young adults. *Int. J. Environ. Res. Public Health* 17, 614. doi: 10.3390/ijerph17020614

Rominger, C., Schneider, M., Fink, A., Tran, U. S., Perchtold-Stefan, C. M., and Schwerdtfeger, A. R. (2022). Acute and chronic physical activity increases creative ideation performance: a systematic review and multilevel meta-analysis. *Sports Med.-Open* 8, 1–17. doi: 10.1186/s40798-022-00444-9

Sakai, Y., Chen, C., Toyomaki, A., Hashimoto, N., Kitagawa, K., Inoue, T., et al. (2021). A brief, individualized exercise program at intensities below the ventilatory threshold exerts therapeutic effects for depression: a pilot study. *Front. Behav. Neurosci.* 15, 787688. doi: 10.3389/fnbeh.2021.787688

Shimura, A., Masuya, J., Yokoi, K., Morishita, C., Kikkawa, M., Nakajima, K., et al. (2023). Too much is too little: estimating the optimal physical activity level for a healthy mental state. *Front. Psychol.* 13, 1044988. doi: 10.3389/fpsyg.2022.1044988

Svensson, M., Brundin, L., Erhardt, S., Hållmarker, U., James, S., and Deierborg, T. (2021). Physical activity is associated with lower long-term incidence of anxiety in a population-based, large-scale study. *Front. Psychiatry* 12, 714014. doi: 10.3389/fpsyt.2021.714014

Toth, E. E., Ihász, F., Ruíz-Barquín, R., and Szabo, A. (2023). Physical activity and psychological resilience in older adults: a systematic review of the literature. *J. Aging Phys. Act.* 1, 1–11. doi: 10.1123/japa.2022-0427

Wanner, P., Cheng, F. H., and Steib, S. (2020). Effects of acute cardiovascular exercise on motor memory encoding and consolidation: a systematic review with meta-analysis. *Neurosci. Biobehav. Rev.* 116, 365–381. doi: 10.1016/j.neubiorev.2020.06.018

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 19 December 2022
DOI 10.3389/fpsyg.2022.1050918

OPEN ACCESS

EDITED BY
Yasuhiro Mochizuki,
Waseda University,
Japan

REVIEWED BY
Farhan Mirza,
University of Management and Technology Sialkot, Pakistan
Kelei Guo,
Zhaoqing University,
China

*CORRESPONDENCE
Hua-Rui Jia
jhr201661@163.com

†These authors have contributed equally to this work

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

RECEIVED 22 September 2022
ACCEPTED 25 November 2022
PUBLISHED 19 December 2022

CITATION
Ma Q-S, Yao S-J and Jia H-R (2022) The effect of exercise intention on exercise behavior in the post-epidemic era: The moderator role of openness personality and the mediated role of exercise-induced feeling.
Front. Psychol. 13:1050918.
doi: 10.3389/fpsyg.2022.1050918

The effect of exercise intention on exercise behavior in the post-epidemic era: The moderator role of openness personality and the mediated role of exercise-induced feeling

Qi-Shuai Ma[1†], Shu-Jun Yao[2†] and Hua-Rui Jia[3*]

[1]School of Physical Education, Huaibei Normal University, Huaibei, China, [2]Department of Physical Education, Guang Dong Technology College, Zhaoqing, China, [3]Department of Recreational Sports, Mokpo National University, Muan, South Korea

Objective: Based on the theory of planned behavior, this study introduced personality traits and exercise-induced feelings and other third variables, aiming to explore the mechanism of personality traits and exercise-induced feelings between exercise intention and exercise behavior, and explore the internal mechanism of promoting exercise behavior of junior high school students.

Methods: This research adopts the Exercise Intention Questionnaire, Simple Big Five Personality Scale, Exercise-induced Feeling Inventory and Exercise Rating Scale, from the three cities of Anhui province 1,166 junior high school students selected from the group psychological measurement, and uses the SPSS23.0 and Process plug-in exercise intention in exercise behavior analysis of the direct and indirect effect.

Results: The results showed that: (1) Exercise intention significantly positively predicted exercise behavior (β=0.265, t=4.261, p<0.01). (2) The moderating effect of openness personality between exercise intention and exercise behavior was significant (β =0.093, t=4.431, p<0.01). (3) Exercise-induced feelings has a significant mediating effect on the relationship between exercise intention and exercise behavior regulated by openness personality.

Conclusion: Exercise intention can effectively predict exercise behavior, and the prediction level is affected by openness personality, and the moderating effect of openness personality is partially realized through the mediating variable of exercise-induced feelings.

KEYWORDS

post-epidemic era, exercise behavior, exercise intention, openness personality, exercise-induced feeling

Introduction

The COVID-19, a public health emergency, has greatly affected the behavior of Chinese junior high school students. Students stay indoors, and the courses are changed to "online" teaching, especially physical education, which can not meet the exercise needs of junior high school students and greatly affect their physical and mental health. With the arrival of the post epidemic era, the school has organized students to return to school on a large scale, face-to-face classes have gradually returned to the normal track, and physical education has also returned to the playground. However, the loss of physical and mental health caused to junior high school students during the epidemic is difficult to recover. Therefore, how to improve the exercise behavior of students in the post epidemic era has become a hot topic in exercise psychology (Huang et al., 2021).

The social anxiety brought by the epidemic has greatly affected the mental health of junior high school students. Physical exercise is recognized as the most effective way to "reduce stress," and a large number of studies have confirmed that moderate physical exercise can help improve the cognitive ability of junior high school students (Wen, 2015). Improve their academic performance (Grigolava et al., 2021), improve their interpersonal skills (Chen et al., 2020; Montse and Claudio, 2020), cultivate their self-esteem and self-confidence (Pan et al., 2022), and promote the development of their social adaptability (Wan et al., 2021). Therefore, it is an important significance to explore the relationship between exercise behavior and its influencing factors. Nowadays, the research on the influencing factors of exercise behavior has gradually moved toward theorization and modeling. There are many psychological theories applied to the study of exercise behavior, such as self-determination theory, expected value theory, stage development theory and planned behavior theory, of which the theory of planned behavior (TPB) is the most widely used. A large number of studies have explored the intention-behavior relationship in adolescents on the basis of the TPB, but current research cannot adequately explain the mechanisms by which intention-behavior occurs and it is unclear how to bridge the gap between intention and behavior (Xiang, 2016), in addition to which few studies have been conducted on the exercise behavior of secondary school students in the post-epidemic period. Based on the TPB model proposed by Ajzen (2011), this paper explores the relationship between exercise behavior and its influencing factors, and provides empirical evidence for improving exercise behavior of junior high school students in the "post epidemic period."

Exercise intention and exercise behavior

Exercise behavior refers to sports activities aimed at developing body, improving health, strengthening physique, regulating spirit, enriching cultural life and controlling leisure time. The theory of planned behavior is one of the most important theoretical models in the field of sports (Hohmann and Garza, 2022). The theory of planned behavior holds that human behavior is the result of deliberate planning. Therefore, exercise intention can predict the generation of exercise behavior, and a large number of studies have confirmed that exercise intention is an effective predictor of exercise behavior (Chen et al., 2022; Teixeira et al., 2022; Zhang et al., 2022). Hou et al. (2022) confirmed in a study of 242 college students in China that exercise intention can effectively predict exercise behavior. Gu et al. (2022) found that exercise attitude was a significant predictor of exercise behavior based on TPA during COVID-19. Liu (2022) used meta-analysis to find that exercise intention influenced exercise behavior to some extent, but many studies have exaggerated the effect of exercise intention in predicting exercise behavior. Therefore, we propose the following hypotheses:

> *H1:* Exercise intention of junior high school students can positively predict exercise behavior.

At present, relevant scholars who study the theory of planned behavior believe that the third variable often affects exercise intention in the process of affecting exercise behavior, that is, under different conditions, the degree of exercise intention affecting exercise behavior will change (Liu, 2019). In order to better promote the formation of physical exercise behavior of junior high school students, it has important research value to study how exercise intention affects exercise behavior.

The moderator role of personality

Junior high school is the golden age of individual development, and it will also face various great challenges. With the arrival of adolescence, there will be rapid changes both physically and psychologically (Yang and Ma, 2014; Heilmann et al., 2021). Personality is one of the important factors that affect how individuals adapt to these changes after entering junior high school. Since Goldberg (1990) discovered the five personality factors through factor analysis, psychologists have invested a lot of energy in exploring the five personality factors (Ka et al., 2021). It is found that having different personalities will have a significant impact on individual psychological and behavioral development (Wilks et al., 2020; Pilch et al., 2021). Van den Akker et al. (2021) found that as adolescents enter puberty, their levels of responsibility, extraversion and openness personality traits will temporarily decline, and their neuroticism personality levels will increase. In fact, this represents a decline in individual personality maturity. At the same time, a study showed that junior high school students' exercise behavior was significantly reduced in adolescence (Cao et al., 2011). So, will personality have a significant impact on exercise behavior? Bandura's (2004) theory of interactive personality in behaviorism holds that behavior is the result of the combination of personality traits and situations, and situations have strong control over behavior. When predicting

behavior, the focus should be on the specific stimulus conditions that can be observed, not on the intrinsic characteristics. Individuals are the active constructors of situations, and situations are the results of interaction between social individuals and the objective environment. That is to say, behavior will be affected by the interaction between individuals and situations. Behavior is often the result of the interaction between individual cognition and the situation, and any individual has its distinctive personality traits. Therefore, under different stimulus conditions (personality traits), the execution of intention will be strengthened or weakened. Research shows that during the COVID-19 epidemic, long-term closure of schools will have harmful mental health consequences for teenagers (Kim et al., 2021). And individuals with higher openness personality have a higher degree of deterioration of mental health (Proto and Zhang, 2021). The characteristic of openness personality is imaginative creative and curious, and closed management during the epidemic may have a greater impact on individuals with openness personality. Research shows that a high level of openness personality and extraversion personality will be more conducive to individuals to put into action and enhance their execution of exercise intentions (Han et al., 2021). And the low-level openness personality does not care about his own ideas and is unwilling to take action (Nave et al., 2016). Therefore, we speculate that personality may affect the extent to which an individual's intention predicts behavior. Based on this, we propose the following hypotheses:

> *H2:* Personality plays a moderating role in the relationship between exercise intention and exercise behavior of junior high school students.

The mediated role of exercise-induced feeling

Feeling usually refers to people's attitude toward and experience of objective things and corresponding behavioral reactions, and is considered as a psychological activity when individuals carry out activities (Heintzelman and King, 2014). Previous studies on exercise intention and exercise behavior mainly focused on their relationship, but few focused on the specific mechanism of the effect of exercise intention on junior high school students' exercise behavior (Mao and Guo, 2013). According to the triadic reciprocal determinism (Bandura, 1989), behavior will be affected by the interaction between environment, thinking, cognition and other individual subjective factors. Research has confirmed that exercise intention will be affected by the individual's surroundings (Guo et al., 2022). The difference in emotional benefits between individuals mainly comes from the difference in cognition between individuals, that is, behavior may be affected by both intention and feeling benefits (Liu and Wang, 2020). Research shows that low level of individual intention will inhibit the generation of positive emotions, and bad emotional experience will reduce the enthusiasm of individuals to engage in activities and discourage enthusiasm (Zhang et al., 2014). A high level of exercise intention will significantly affect the development of exercise feelings. The stronger the intention is, the easier it is for individuals to experience positive feelings (Zhang and Mao, 2016). In addition, the high level of feeling benefits of exercise is also the source of promoting individual exercise behavior (Huellemann et al., 2021). Because the exercise-induced feeling is the result of individuals' high recognition of exercise intentions, it has become the most direct motivation for junior high school students to actively participate in exercise activities, and can help them develop good exercise habits. At the same time, junior high school students who have bad feeling benefits of exercise are prone to the phenomenon of inactivity. It can be inferred that while improving the level of exercise intention of junior high school students, it may also improve their cognition of physical exercise, meet their own exercise needs and interpersonal needs, promote their participation in exercise activities to bring more feeling benefits, and thus affect the behavioral results. Thus, we propose the following hypotheses:

> *H3:* Exercise-induced feeling plays a mediated role in the relationship between exercise intention and exercise behavior of junior high school students.

Does the mediating effect of exercise-induced feeling still exist in the path of personality traits and exercise behavior? Feeling is not only the core factor of personality formation, but also related to all aspects of social life, playing a pivotal psychological role in coordinating various elements of social life (Damasio, 2021). According to embodied emotion theory, feeling and body change are unified. In the process of emotional information processing, they are an interactive whole. The generation of feeling is the result of the interaction between body, mind and the external world (Burkitt, 2021). Under the framework of embodied cognition, cognition and feeling work together, making it easier for human beings to adapt to the challenge of evolution (Xu and Zhang, 2021). Good ability to regulate feeling can promote the development of physical and mental health, while cognition can promote individual feeling regulation, and exercise intention comes from individual cognition of their own needs (Hermann et al., 2021). Regular physical exercise can promote the individual's ability to adjust feelings (Perchtold-Stefan et al., 2020). Previous studies have found that exercise-induced feeling has a significant positive predictive effect on personality and motivation (Zhu and Dong, 2016). Self-determination theory believes that personality traits have an important impact on emotion or emotion regulation strategies (Sheldon and Prentice, 2019). Exercise-induced feeling is a cognitive factor, and the change of psychological environment can significantly affect emotion. Halevy et al. (2019) comprehensively investigated the relationship between feeling, psychological environment factors and behavior results, and found that feeling can affect behavior results by influencing

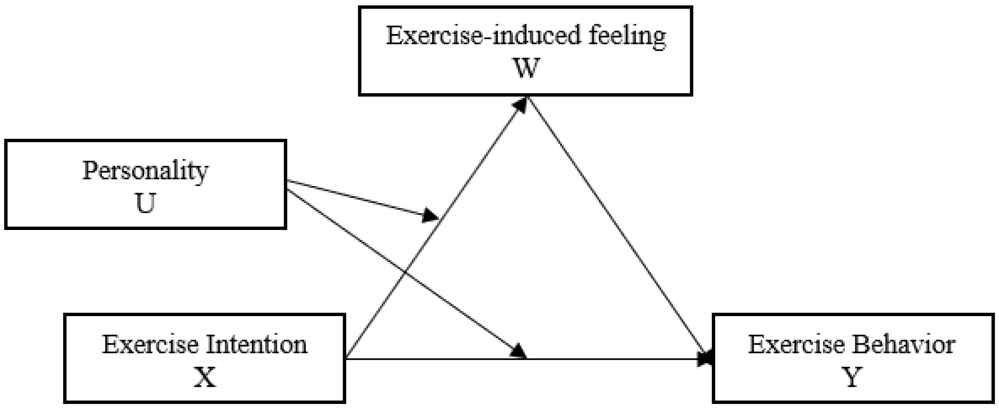


FIGURE 1
Hypothetical model.

TABLE 1 Differences in gender.

Variable	Gender	Number (%)	*M*	SD	*t*	*p*
EI	Male	581(49.83)	6.32	1.25	7.372	<0.001
	Female	585(50.17)	5.79	1.23		
EIF	Male	581(49.83)	3.91	0.43	1.475	0.119
	Female	585(50.17)	3.82	0.40		
Extraversion	Male	581(49.83)	2.77	0.25	−2.394	0.038
	Female	585(50.17)	2.89	0.27		
Agreeableness	Male	581(49.83)	3.29	0.51	1.576	0.095
	Female	585(50.17)	3.27	0.43		
Conscientiousness	Male	581(49.83)	3.59	0.44	5.469	<0.001
	Female	585(50.17)	3.17	0.39		
Neuroticism	Male	581(49.83)	3.53	0.57	0.713	0.261
	Female	585(50.17)	3.52	0.51		
Openness	Male	581(49.83)	3.61	0.42	0.841	0.219
	Female	585(50.17)	3.57	0.61		
EB	Male	581(49.83)	22.71	7.54	8.816	<0.001
	Female	585(50.17)	18.74	6.55		

EI, exercise intention; EIF, exercise-induced feeling; EB, exercise behavior.

psychological environment. Kim (2022) found that the openness personality and extraversion personality in personality traits can improve junior high school students' motivation during exercise, meet the needs of students' autonomy, interpersonal relationship and ability development, and thus enhance their exercise induced emotions. Thus, we propose the following hypotheses:

> *H4:* The moderating effect of personality traits on exercise intention and exercise behavior may be realized through the mediating effect of exercise-induced feeling.

To sum up, this study built a conceptual model of exercise intention and exercise impact mechanism (Figure 1).

Materials and methods

Procedure and participants

From September to October 2021, a cross-sectional survey was conducted by using the convenience sampling method in Anhui Province. This study selected one junior high school in urban and rural areas in the north, middle and south of Anhui Province (6 junior high schools in total). Two classes will be randomly selected from each grade of each junior high school (36 classes in total), and 1,355 questionnaires will be issued. The students were tested in the classroom, and the main testers were all psychology students who had received professional training. The test was approved by the school leaders, head teachers and participants, and all questionnaire were completed within 10 min. After the questionnaire was collected, the invalid questionnaires caused by regular answers and missing data were removed, and 1,166 valid questionnaires were recovered, with a recovery rate of 86.05%. The participants age ranging from 11 to 17 years (M_{age} = 14.51, SD_{age} = 0.66), including 581 boys and 585 girls. There are 391 students in Grade One, 389 students in Grade Two and 386 students in Grade Three.

The study complied with the principles of the Declaration of Helsinki, and it is supported and approved by the Institutional Review Board of Huaibei Normal University. Parents or guardians of all participants signed informed consent. The informed consent described the purpose and process of the study, the method used and publication plans. It also included confidentiality assurance, the principles for voluntary participation and included contact information to the researcher and organization behind the study.

Demographic characteristics of the study sample

As shown in Table 1, of the total sample, 49.83% (581) were boys, and 50.17% (585) were girls. The exercise intention level of

boys was significantly higher than that of girls, personality of extraversion level of boys was significantly lower than that of girls, personality of conscientiousness level of boys was significantly higher than that of girls, exercise behavior level of boys was significantly higher than that of girls, and there was no significant difference between boys and girls in exercise-induced feeling, agreeableness, neuroticism and openness.

As shown in Table 2, of the total sample, 33.53% (391) were grade one students, 33.36% (389) were grade two students, and 33.10% (386) were grade three students. There are no significant differences in each variable among different grades.

Measures and instruments

Exercise intention

Exercise Intention Scale was compiled by Ajzen (2006). Fang (2012) translated and revised this scale to measure the exercise intention among Chinese junior high school students. This study adopted revised *Exercise Intention Scale* by Fang to measure exercise intention. It is a 7-point-Likert scale consisting of 3 items. (e.g., "I plan to exercise for at least 20 min at least three times a week, in the next 2 weeks," "I intend to exercise for at least 20 min at least three times a week, in the next 2 weeks" and "I hope to exercise for at least 20 min at least three times a week, in the next 2 weeks."). Each item is rated from 1 (completely disagree) to 7 (completely agree), use average score to represent individual exercise intention and a higher score means a stronger the intention of exercise. Previous research has confirmed that *Exercise Intention Scale* has good reliability and validity among Chinese junior high school students (Liu, 2022). In the present study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 4.19$, CFI = 0.91, TLI = 0.89, RMSEA = 0.049, SRMR = 0.048, and the Cronbach's α was 0.86.

TABLE 2 Differences in grade.

Variable	Grade	Number (%)	*M*	SD	*F*	*p*
EI	One	391(33.53)	5.81	1.23	2.46	0.659
	Two	389(33.36)	5.88	1.22		
	Three	386(33.10)	5.97	1.20		
EIF	One	391(33.53)	3.88	0.57	1.48	0.753
	Two	389(33.36)	3.84	0.52		
	Three	386(33.10)	3.86	0.55		
Extraversion	One	391(33.53)	2.84	0.23	1.87	0.712
	Two	389(33.36)	2.86	0.21		
	Three	386(33.10)	2.82	0.21		
Agreeableness	One	391(33.53)	3.31	0.57	2.35	0.675
	Two	389(33.36)	3.25	0.55		
	Three	386(33.10)	3.27	0.54		
Conscientiousness	One	391(33.53)	3.49	0.63	3.94	0.521
	Two	389(33.36)	3.37	0.68		
	Three	386(33.10)	3.34	0.66		
Neuroticism	One	391(33.53)	3.48	0.59	2.73	0.618
	Two	389(33.36)	3.55	0.61		
	Three	386(33.10)	3.38	0.64		
Openness	One	391(33.53)	3.68	0.66	1.98	0.703
	Two	389(33.36)	3.49	0.58		
	Three	386(33.10)	3.55	0.60		
EB	One	391(33.53)	18.76	7.49		
	Two	389(33.36)	20.74	7.51	2.51	0.634
	Three	386(33.10)	22.23	6.58		

EI, exercise intention; EIF, exercise-induced feeling; EB, exercise behavior.

Personality

NEO-PI-R (Revised NEO Personality Inventory) Scale was compiled by Costa and McCrae (1995) and it is the most widely used tool for measuring the five-factor model of personality (Jiang et al., 2022). Wang et al. (2011) translated and revised this scale to measure the five-factor model of personality among Chinese junior high school students. This study adopted revised *Chinese Big Five Personality Inventory Scale* (CBF-PI) by Wang et al. to measure five-factor model of personality. The *CBF-PI* is a 5-point-Likert scale consisting of 10 items and 5 dimensions: extraversion (e.g., "I see myself as someone who is outgoing, sociable"), agreeableness (e.g., "I see myself as someone who is generally trusting"), conscientiousness (e.g., "I see myself as someone who does a thorough job"), neuroticism, (e.g., "I see myself as someone who gets nervous easily") and openness (e.g., "I see myself as someone who has an active imagination"). Each item is rated from 1 (disagree strongly) to 5 (agree strongly), use average score to represent the degree of various personality traits and a higher score shows a higher level of this personality trait (Beatrice and Oliver, 2007). Previous research has confirmed that *CBF-PI* has good reliability and validity among Chinese junior high school students (Jiang et al., 2015). In the present study, confirmatory factor analysis results demonstrated that a five-factors model fit the data satisfactorily: $\chi^2/df = 3.21$, CFI = 0.97, TLI = 0.95, RMSEA = 0.052, SRMR = 0.038. The Cronbach's α of the extraversion dimension was 0.91, agreeableness was 0.85, conscientiousness was 0.88, neuroticism was 0.86 and openness was 0.82.

Exercise-induced feeling

The *Exercise-induced Feeling Inventory* (EFI) was compiled by Gauvin and Rejeski (1993). Chen et al. (2007) translated and revised this scale to measure the exercise-induced feeling of Chinese junior high school students. This study adopted revised *EFI* by Chen et al. to measure exercise-induced feeling. The *EFI* is a 6-point-Likert scale consisting of 12 items and 4 dimensions: energize (e.g., "During or after physical exercise, I feel exhilarated"), calm (e.g., "During or after physical exercise, I feel relaxed"), exhausted (e.g., "During or after physical exercise, I feel tired") and active, (e.g., "During or after physical exercise, I feel passionate"). Each item is rated from 1 (completely disagree) to 6 (completely agree), use average score

to represent the degree of various exercise feeling and a higher score shows a higher level of conformity of this dimension (Wang, 2015). Previous research has confirmed that *EFI* has good reliability and validity among Chinese junior high school students (Liu, 2016). In the present study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 4.15$, CFI = 0.88, TLI = 0.94, RMSEA = 0.051, SRMR = 0.047, The Cronbach's α of the energize dimension was 0.90, calm was 0.86, exhausted was 0.91 and active was 0.89.

Exercise behavior

Physical Activity Rating Scale (PARS-3) was compiled by Liang (1994). *PARS-3* is widely used to measure the physical exercise behavior among Chinese junior high school students (Wang et al., 2022), and this study adopted it to measure exercise behavior. The *PARS-3* includs three aspects: exercise intensity (e.g., "What is the intensity of your physical exercise?"), exercise time (e.g., "How many minutes do you spend on the physical activities?") and exercise frequency (e.g., "How many times do you do physical activities in a month?"). Each item is rated from 1 to 5, and the following equation computes the total score of physical activity: exercise intensity × (exercise time-1) × exercise frequency, with a range of 0 to 100. A higher score shows a higher amount of physical exercise. Previous research has confirmed that *PARS-3* has good reliability and validity among Chinese junior high school students (Dong and Mao, 2021). In the present study, the scale has high reliability and validity, its retest reliability $r = 0.87$, and Cronbach's α was 0.89.

Statistical analyzes

After the questionnaire data were collected, Amos 24.0 was used for confirmatory factor analysis to test the validity of variables, and IBM SPSS23.0 for *Pearson* correlation analysis and common method bias test. According to the study of Ye and Wen (2013). Using process macro in IBM SPSS23.0 to examine our model. Firstly, we used process Model 1 to test the moderating effect of personality on exercise intention and exercise behavior. Secondly, used process Model 1 to test the moderating effect of personality on exercise intention and exercise-induced feeling. Finally, used process Model 8 to test the relationship between the moderating effect of personality on exercise intention and exercise behavior with exercise-induced feeling. During the model test, grade and gender were included in the model as covariates. The continuous variables of normal distribution were expressed as mean (M) ± standard deviation (SD) and the incomplete questionnaire has been deleted when enter data, so there is no missing date in this study. Goodness of fit index χ^2/df less than 5, RMSEA less than 0.08, NNFI and CFI greater than 0.8, and SRMR less than 0.05 are acceptable. In this study, significance level was set as $p < 0.05$ and effect sizes of the correlation coefficient r (Wangzhou et al., 2021) to estimate the magnitude of significant differences during statistical analysis.

Results

Common method bias test

In this study, two common method bias test methods will be used to test data to ensure that there is no serious man-made covariant problem between predictive variables and standard variables (Tang and Wen, 2020). First, Harman single factor was used to test the common method bias (Aguirre-Urreta and Hu, 2019). The results showed that the characteristic roots of five factors were greater than 1, and the first factor could explain 31.032%, which was less than the standard critical value of 40%. The common method bias of this study was acceptable. Secondly, a single common method factor control method is used to test the common method bias. The results show that the model containing common method factors cannot fit the data. To sum up, the results of both test methods show that there is no obvious problem of common method bias in this study.

Descriptive statistics and correlation analysis

Descriptive statistics and related analysis results of each research variable are shown in Table 3. Table 3 shows that exercise intention, openness personality, exercise-induced feeling, extraversion personality, conscientiousness personality, neuroticism personality are significantly positively correlated with exercise behavior of junior high school students; Agreeableness personality is negatively correlated with exercise behavior; Exercise intention, openness personality, extroversion personality, agreeableness personality, conscientiousness personality, neuroticism personality and exercise-induced feeling were significantly positively correlated; Openness personality, agreeableness personality, conscientiousness personality, neuroticism personality and exercise intention were significantly positively correlated. The relationship between variables supports subsequent hypothesis testing.

Test of mediated moderating model

In this study, the five dimensions of personality of the Big Five Personality Scale were tested by regulatory analysis. The test results showed that there was no regulatory effect on extraversion personality in exercise intention and exercise behavior ($p = 0.195 > 0.05$), no regulatory effect on agreeableness personality in exercise intention and exercise behavior ($p = 0.062 > 0.05$), and no regulatory effect on conscientiousness personality in exercise intention and exercise behavior ($p = 0.736 > 0.05$) Neurotic personality has no regulatory effect on exercise intention and exercise behavior ($p = 0.658 > 0.05$), but only openness personality has significant regulatory effect on exercise intention and exercise behavior ($p < 0.001$, $t = 4.431$).

TABLE 3 Means, standard deviations, and correlations among variables.

Variable	*M*	SD	1	2	3	4	5	6	7	8
1. EI	5.93	1.22	1							
2. EB	20.91	7.78	0.265**	1						
3.Openness	3.59	0.81	0.246**	0.206**	1					
4. EIF	3.87	0.80	0.401**	0.220**	0.218**	1				
5. Extraversion	2.84	0.69	0.054*	0.074**	0.121**	0.140**	1			
6. Agreeableness	3.28	0.69	0.148**	−0.019	−0.125**	0.121**	−0.015	1		
7. Conscientiousness	3.39	0.71	0.167**	0.124**	0.234**	0.126**	−0.016	−0.037	1	
8. Neuroticism	3.52	0.82	0.310**	0.159**	0.296**	0.293**	0.123**	0.308**	0.118**	1

EI, exercise intention; EIF, exercise-induced feeling; EB, exercise behavior. $^{**}p < 0.01$, $^{*}p < 0.5$.

TABLE 4 Test of mediated moderating model.

Variable	Model 1(Output variable:EB)			Model 2(Output variable:EIF)			Model 3(Output variable:EB)		
	β	SE	*t*	*β*	SE	*t*	*β*	SE	*t*
Constant	2.88	0.02	148.55**	3.84	0.02	201.78**	2.89	0.02	146.15**
EI(*X*)	0.16	0.02	9.97**	0.26	0.07	16.48**	0.14	0.02	7.38**
Openness(*U*)	0.12	0.02	4.84**	0.1	0.02	4.06**	0.11	0.03	4.22**
X × *U*	0.09	0.02	4.43**	0.11	0.02	5.15**	0.08	0.02	3.60**
EIF(W)							0.1	0.03	3.66**
R^2	0.102			0.189			0.111		
ΔR^2	0.101			0.188			0.108		
F	$F(3,1,569) = 59.695$, $p = 0.000$			$F(3,1,569) = 122.211$, $p = 0.000$			$F(4,1,568) = 49.019$, $p = 0.000$		

EI, exercise intention; EIF, exercise-induced feeling; EB, exercise behavior. $^{**}p < 0.01$.

Therefore, according to a procedure proposed of test mediated moderating effects by Ye and Wen (2013), this study is conducted according to the following steps:

1. Test whether the moderating effect of open personality on the relationship between exercise intention and exercise behavior of junior high school students is significant. If so, continue with the following steps. Otherwise, stop the analysis.
2. Test whether the moderating effect of openness personality on the relationship between exercise intention and exercise-induced feeling of junior high school students is significant, and whether the relationship between exercise-induced feeling and exercise behavior is significant. If both are significant, then at least one part of the moderating effect of openness personality on exercise intention and exercise behavior is realized through the intermediary variable exercise-induced feeling.
3. The interaction between exercise intention, openness personality, exercise-induced feeling and exercise intention and openness personality (U × X). The regression test of the relationship between exercise intention and exercise behavior is significant. If it is not significant, it indicates that the regulatory effect is completely mediated; If significant, it indicates that the moderating effect is partially mediated. The inspection is completed.

Except for the dependent variable exercise behavior, all variables were standardized in this study. See Table 4 for specific estimated parameters. The results showed that in Table 4, junior high school students' exercise intention, openness personality and their interaction items were significantly positive predictors of exercise behavior. Further simple slope test analysis results show that (Figure 2), when the level of openness personality is high, junior high school students' exercise intention has a strong predictive effect on exercise behavior ($\beta = 0.236$, $t = 9.175$, $p < 0.01$). When the level of openness personality is low, junior high school students' exercise intention has a weak predictive effect on exercise behavior ($\beta = 0.085$, $t = 4.094$, $p < 0.01$), that is, openness personality can regulate the relationship between exercise intention and exercise behavior of junior high school students. Table 4 shows that junior high school students' exercise intention, openness personality and the interaction between exercise intention and openness personality can significantly predict junior high school students' exercise-induced feeling. That is to say, openness personality only has a moderating effect between exercise intention and exercise-induced feeling of junior high school students. Further simple slope test shows that (Figure 3), when the level of openness personality is high, exercise intention has a strong predictive effect on exercise-induced feeling ($\beta = 0.347$, $t = 13.730$, $p < 0.01$). When the level of openness personality is low, the predictive effect of exercise intention on exercise-induced feeling of junior high school students is weak ($\beta = 0.175$, $t = 8.540$, $p < 0.01$). Table 4 and Figure 4 show that

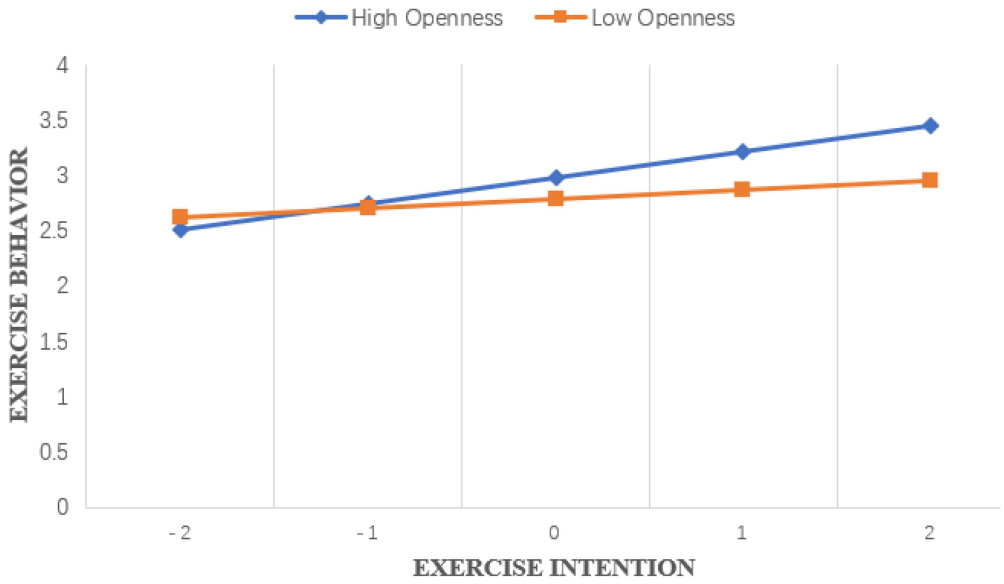


FIGURE 2
The moderating effect of openness on exercise behavior and exercise intention.

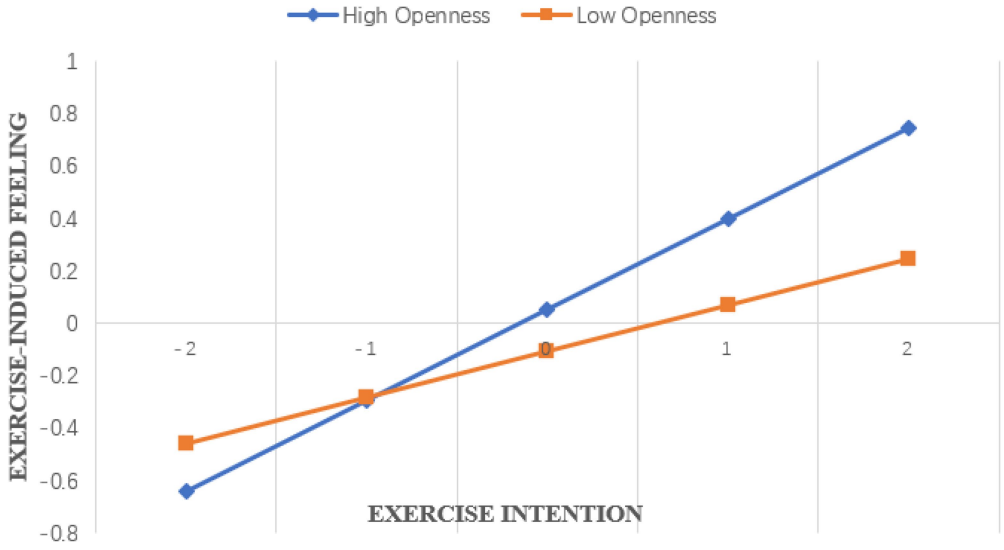


FIGURE 3
The moderating effect of openness on exercise-induced feeling and exercise intention.

exercise-induced feeling has a significant positive predictive effect on exercise behavior, and the interaction term of exercise intention and openness personality has a significant predictive effect on exercise behavior, indicating that exercise-induced feeling of junior high school students plays a partial intermediary role in the relationship between openness personality moderated exercise intention and exercise behavior, and the intermediary effect value is $0.106 \times 0.10 = 0.0106$, the proportion of intermediary effect in the total effect is $0.0106/(0.0106 + 0.082) = 11.45\%$. To sum up, the four relationship models of junior high school students' exercise intention, openness personality, exercise-induced feeling and exercise behavior conform to the mediated moderating model.

Discussion

Through correlation analysis and structural equation model analysis, this study found that exercise intention can positively

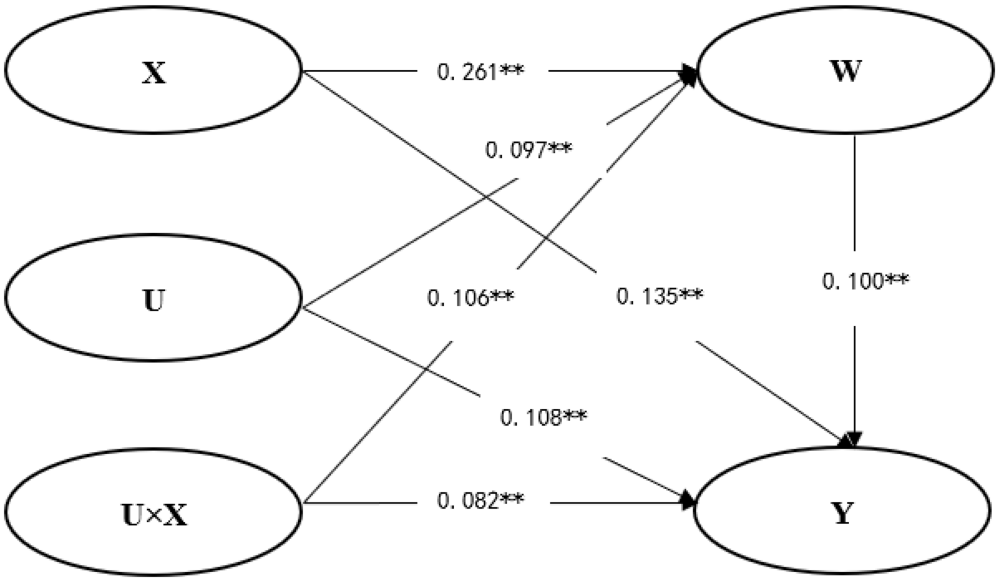


FIGURE 4
The mediated moderating model (**p<0.01).

predict exercise behavior, that is, the stronger the exercise intention, the higher the level of exercise behavior, which verifies Hypothesis 1. This result reaffirms the TBA's view that intention to exercise is a valid predictor of exercise behavior, and it is consistent with the pre-epidemic research (Xiang, 2016; Liu et al., 2017). The reason is that the stronger the junior high school students' exercise intention is, the higher the degree of effort they are willing to pay in the planned exercise behavior, and the more positive their attitude will be, which is bound to significantly improve the level of junior high school students' exercise behavior. Therefore, in the post epidemic period, improving the exercise intention of junior high school students is still one of the main ways to improve exercise behavior.

Moderating effect of openness personality

Bases on this result, this study also found that openness personality plays a regulatory role in the relationship between exercise intention and exercise behavior, which verifies Hypothesis 2. High level openness personality significantly enhances the predictive effect of exercise intention on exercise behavior, while low level openness personality weakens the predictive effect of exercise intention on exercise behavior, which once again proves that the executive power of different levels of openness personality is significantly different, consistent with previous studies (Pérez-Fuentes et al., 2019). The theory of personality traits points out that personality traits have the ability to guide behavior intention and individual behavior, and the behavior motivation that individuals choose or show when facing social behavior may directly originate from personality traits (Mao, 2019). The social communication ability and behavior motivation of the high level openness personality individuals are significantly higher than those of the low level openness personality individuals. In other words, individuals will be moderated by openness personality in the process of transforming from exercise intention to exercise behavior. The stronger the exercise intention of high-level openness personality individuals, the more motivated individuals will be and the more positive emotions they will experience, and the higher their ability to exercise behavior will be. Low level openness personality individuals, due to their low social interaction ability, lack of confidence, and dislike participating in social interaction activities (Chen and Liu, 2018), reduce the possibility of participating in exercise behavior, thus weakening the positive relationship between exercise intention and exercise behavior. This study suggests that, on the one hand, in the post epidemic period, we can stimulate junior high school students' exercise intentions by enriching teaching content, actively organizing extracurricular sports activities and other diversified ways. On the other hand, we should strengthen the intervention of low level openness personality, promote its positive cognition and self-evaluation, improve its social interaction ability, and promote its active participation in physical exercise.

Mediating effect of exercise-induced feeling

This study also found that the moderating of openness personality on the relationship between exercise intention and exercise behavior is realized through the mediator variable of

exercise-induced feeling, which verifies Hypothesis 4. This result supports the theoretical view that feeling is the key factor to trigger and maintain the exercise intention of junior high school students, and is the key factor to affect exercise behavior (Brunet et al., 2018; Zhang and Chang, 2019).

The results show that after adding the mediator variable of exercise-induced feeling into the model, the moderating role of openness personality increases, and it can still significantly predict exercise behavior, which indicates that exercise-induced feeling plays a part of the mediator role in the relationship between openness personality and exercise behavior, which is consistent with previous research conclusions (Zhu and Dong, 2016). According to the theory of field dynamics, people are a field, and their psychological activities occur in a psychological field or living space. The direction and vector of individual behavior depend on the environmental stimulus and internal motivation of the individual. Individuals' behavior is stimulated by internal motivation, exercise intention stimulates exercise behavior, and exercise-induced feeling and an openness personality stimulate individuals to be more willing to participate in exercise. The characteristics of openness personality, such as enthusiasm, good communication, activity, optimism and openness, can help junior high school students to encourage their ability to solve problems when encountering difficulties, give students full freedom of choice, and give students timely emotional interaction when they need emotional comfort. These supports meet the students' development needs in three aspects of autonomy, competence and relationship, so as to enhance their exercise feeling. A high level of exercise-induced feeling can then predict a higher degree of exercise behavior. This result shows that exercise-induced feeling is an important mediator variable between exercise intention and exercise behavior. As an important variable at the level of individual non cognitive factors, it is not only affected by the external social environment, but also can effectively predict exercise behavior, playing a connecting role.

Practical significance

The theoretical significance of this study is to expand the application of planned behavior theory in Chinese junior high school students. It explores the regulatory role of personality traits in the relationship between exercise intention and exercise behavior. Firstly, exercise intention remains an important predictor variable of exercise behavior, as well as exercise-induced feeling, which can mediate between exercise intention and behavior, while openness personality plays a moderating role in this process. It enriches the research related to the field of exercise intention and exercise behavior.

The practical significance of this study is to provide practical basis for Chinese junior high school students to improve their exercise behavior in the post epidemic period. Junior high school students are in the puberty stage. Students at this stage are more sensitive and vulnerable to interference from the external environment. The COVID-19 epidemic led to the closure of schools, which will cause a lot of damage to students. From the perspective of the theory of planned behavior, this paper discusses how personality traits and exercise induced emotions affect the transformation of junior high school students' exercise intentions into exercise behaviors. Research shows that the open personality in personality traits can significantly enhance the transformation of exercise intentions into exercise behaviors. At the same time, exercise induced emotions play a mediating role in this process. This study also found that the exercise behavior of girls will be significantly lower than that of boys, which suggests that parents and teachers need to improve the exercise situation of girls and the reasons why girls do not like to exercise, so as to help them improve their exercise behavior and promote their physical and mental health.

Limitations and prospectives

Firstly, the study on the mechanism of exercise intention on exercise behavior is based on cross-sectional study. Although cross-sectional research can effectively answer many types of questions and the findings can explain complex models, it is difficult to obtain causal relationships between variables in this type of study. In the future research, the longitudinal tracking design can be combined to be more effectively explain how exercise intention affects the exercise behavior of junior high school students. Secondly, the scope of this research is only Anhui Province, China. The research results may only apply to China or Asia, but not to the world. In future research, we can expand the sample range and conduct surveys around the world to obtain more authoritative results. Thirdly, this study focused primarily on junior high school students, and more samples are needed in the future, such as college students and adults. Despite these limitations, this study improves junior high school students' exercise behavior by revealing the mediating and moderating mechanisms between exercise intention and exercise behavior.

Conclusion

(1) In the post-epidemic period, intention to exercise significantly predicted exercise behavior in junior high school students, with the openness personality of junior high school students playing a moderating role in the process, i.e., influencing the strength and direction of the relationship. The stronger the intention to exercise, the lower the increase in exercise behavior for junior high school students with a low level of openness, and the stronger the intention to exercise, the higher the increase in exercise behavior for junior high school students with a high level of openness. It is important to be fully aware of the important role of openness in the process of exercise intention to promote exercise behavior.

(2) Exercise intention not only directly predicts exercise behavior, but also indirectly predicts exercise behavior through exercise-induced feeling, with openness personality playing a moderating role in this process. It suggests that in the post-epidemic era, not only the cultivation of exercise intention but also the cultivation of exercise-induced feeling in junior high school students should be emphasized in improving their exercise behavior.

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.

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki, and it has been approved by the Human Research Ethics Committee of Huaibei Normal University.

Author contributions

Q-SM collected and analyzed the data. Q-SM and S-JY wrote original draft preparation and revised the manuscript. H-RJ supported funding. All authors designed the study, 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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aguirre-Urreta, M. I., and Hu, J. (2019). Detecting common method bias. ACM SIGMIS database. *Database Adv. Inf. Syst.* 50, 45–70. doi: 10.1145/3330472.3330477

Ajzen, I. (2006). TPB measurement: conceptual and methodological considerations [EB/OL]. Available at: http://people.umass.edu/aizen/pdf/tpb.measurement.pdf

Ajzen, I. (2011). The theory of planned behaviour: reactions and reflections. *Psychol. Health* 26, 1113–1127. doi: 10.1080/08870446.2011.613995

Bandura, A. (1989). Human agency in social cognitive theory. *Am. Psychol.* 44, 1175–1184. doi: 10.1037/0003-066x.44.9.1175

Bandura, A. (2004). Health promotion by social cognitive means. *Health Educat. Behav.* 31, 143–164. doi: 10.1177/1090198104263660

Beatrice, R., and Oliver, P. J. (2007). Measuring personality in one minute or less: a 10-item short version of the big five inventory in English and German. *J. Res. Pers.* 41, 203–212. doi: 10.1016/j.jrp.2006.02.001

Brunet, J., Guérin, E., and Speranzini, N. (2018). An examination of exercise-induced feeling states and their association with future participation in physical activity among older adults. *J. Aging Phys. Act.* 26, 52–60. doi: 10.1123/japa.2016-0342

Burkitt, I. (2021). The emotions in cultural-historical activity theory: personality, emotion and motivation in social relations and activity. *Integr. Psychol. Behav. Sci.* 55, 797–820. doi: 10.1007/s12124-021-09615-x

Cao, H., Qian, Q., Weng, T., Yuan, C., Sun, Y., Wang, H., et al. (2011). Screen time, physical activity and mental health among urban adolescents in China. *Prev. Med.* 53, 316–320. doi: 10.1016/j.ypmed.2011.09.002

Chen, H. B., and Liu, J. (2018). The relationship between family socio economic status and adolescent intelligence: the mediation between positive parenting styles and open personality. *Psychol. Dev. Educ.* 5, 558–566. doi: 10.16187/j.cnki.issn1001-4918.2018.05.06

Chen, R., Peng, K., Liu, J., and Lu, J. (2020). Interpersonal trauma and risk of depression among adolescents: the mediating and moderating effect of interpersonal relationship and physical exercise. *Front. Psych.* 11:194. doi: 10.3389/fpsyt.2020.00194

Chen, J., Si, G. Y., and Xia, M. (2007). Test of exercise-induced feeling questionnaire. *J. Wuhan Instit. Phys. Educat.* 7, 48–50. doi: 10.15930/j.cnki.wtxb.2007.07.010

Chen, Y., Yao, S. J., Ma, Q. S., Shao, W., Liu, C., and Guo, K. L. (2022). The relationship between exercise intention and exercise behavior of junior school students: an analysis of chain mediating effect. *Front. Psychol.* 13:935264. doi: 10.3389/fpsyg.2022.935264

Costa, J. P. T., and McCrae, R. R. (1995). Domains and facets: hierarchical personality assessment using the revised NEO personality inventory. *J. Pers. Assess.* 64, 21–50. doi: 10.1207/s15327752jpa6401_2

Damasio, A. (2021). Feeling and knowing: making minds conscious. *Cogn. Neurosci.* 12, 65–66. doi: 10.1080/17588928.2020.1846027

Dong, B. L., and Mao, L. J. (2021). The relationship between school natural environment, interpersonal environment and teenagers' physical exercise. *J. Phys. Educ.* 2, 111–117. doi: 10.16237/j.cnki.cn44-1404/g8.2021.02.018

Fang, M. (2012). The relationship between adolescents' exercise intention and exercise behavior: mediation. *J. Shanghai Univ. Sport* 2, 45–49. doi: 10.16099/j.cnki.jsus.2012.02.012

Gauvin, L., and Rejeski, W. J. (1993). The exercise-induced feeling inventory: development and initial validation. *J. Sport Exerc. Psychol.* 15, 403–423. doi: 10.1123/jsep.15.4.403

Goldberg, L. R. (1990). An alternative "description of personality": the big-five factor structure. *J. Pers. Soc. Psychol.* 59, 1216–1229. doi: 10.1037//0022-3514.59.6.1216

Grigolava, T. R., Vishnyakova, A. V., Sinitsyna, A. A., Voronina, A. V., Zubko, O. N., Zudova, O. V., et al. (2021). Methodological approaches for producing doubled haploids in sugar beet and red beet (*Beta vulgaris* L.). *Vavilovskii zhurnal genetiki i selektsii* 25, 276–283. doi: 10.18699/VJ21.031

Gu, P., Liang, Z., Zhang, H., and Zhang, D. (2022). Effects of attitudes towards exercise behaviour, use of sports apps and COVID-19 on intentions to exercise. Journal of. *Pers. Med.* 12:1434. doi: 10.3390/JPM12091434

Guo, K. L., Ma, Q. S., Yao, S. J., Liu, C., Hui, Z., Jiang, J., et al. (2022). The relationship between physical exercise and mobile phone addiction tendency of university students in China: a moderated mediation model. *Front. Psychol.* 13:730886. doi: 10.3389/fpsyg.2022.730886

Halevy, N., Kreps, T. A., and De Dreu, C. K. W. (2019). Psychological situations illuminate the meaning of human behavior: recent advances and application to social influence processes. *Soc. Personal. Psychol. Compass* 13:e12437. doi: 10.1111/spc3.12437

Han, J., Zhang, S. T., and Bai, S. Y. (2021). The influence of social network Users' personality traits on social capital accumulation -- a study based on WeChat. *Manage Comments* 33, 239–248. doi: 10.14120/j.cnki.cn11-5057/f.2021.02.021

Heilmann, K., Hinrichs, R., Herke, M., Richter, M., and Rathmann, K. (2021). The importance of the "big five" personality traits for subjective health and life satisfaction in adolescence: results of the National Educational Panel Study (NEPS). *Gesundheitswesen* 83, 8–16. doi: 10.1055/a-1068-2280

Heintzelman, S. J., and King, L. A. (2014). (The feeling of) meaning-as-information. *Personal. Soc. Psychol. Rev.* 18, 153–167. doi: 10.1177/1088868313518487

Hermann, A., Neudert, M. K., Schäfer, A., Zehtner, R. I., Fricke, S., Seinsche, R. J., et al. (2021). Lasting effects of cognitive emotion regulation: neural correlates of reinterpretation and distancing. *Soc. Cogn. Affect. Neurosci.* 16, 268–279. doi: 10.1093/scan/nsaa159

Hohmann, L. A., and Garza, K. B. (2022). The moderating power of impulsivity: a systematic literature review examining the theory of planned behavior. *Pharmacy* 10:85. doi: 10.3390/pharmacy10040085

Hou, B., Li, L., Zheng, L., Qi, Y., and Zhou, S. (2022). Linking exercise intention to exercise action: the moderating role of self-efficacy. *Front. Psychol.* 13:921285. doi: 10.3389/FPSYG.2022.921285

Huang, W., Shi, X., Wang, Y., Li, X., Gao, P., Lu, J., et al. (2021). Determinants of student's physical activity: a 12-month follow-up study in Ningxia province. *BMC Public Health* 21:512. doi: 10.1186/s12889-021-10525-1

Huellemann, K. L., Pila, E., Gilchrist, J. D., Nesbitt, A. E., and Sabiston, C. M. (2021). Body-related self-conscious emotions and reasons for exercise: a latent class analysis. *Body Image* 38, 127–136. doi: 10.1016/j.bodyim.2021.03.016

Jiang, X., Li, X., Dong, X., and Wang, L. (2022). How the big five personality traits related to aggression from perspectives of the benign and malicious envy. *BMC Psychol.* 10:203. doi: 10.1186/s40359-022-00906-5

Jiang, Y., Zhang, L. W., and Mao, Z. X. (2015). The effect of personality, exercise motivation and exercise orientation on emotional benefits of physical exercise. *J. Tianjing Univ. Sport* 2, 147–151. doi: 10.13297/j.cnki.issn1005-0000.2015.02.011

Ka, L., Elliott, R., Ware, K., Juhasz, G., and Lje, B. (2021). Associations between facets and aspects of big five personality and affective disorders:a systematic review and best evidence synthesis. *J. Affect. Disord.* 288, 175–188. doi: 10.1016/j.jad.2021.03.061

Kim, J. S. (2022). The relationship between enjoyment factors, exercise emotions, and personality development in youth participation in school sports Club. *Korea J. Sport* 20, 117–124. doi: 10.46669/kss.2022.20.2.010

Kim, S. J., Lee, S., Han, H., Jung, J., Yang, S. J., and Shin, Y. (2021). Parental mental health and Children's behaviors and media usage during COVID-19-related school closures. *J. Korean Med. Sci.* 36:e184. doi: 10.3346/jkms.2021.36.e184

Liang, D. Q. (1994). Stress level of college students and its relationship with physical exercise. *Chin. Ment. Health J.* 1, 5–6.

Liu, W. W. (2016). A study on the relationship between different exercise types and frequencies and peer relations and coping styles of junior middle school students. master's thesis. Beijing: Beijing Sport University.

Liu, Z. L. (2019). A study on the transformation process from exercise intention to behavior of college students. master's thesis. Shanghai: East China Normal University.

Liu, P. (2022). The Main effect and regulation effect of physical exercise intention in predicting physical exercise behavior – evidence based on meta analysis. *Bull. Sport Sci. Technol.* 4, 87–91. doi: 10.19379/j.cnki.issn.1005-0256.2022.04.025

Liu, L., Li, J., Zhang, F., and Xu, J. S. (2017). The forming mechanism of adolescent exercise behavior: based on the theory of planned behavior. *Sports Sci. Technol.* 6, 40–41+49. doi: 10.14038/j.cnki.tykj.2017.06.016

Liu, Y., and Wang, X. (2020). Differences in driving intention transitions caused by Driver's emotion evolutions. *Int. J. Environ. Res. Public Health* 17:6962. doi: 10.3390/ijerph17196962

Mao, X. C. (2019). Analysis of personality characteristics of freshmen majoring in physical education. *Shandong Sports Sci. Technol.* 6, 60–65. doi: 10.14105/j.cnki.1009-9840.2019.06.011

Mao, Z. X., and Guo, L. (2013). Progress in contemporary sports psychology: exercise psychology. *J. Beijing Sport Univ.* 9, 56–63. doi: 10.19582/j.cnki.11-3785/g8.2013.09.011

Montse, C. R., and Claudio, R. (2020). *Feelings in sport: Theory, research, and practical implications for performance and well-being, 1st Edn*. eds. M. C. Ruiz and C. Robazza (New York: Taylor and Francis Press).

Nave, C. S., Edmonds, G. W., Hampson, S. E., Murzyn, T., and Sauerberger, K. S. (2016). From elementary school to midlife: childhood personality predicts behavior during cognitive testing over four decades later. *J. Res. Pers.* 67, 183–189. doi: 10.1016/j.jrp.2016.10.001

Pan, Y., Zhou, D., and Shek, D. T. L. (2022). After-school extracurricular activities participation and depressive symptoms in Chinese early adolescents: moderating effect of gender and family economic status. *Int. J. Environ. Res. Public Health* 19:4231. doi: 10.3390/ijerph19074231

Perchtold-Stefan, C. M., Fink, A., Rominger, C., Weiss, E. M., and Papousek, I. (2020). More habitual physical activity is linked to the use of specific, more adaptive cognitive reappraisal strategies in dealing with stressful events. *Stress Health* 36, 274–286. doi: 10.1002/smi.2929

Pérez-Fuentes, M., Molero Jurado, M., Gázquez Linares, J. J., Oropesa Ruiz, N. F., Simón Márquez, M., and Saracostti, M. (2019). Self-expressive creativity in the adolescent digital domain: personality, self-esteem, and emotions. *Int. J. Environ. Res. Public Health* 16:4527. doi: 10.3390/ijerph16224527

Pilch, I., Wardawy, P., and Probierz, E. (2021). The predictors of adaptive and maladaptive coping behavior during the COVID-19 pandemic: the protection motivation theory and the big five personality traits. *PLoS One* 16:e0258606. doi: 10.1371/journal.pone.0258606

Proto, E., and Zhang, A. (2021). COVID-19 and mental health of individuals with different personalities. *Proc. Natl. Acad. Sci. U. S. A.* 118:e2109282118. doi: 10.1073/pnas.2109282118, 118

Sheldon, K. M., and Prentice, M. (2019). Self-determination theory as a foundation for personality researchers. *J. Pers.* 87, 5–14. doi: 10.1111/jopy.12360

Tang, D. D., and Wen, Z. L. (2020). Common method bias test: problems and suggestions. *Psychol. Sci.* 1, 215–223. doi: 10.16719/j.cnki.1671-6981.20200130

Teixeira, D. S., Rodrigues, F., Cid, L., and Monteiro, D. (2022). Enjoyment as a predictor of exercise habit, intention to continue exercising, and exercise frequency: the intensity traits discrepancy moderation role. *Front. Psychol.* 13:780059. doi: 10.3389/FPSYG.2022.780059

Van den Akker, A. L., Briley, D. A., Grotzinger, A. D., Tackett, J. L., Tucker-Drob, E. M., and Harden, K. P. (2021). Adolescent Big Five personality and pubertal development: pubertal hormone concentrations and self-reported pubertal status. *Dev. Psychol.* 57, 60–72. doi: 10.1037/dev0001135

Wan, Y., Zhao, Y., and Song, H. (2021). Effects of physical exercise on prosocial behavior of junior high school students. *Children* 8:1199. doi: 10.3390/children8121199

Wang, X. Z. (2015). Comparison of the emotional state induced by exercise between jogging and basketball. *J. Henan Univ. Educat.* 24:3. doi: 10.3969/j.issn.1007-0834.2015.03.021

Wang, M. C., Dai, X. Y., and Yao, S. Q. (2011). The preliminary development of the Chinese big five personality questionnaire III: the development of the simplified version and the test of its reliability and validity. *Chin. J. Clin. Psych.* 4, 454–457. doi: 10.16128/j.cnki.1005-3611.2011.04.004

Wang, L. Y., Jin, G. H., Zhang, Y. W., Liu, Y. N., Wang, F. S., Peng, X. T., et al. (2022). The influence of physical exercise on junior high school students' suffering from campus bullying – the chain intermediary effect of psychological resilience and self-efficacy. *J. Phys. Educ.* 1, 67–73. doi: 10.16419/j.cnki.42-1684/g8.2022.01.005

Wangzhou, K., Khan, M., Hussain, S., Ishfaq, M., and Farooqi, R. (2021). Effect of regret aversion and information cascade on investment decisions in the real estate sector: the mediating role of risk perception and the moderating effect of financial literacy. *Front. Psychol.* 12:736753. doi: 10.3389/fpsyg.2021.736753

Wen, X. (2015). The influence of physical exercise on adolescent cognitive ability and academic performance: history, present situation and future of research. *China Sport Sci.* 3, 73–82. doi: 10.16469/j.css.2015.03.010

Wilks, Z., Perkins, A. M., Cooper, A., Pliszka, B., Cleare, A. J., and Young, A. H. (2020). Relationship of a big five personality questionnaire to the symptoms of affective disorders. *J. Affect. Disord.* 277, 14–20. doi: 10.1016/j.jad.2020.07.122

Xiang, M. Q. (2016). Promoting strategies of Pupils' exercise intention and behavior: TPB based action plan intervention. *J. Nanjing Instit. Phys. Educat.* 5, 14–20. doi: 10.15877/j.cnki.nsin.2016.05.003

Xu, R. F., and Zhang, Y. X. (2021). Examination of labor education from the perspective of embodied cognition: foundation, value and path. *Res. Educat. Develop.* 22, 54–61. doi: 10.14121/j.cnki.1008-3855.2021.22.010

Yang, L. Z., and Ma, S. C. (2014). A study on the personality type division and the characteristics of personality type development of junior middle school students. *Psychol. Sci.* 6, 1377–1384. doi: 10.16719/j.cnki.1671-6981.2014.06.016

Ye, B. J., and Wen, Z. L. (2013). Mediated adjustment model test method: discrimination and integration. *Psychol. Sci.* 45, 1050–1060. doi: 10.3724/SP.J.1041.2013.01050

Zhang, S. S., and Chang, B. F. (2019). Research on the relationship between college Students' psychological resilience and emotional benefits of exercise. *Fujian Sports Sci. Technol.* 2, 43–45+54.

Zhang, C. B., Hou, R. J., and Yi, M. N. (2014). The relationship among perceived justice, emotion and behavior intention after online shopping service recovery – a mediation model based on relationship quality. *J. Shanxi Univ. Finan. Econ.* 1, 54–64. doi: 10.13781/j.cnki.1007-9556.2014.01.005

Zhang, W. J., and Mao, Z. X. (2016). The relationship between Teenagers' sports intention and behavior: the mediation of action control and emotion. *J. Beijing Sport Univ.* 3, 81–87. doi: 10.19582/j.cnki.11-3785/g8.2016.03.012

Zhang, W. J., Xu, M., Feng, Y. J., Mao, Z. X., Yan, Z. Y., and Fan, T. F. (2022). The value-added contribution of exercise commitment to college Students' exercise behavior: application of extended model of theory of planned behavior. *Front. Psychol.* 13:869997. doi: 10.3389/fpsyg.2022.869997

Zhu, C. Q., and Dong, B. L. (2016). Personality traits and exercise motivation of college students: mediating effect of emotional regulation. *J. Wuhan Instit. Phys. Educat.* 1, 94–100. doi: 10.15930/j.cnki.wtxb.2016.01.016

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 06 February 2023
DOI 10.3389/fpsyg.2023.1103109

OPEN ACCESS

EDITED BY
Yasuhiro Mochizuki,
Waseda University, Japan

REVIEWED BY
Mona Vintilă,
West University of Timişoara, Romania
Arlette Setiawan,
Padjadjaran University, Indonesia
Masoud Yazdanpanah,
University of Florida, United States

*CORRESPONDENCE
Jiazhi Sheng
✉ shengjiazhi2010@hotmail.com

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

RECEIVED 19 November 2022
ACCEPTED 13 January 2023
PUBLISHED 06 February 2023

CITATION
Sheng J, Gong L and Zhou J (2023) Exercise health belief model mediates the relationship between physical activity and peer support among Chinese college students: A cross-sectional survey.
Front. Psychol. 14:1103109.
doi: 10.3389/fpsyg.2023.1103109

Exercise health belief model mediates the relationship between physical activity and peer support among Chinese college students: A cross-sectional survey

Jiazhi Sheng[1,2]*, Lamei Gong[1] and Jian Zhou[3]

[1]Laboratory of Sports and Health Promotion, School of Physical Education, Sichuan University of Arts and Science, Dazhou, China, [2]Graduate School of Management, Management and Science University, Shah Alam, Malaysia, [3]School of Health Caring Industry, Sichuan University of Arts and Science, Dazhou, China

This study explored the influence of the exercise health belief model and peer support on university students' physical activity PA and clarified the related mechanism. Three hundred and thirty-six healthy university students (aged 19.4 ± 1.3 years, 166 male and 170 female) from Sichuan University of Arts and Science in China were evaluated by the peer support scale, the health belief model scale for exercise, and the physical activity scale (short volume). The results showed that the male students' exercise self-efficacy and PA were markedly higher than female university students. Peer support was positively correlated with perceived benefits, exercise self-efficacy, perceived severity, and cues to action, and was adversely associated with perceived objective and subjective barriers. PA was positively correlated with perceived benefits and exercise self-efficacy, and negatively correlated with perceived objective and subjective barriers. Among the components of the exercise health belief model, only exercise self-efficacy was suitable for constructing a structural equation model (SEM) with peer support and PA. The analysis showed that the predictive effect of exercise self-efficacy on PA was more significant than peer support, and exercise self-efficacy played a critical intermediary role. It is worth noting that, in the grouping model, the effect of male college students' exercise self-efficacy on PA was greater than that of female students, and the model fit of male peer support was better than that of female students. Although the impact of peer support on PA was less than that of exercise self-efficacy and the direct effect of peer support was less than the indirect effect, the impact of peer support on the PA of female university students was higher than that of male university students. This study revealed the impact of exercise self-efficacy and peer support on university students' PA and suggested that exercise self-efficacy is the main path to promoting university students' PA, followed by peer support. Peer support could affect university students' PA not only through direct effects but also through indirect effects. This study also suggested that female university students' peer support has a higher impact on PA than male students. Therefore, when formulating physical exercise courses in the future, it is necessary to give more peer support to female university students to compensate for their low exercise self-efficacy.

KEYWORDS

perceived benefits, perceived barriers, perceived severity, self-efficacy of exercise, gender differences

Introduction

Insufficient PA is a global health crisis. The World Health Organization (WHO) recently estimated that more than 25% of adults and 80% of adolescents worldwide were physically inactive (World Health Organization [WHO], 2022), increasing the risk of them suffering from various chronic metabolic diseases. The latest guidelines emphasized that people aged 18 to 64 should carry out moderate-intensity aerobic PA for at least 75–150 min or 150–300 min or the same amount of PA to maintain better or promote their health. In recent years, the physical quality of Chinese college students has been declining year by year. In past college students' physical fitness tests, the excellent rate of physical performance was far lower than the proportion of obesity and overweight. The physical condition of college students from Tsinghua University in China was studied (Wang, 2019), and the results showed that the risk of obesity among college students with insufficient exercise was 1.25 times higher than that of students with regular exercise. There was consensus on the factors affecting the PA of teenagers and college students, such as family support factors (Treiber et al., 1991), social support (Ling et al., 2014), and peer support (Sanz-Martín et al., 2022). Many studies have subdivided the influencing factors into external and internal factors, such as interest, physical exercise confidence and skills, and awareness of the exercise health belief model. However, relying only on internal or external factors, it was difficult to comprehensively and scientifically explain their PA. Relevant studies in this field should be paid adequate attention to explore the relationship between family support/peer support, exercise health belief model and PA.

Peer support and PA

Peers play an essential role in adolescents' behavior changes. Peer support mainly includes physical exercise attitude and exercise companionship; through physical exercise, adolescents can make friends and establish a significant correlation between peer relationships and motivation to participate in sports (Klint and Weiss, 1987). Peers can influence teenagers' exercise experience and motivate them (Agans et al., 2018), uninfluenced by the origin country of the teenagers, whether China (Luo et al., 2011) or the United States (Ling et al., 2014). With increasing age, peer support has an increasingly significant impact on PA. For example, Rajbhandari-Thapa et al. (2022) reported that, with the improvement of a supportive school environment and peer support, students' PA increased (Rajbhandari-Thapa et al., 2022). Through a survey of families and adolescents from 74 countries, scholars found that Western Pacific countries have the highest correlation between parental support and adolescents' PA, while in Southeast Asia, peer support has the highest correlation with adolescents' PA (Khan et al., 2020). Treiber et al. (1991) reported that gender and ethnic factors could affect PA through family and peer support. They found that white women's physical exercise and PA of leisure time positively correlated with their friends' support. In white men, PA and total energy consumption correlated with support from family and friends, and the PA of black women positively correlated with family support. The PA of black men positively related to family support and support from friends (Treiber et al., 1991). Based on the above research, we propose hypothesis 1: Peer support is significantly positively correlated with PA, and is affected by gender.

Exercise health belief model and PA

The health belief model (HBM), as a framework theory, can predict and explain PA (Rahmati-Najarkolaei et al., 2015), and is widely used in the research of people from different demographics, such as PA of older adults (Gristwood, 2011; Kaushal et al., 2021) or women (Hosseini et al., 2017; Shafieian and Kazemi, 2017). The health belief model for exercise evolved from the HBM and can effectively predict or explain PA. For example, Soleymanian et al. (2014) developed and evaluated a tool based on the HBM to estimate the factors affecting exercise behavior and preventing pre-menopausal osteoporosis in women, indicating that the scale has excellent reliability and validity (Soleymanian et al., 2014). Our previous research structured a new scale based on the HBM; we verified the reliability and validity of the exercise health belief model and explored the relationship between the internal components of the model. Further factors can be used to explain PA's impact on college students (Gong and Sheng, 2022). Exercise self-efficacy and perceived barriers are the two most essential elements in the model. Exercise self-efficacy is a person's confidence in implementing physical exercise, which is not related to the exercise level or exercise skills, and indicates the possibility of an individual adopting a specific behavior to maintain or promote health (Bandura, 1977). A previous study reported that increased self-efficacy significantly improved the PA of Chinese immigrant women (Cho and Lee, 2013).

In contrast, in a survey of college students from Chongqing (China), Ouyang et al. (2019) found that self-efficacy played a significant mediating role between body image and exercise participation (Ouyang et al., 2019). A cross-sectional survey of 1296 junior middle school students in Shanghai (China) was reported by Yang (2016); he found that parents' support for teenagers' exercise behavior do not affect their self-efficacy and satisfaction in participating. It was worth noting that the higher the peer support for exercise behavior, the easier it was for teenagers to overcome barriers and participate in physical exercise. In the meantime, he suggested that self-efficacy mediates the relationship between peer support and PA. Dong (2017) surveyed 1,945 young students aged 13–18, and found that girls had a higher level of social support, while boys had a higher health belief in physical fitness (Dong, 2017). Based on the above research, we propose hypothesis 2: There are differences in health belief model for exercise, peer support, and PA between male and female university students, and hypothesis 3 is proposed as follows: Exercise self-efficacy acts as a mediator on the association between peer support and PA.

This study used the peer support scale, the health belief model scale for exercise, and the PA scale to investigate university students from China, compare and analyze the differences between male and female students in peer support, exercise health belief and PA, and investigate the role of exercise health belief in the relationship between peer support and PA of college students.

Participants and methods

Participants

This study used random sampling to select 400 university students from a Western China public university to complete the test voluntarily. The criteria for the inclusion of participants in this study

were as follows: (1) full-time college students without any action and physical exercise disorders; (2) no mental illness or mental disorder; and (3) the ability to independently understand language and words. At each instance, the teacher provided the instructions in detail, and then, the participants filled in the questionnaire and submitted it to the teacher on the spot.

Data collection

The data collection period of this study was from May to June 2022. Two staff members independently reviewed the collected questionnaires. Incomplete or apparent contradictions in the questionnaires were regarded as invalid questionnaires. There were 192 questionnaires from the School of Physical Education (including 25 invalid questionnaires) and 208 questionnaires from the School of Teacher Education and the School of Health Caring Industry (including 39 invalid questionnaires), resulting in 336 final valid questionnaires (effective rate of 84%).

Ethical statement

The Human Academic Ethics Committee of the Sichuan University of Arts and Science approved this study (approval No. 2022SASULL–002) following the Declaration of Helsinki. All the participants completed the questionnaire after signing the informed consent, and they volunteered to participate in the survey. The data were collected with the intention to hide the participant's name and declared (before completing the questionnaire) that these data were only available for research purposes.

General demographic information survey

The participants' age, sex, BMI (body mass index), and monthly family income were counted and scored. Our previous study detailed the rules (Gong and Sheng, 2022).

PA survey

The International PA Questionnaire–Short Volume (Chinese Version) (Bassett, 2003) was used to calculate the PA of the participants. The questionnaire required the participants to recall the physical activities (including high, moderate, and low-intensity) carried out in the previous 7 days. The total amount of high-intensity, moderate-intensity, and low-intensity activities was calculated by multiplying the corresponding number of activities carried out per day with the number of days of the type of PA. Previous relevant investigations have confirmed that the scale has good reliability and validity in a survey of the Chinese population (Macfarlane et al., 2007; Deng et al., 2008).

Peer support survey

The social support scale for physical exercise (Sallis et al., 1987) was used to estimate peer support for PA. The current study drew on a report by Chen et al. (2017) which assessed peer support for physical exercise of middle school students from Fuzhou (China), and ultimately retained five independent factors, such as "changing their schedule to exercise with me." A Likert 5-point scoring method indicated that attitudes ranged from 1 (very disagree) to 5 (very agree). The internal consistency coefficient α was from 0.7 to 0.80 and the coefficient was from 0.80 to 0.90, both of which are considered good reliability (Terwee et al., 2007). The internal consistency coefficient α of peer support in the current study was 0.850, indicating good reliability. Using exploratory factor analysis, we found that the factor loadings of the five measurable variables were 0.811, 0.837, 0.798, 0.785, and 0.736, indicating that the scale had reliable validity.

A survey of exercise health belief model

The exercise health belief scale based on the HBM can more effectively predict or explain PA. Wu et al. (2020) developed a scale comprising six dimensions for Chinese adults (Wu et al., 2020), and the internal consistency coefficient of this scale α (0.609) is considered acceptable. The scale consists of perceived benefits (3 measurable variables), perceived subjective barriers (3 measurable variables), perceived objective barriers (4 measurable variables), exercise self-efficacy (5 measurable variables), perceived severity (3 measurable variables), and cues to action (3 measurable variables). The Likert 5-point scoring method indicated that attitudes ranged from 1 (very disagree) to 5 (very agree). At first, the corresponding dimensions were perceived benefits 0.628, perceived objective barriers 0.713, perceived subjective barriers 0.628, exercise self-efficacy 0.801, perceived severity 0.676, and cues to action 0.838. Previous research indicated that only those measured variables whose Cronbach's alpha coefficients are greater than or equal to 0.6 should be retained in the scale (Bagozzi and Yi, 1988). After removing the factors with a coefficient less than 0.6, the factors constituting the exercise health belief model scale were as follows: perceived benefits (3 measurable variables), perceived subjective barriers (2 measurable variables), perceived objective barriers (3 measurable variables), exercise self-efficacy (4 measurable variables), perceived severity (3 measurable variables), and cues to action (3 measurable variables). The internal consistency coefficient α of the exercise health belief model in the current research was 0.762, perceived benefits 0.712, perceived objective barriers 0.649, perceived subjective barriers 0.637, exercise self-efficacy 0.798, perceived severity 0.665, and cues to action 0.758. This showed that the scale had good reliability. The factor load analysis of the measurable variables included: perceived benefits (3 measurable variables were 0.761, 0.839, and 0.711, respectively), perceived subjective barriers (2 measurable variables were 0.690, and 0.630, respectively), perceived objective barriers (3 measurable variables were 0.711, 0.645, and 0.697, respectively), exercise self-efficacy (4 measurable variables were 0.720, 0.827, 0.662, and 0.654, respectively), perceived severity (3 measurable variables were 0.693, 0.832, and 0.732, respectively), and cues to action (3 measurable variables were 0.735, 0.850, and 0.791, respectively). The above data showed that the scale had good reliability, which was consistent with the conclusion of our previous research report (Gong and Sheng, 2022).

TABLE 1 Basic information of participants (M ± SD).

Items	Over all (336)	Men (160)	Women (176)	*P*-value
Age (year)	19.4 ± 1.3	19.4 ± 1.2	19.5 ± 1.4	0.363
BMI (kg/m^2)	21.0 ± 2.4	21.8 ± 2.1	20.3 ± 2.4	0.000
Incoming (Yuan/ month)	3.7 ± 2.3	4.1 ± 2.5	3.2 ± 2.0	0.000

TABLE 2 Physical activity (PA) of college students.

Items	H_{Q1}	H_{Q2}	H_{Q3}	M_{Q1}	M_{Q2}	M_{Q3}	L_{Q1}	L_{Q2}	L_{Q3}
All (336)	0.0	120.0	247.0	30.0	120.0	240.0	140.0	210.0	420.0
Male (160)	90.0	180.0	300.0	60.0	180.0	360.0	150.0	245.0	420.0
Female (176)	0.0	40.0	180.0	12.5	60.0	195.0	101.3	210.0	420.0
P		0.000			0.001			0.310	

Q1, first quartile; Q2, second quartile; Q3, third quartile; H, high-intensity PA; M, moderate-intensity PA; L, low-intensity PA.

Data analysis

SPSS 23.0 and Amos 23.0 were used to analyze the data. Mean ± standard deviation was used to summarize the participants' demographic characteristics, peer support of physical exercise, exercise health belief characteristics and PA. Independent *T*-tests were used to evaluate the differences between male and female students in peer support, exercise health belief and PA. Variance analysis was used to evaluate the interaction between peer support, exercise health belief and PA. Amos 23.0 software was used to evaluate the hypothetical model fit, the direct/indirect relationship among peer support, the constituent elements of the exercise health belief model and PA. We followed the two-step method proposed by Gerbing and Anderson (1988): The first step used confirmatory analysis to evaluate the effectiveness of the measurement model (Gerbing and Anderson, 1988) and the second step used the SEM analysis to measure the fitness and path coefficient of the model. According to the suggestions of scholars, CMID/DF, GFI, AGFI, RMSEA, SRMR, TLI, IFI, and CFI were used to estimate the model's fitness, and the difference was statistically significant at a *P*-value of < 0.05.

Results

Characteristics of participants

The survey results showed that the PA level of male university students was significantly higher than that of female students in high-intensity and moderate-intensity; but there was no significant difference in low-intensity PA (Tables 1, 2).

To compare the differences between male and female university students in peer support and exercise health belief, we used an independent sample *T*-test to evaluate. We found that male university students' peer support was significantly higher than that of female students. Among the constituent elements of the health belief model scale for exercise, male university students' scores of perceived subjective and objective barriers were lower than those of female students, and their exercise self-efficacy was significantly higher than that of female students (Figures 1A, B).

Relationship between peer support, exercise health belief model, and PA of college students

Through Pearson correlation analysis, we found that peer support significantly correlated with perceived benefits, exercise self-efficacy, perceived severity, and cues to action, and was negatively associated with perceived objective and subjective barriers. It significantly correlated with high, moderate, and low-intensity PA. Perceived benefits were significantly associated with moderate-intensity PA, and perceived objective barriers and perceived subjective barriers were significantly associated with high, moderate, and low-intensity PA (and the correlation coefficient between perceived subjective barriers and PA level parameters were more significant than that of perceived objective barriers); exercise self-efficacy was significantly positively correlated with the PA. Perceived severity was significantly correlated with moderate-intensity PA. No significant correlation was found between cues to action and PA (Table 3).

Structural equation model has been used widely in the research of social sciences. For example, it was used to assess the association between self-efficacy, social support, and the PA level of Peking University students in China (Wang et al., 2019). A survey and SEM of 2206 fourth-grade students and their parents in Turkey found that (Mirzayi et al., 2021) students' self-efficacy was significantly correlated with moderate and high-intensity PA, and negatively correlated with sedentary behavior. Therefore, we initially attempted to build an SEM of the health belief model for exercise, the peer support, and the PA of university students. After further statistical analysis, we found that only exercise self-efficacy significantly affected university students' PA. Hence, we constructed an SEM of exercise self-efficacy, peer support, and university students' PA (see Figure 2), and a grouping model of male and female university students (see Figure 3). According to the total SEM, the effect of peer support on university students' PA was 0.14, and the indirect effect was 0.27 (0.47 * 0.58). The indirect effect was more significant than the direct effect, suggesting that exercise self-efficacy mediated the relationship between peer support and PA. The effect of exercise self-efficacy on university students' PA was 0.58, and the effect of exercise self-efficacy on PA was substantially more significant than that of peer support (see Figure 2). Further analysis showed no interaction between peer support and exercise self-efficacy in the relationship between PA. The exciting discovery was that the results of the grouping model showed that the effect of exercise self-efficacy on PA in the male group was 0.63, which was more significant than 0.48 in the female group. The model fitting of the SEM of male students was better that of female students (Figure 3). Although the impact of peer support on PA was less than that of exercise self-efficacy, and the direct effect of peer support was less than the indirect effect, the impact of peer support on the PA of female college students was higher than that of male students.

Discussion

The main findings of this survey are as follows: (1) Male university students' peer support was markedly higher than that of female university students, and moderate to high-intensity PA

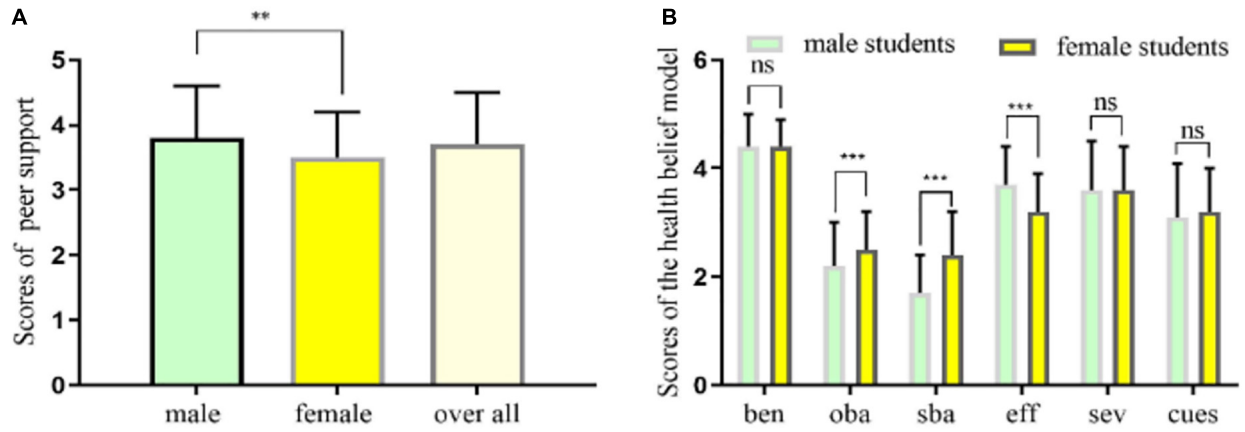


FIGURE 1
(A,B) Male college students' sup was significant higher than female, the scores of sba and oba was significant lower than female, and eff-e was significant higher than female. ben, perceived benefits; sba, perceived subjective barriers; oba, perceived objective barriers; sev, perceived severity; cues, cues to action; eff-e, exercise self-efficacy. $^{**}p < 0.01$, $^{***}p < 0.001$, ns, there was no statistical difference between two groups.

TABLE 3 Relationship between peer support, Health Belief Model Scale for Exercise, and physical activity (PA) (n = 336).

Items	sup	ben	oba	sba	eff-e	sev	cues
ben	0.186**	–	–	–	–	–	–
oba	−0.432***	−0.114*	–	–	–	–	–
sba	−0.376***	−0.172**	0.473***	–	–	–	–
eff-e	0.391***	0.207***	−0.426***	−0.641***	–	–	–
sev	0.161**	0.129*	−0.079	−0.137*	0.168**	–	–
cues	0.308***	0.069	−0.100	0.050	0.186**	0.165**	–
H	0.272***	0.141**	−0.274***	−0.358***	0.429***	0.049	0.020
M	0.251***	0.142**	−0.285***	−0.336***	0.399***	0.129*	0.061
L	0.119*	0.085	−0.131*	−0.189**	0.243***	0.050	0.024

$^{*}p < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$. sup, peer support; ben, perceived benefits; oba, perceived objective barriers; sba, perceived subjective barriers; eff-e, self-efficacy of exercise; sev, perceived severity; cues, cues to action. H, high-intensity PA; M, moderate-intensity PA; L, low-intensity PA.

was significantly higher than that of female university students. In terms of the constituent elements of the exercise health belief model, compared with female university students, male university students had higher exercise self-efficacy and lower perceived subjective barriers and perceived objective barriers, and other factors had no significant difference. (2) Peer support was significantly positively correlated with perceived benefits, exercise self-efficacy, perceived severity, and cues to action. It was negatively correlated with perceived subjective barriers and perceived objective barriers, and was significantly positively correlated with high-intensity, moderate-intensity, and low-intensity PA. Perceived subjective and objective barriers were negatively correlated with high-intensity, moderate-intensity, and low-intensity PA. Perceived benefits and exercise self-efficacy were significantly correlated with high-intensity and moderate-intensity PA. (3) Based on the SEM analysis, we found that peer support and exercise self-efficacy significantly affected university students' PA, and exercise self-efficacy was higher than that of peer support. Through further grouping, we found that female university students' peer support impact on PA was higher than that of male students, and the impact of exercise self-efficacy on PA was lower than that of male students, reflecting significant gender differences.

Relationship between demographic information and PA

Insufficient or lack of PA is a complex and long-term problem that needs to be evaluated for many factors. In the process of individual development, boys were more active than girls, and their level of PA was higher than girls. Hopkins et al. (2022) found that the self-concept related to physical exercise was closely related to the physical exercise of female adolescents through a comprehensive analysis. The study emphasized the need for improvement in macro and micro aspects to improve adolescents' PA and promote fairness (Ricardo et al., 2022). The most significant barriers for girls to participate in PA most likely came from personal factors, such as the values and support of family and friends, a safe environment and the opportunity to participate in PA in school (Guthold et al., 2022). In our study, we found that male university students' PA was higher than that of females, consistent with the overall gender differences in PA in adolescence. A previous study showed that in exercise practice at the middle school stage, female physical education (PE) teachers were more popular with male students in middle school, and male PE teachers were more popular with female students (Cruz et al., 2021). This investigation affirmed that we should pay attention to the course content, and create a good relationship between teachers and students in the PE curriculum.

The relationship between peer support and the PA of college students

With increasing age, the effect of peers on PA gradually became more remarkable than that of family and had significant gender characteristics. Hong et al. (2020) surveyed 61,429 school-age children (aged 6–18, boys accounted for 50.7%) and their families in Shanghai (China). They found that boys were more active than girls, and the survey also showed that girls were more vulnerable

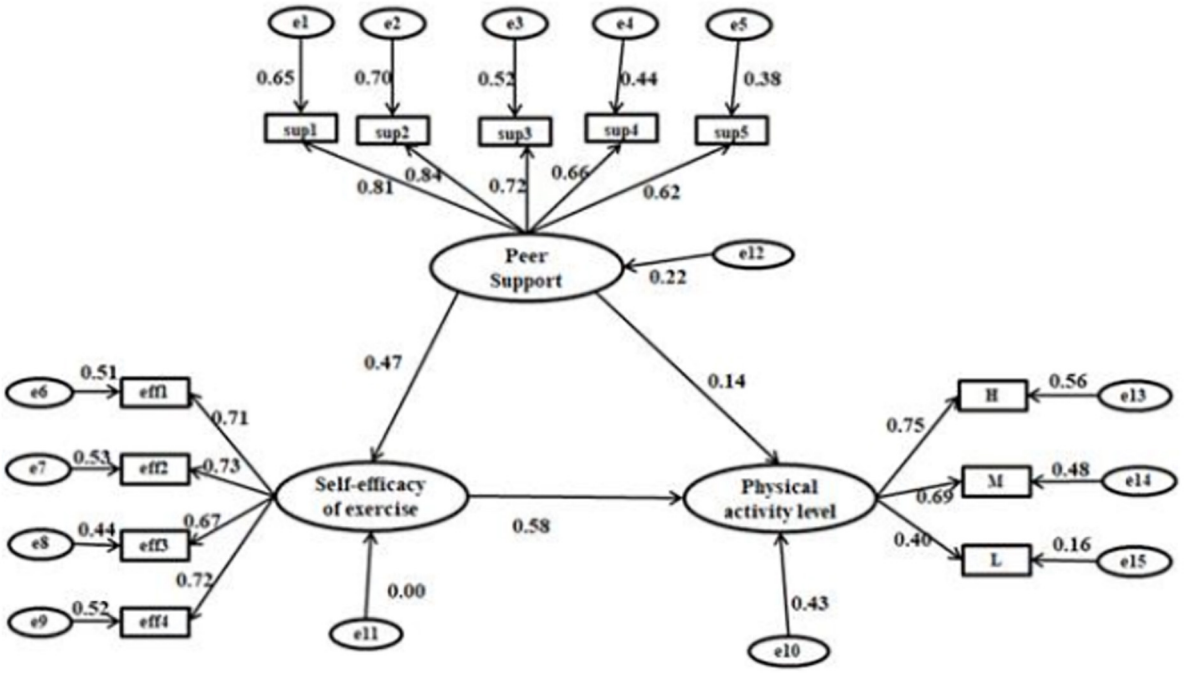


FIGURE 2
The overall structural equation model. Model–fit indices were statistically acceptable (CMID/DF = 2.778, GFI = 0.926, AGFI = 0.892, RMSEA = 0.073, p = 0.001, CFI = 0.926, IFI = 0.906).

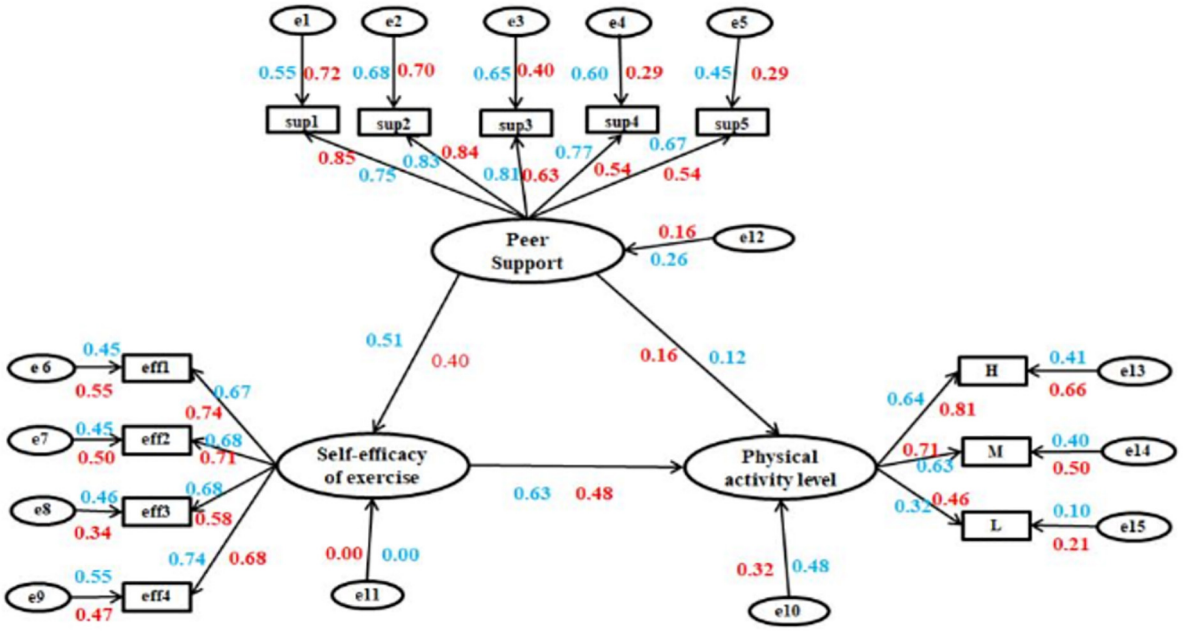


FIGURE 3
The grouping structural equation model. The light blue represents the data of male college students, and red represents the data of female. In the male group: CMID/DF = 1.948, GFI = 0.905, AGFI = 0.855, RMSEA = 0.073, p = 0.001, CFI = 0.929, IFI = 0.932, RMSEA = 0.05–0.08, it indicated model-fit was good. In the female group: Model–fit indices was acceptable. CMID/DF = 2.204, GFI = 0.904, AGFI = 0.853, RMSEA = 0.083, p = 0.001, CFI = 0.908, IFI = 0.911, RMSEA = 0.08–0.10, it indicated that model-fit was acceptable.

to family factors than boys. The research suggested that paying attention to the role model of parents' physical exercise may be more important than other factors (Hong et al., 2020). Khan and Uddin (2020) investigated Malaysian adolescents (aged 11–17, boys accounted for 49%) and their families, where 15.3% reported having a positive lifestyle, of which 22% were boys and 8.8% were girls, 47% reported having a higher level of peer support, and 31% reported having higher parental support (Khan and Uddin, 2020). Higher parental support significantly correlated with the positive lifestyle of boys, and girls with higher parental support had a higher

probability of a positive lifestyle, while girls aged 11–14 years had a more significant correlation between peer support and a positive lifestyle. Peterson et al. (2013) conducted a cross-sectional survey of sixth-grade students from South Carolina and found that the instrumental social support of parents significantly correlated with girls' PA. It was worth noting that the emotional support of parents negatively correlated with the PA of girls, and self-efficacy mediated the relationship between parents' instrumental social support and boys' PA (Peterson et al., 2013).

Kulik et al. (2014) found that increasing peer support for 4 months significantly increased the PA of American girls, who eventually lost weight. Gruber (2008) surveyed American college students (North Carolina State University) and found that compared with men, women's reports showed that their healthy eating behavior and exercise habits were more supported. The study further found gender differences in the composition of peers. For example, when more than half of their friends were men, female students received more support in physical exercise and good eating habits. When more than half of their peers or friends were female students, male students reported the highest level of peer support. On the other hand, when more than half of their peers were men, male students' exercise habits received a higher evaluation. When most of their peers or friends were female students, female students reported the highest level of peer support. In our study, male university students' peer support was significantly higher than female students. However, the peer support of female university students was higher than that of male university students in the impact of PA, and self-efficacy played a mediating role in the relationship between peer support and PA.

Effect of exercise self-efficacy on the relationship between peer support and the PA of college students

Exercise self-efficacy is the confidence to perform physical exercise behavior, which was compared to internal motivation. However, peer support could be compared to the external support environment for individual physical exercise and termed external cause. Self-efficacy and perceived barriers were the two action items that affect exercise behavior in the exercise health belief and were the main factors that predict or explain the level of PA (Fletcher and Banasik, 2001). Better exercise compliance was significantly related to increased exercise self-efficacy. A cross-sectional investigation of 101 menopausal women from Queensland was conducted by Barnett and Spinks (2007). This survey showed that participants with high self-efficacy in the preceding 7 days had a significantly greater capacity to overcome barriers to physical exercise than those with low self-efficacy. The study suggested that improving exercise self-efficacy helps to reduce perceived barriers to exercise and helps to assist menopausal women in obtaining health benefits from physical exercise. As an essential predictor of exercise behavior adoption and maintenance, exercise self-efficacy could express a person's confidence in successfully performing physical exercise (Fletcher and Banasik, 2001), but it could also significantly predict the PA level of sedentary individuals (McAuley and Jacobson, 1991). For example, Hamilton et al. (2017) found that self-efficacy became the main predictor (intrinsic motivation) of violent adolescent sports, followed by support (extrinsic support) of friends; furthermore, friends' support and self-efficacy were interrelated (Hamilton et al., 2017). In the youth group with high self-efficacy, the intention of PA had nothing to do with peer support. In the group with low self-efficacy, the physical exercise activities of peers made up for the lack of self-efficacy. The research suggested that, for the group with poor self-efficacy, giving enough peer exercise peer support is an effective way to promote their participation in physical exercise. Spence et al. (2010) surveyed young people from Alberta (Canada) and found that self-efficacy had a stronger correlation with girls' PA (Spence et al., 2010). In our research, exercise self-efficacy was the most significant factor in explaining PA, whether in the overall model or the group model, which is consistent with the conclusion of Hamilton et al. (2017). Furthermore, in our study, a stronger correlation was found between exercise self-efficacy and PA of male college students (0.63 vs. 0.48) in the group analysis, which is significantly different from the findings of Spence et al. (2010). Our study also showed that, in the relationship between peer support and PA, the correlation coefficient of female university students was higher than that of male university students.

Seo and Ha (2019) conducted a cross-sectional study of college students from South Korea. They found that the factors affecting the PA of male college students were exercise self-efficacy and personal economic level. In contrast, the factors affecting the PA of female college students were exercise self-efficacy, subjective health status, activity-related emotions, and peer support (Seo and Ha, 2019). It suggested that gender differences should be considered when focusing on exercise self-efficacy and plans. Xue-Liu and Mu (2021) surveyed 801 college students at a university in Chongqing in Southwest China; using the college students' health belief model scale for exercise and PA rating scale (PARS-3) (Xue-Liu and Mu, 2021), multiple regression analysis showed that perceived exercise benefits, self-efficacy, and exercise volume were positively correlated. The effect of physical health belief-based self-efficacy on exercise volume was greater than that of perceived exercise benefits. Aware of the severity of illness and weakness, their research suggested that the self-efficacy of physical evaluation can strongly predict the amount of exercise of college students. Their data processing used a multiple regression equation related to the single equation model method. Regression analysis can only deal with dominant variables, while SEM can more effectively find potential variables. A multiple regression model has only one dependent variable and is unidirectional, while SEM could be unidirectional or bidirectional. A multiple regression model, was the basis of their study. However, in terms of statistical methods, SEM has its advantages. In our study, using SEM, we found that only exercise self-efficacy significantly correlated with college students' PA in exercise health belief. We also found that exercise self-efficacy significantly mediated between university students' peer support and PA.

Limitations and future directions

Although this study investigated peer support, exercise health beliefs, and PA of Chinese university students, analyzed exercise self-efficacy's significant mediating role in the relationship between peer support and PA, and initially explored the practical path to promote university students' extracurricular physical exercise, it still had the following limitations. First, the sampling method used in this study was random sampling, which may not accurately represent the situation of the whole school. Therefore, the stratified

sampling method should be used in future research. Second, this investigation was a cross-sectional survey, and the data obtained could not provide conclusive evidence of causality between variables. Therefore, future studies should include longitudinal cohort studies and further evaluate the impact of increasing health education on exercise health belief and PA. Third, the data collected in this study were only from one public university in Western China, which means that the conclusions obtained in this study have significant regional characteristics, and need to be carefully inferred when applying them to colleges and universities in other regions of China. Therefore, future research should fully consider more geographical factors (coastal cities in eastern China, cities in the southeast, cities in the north, etc.), the attributes of colleges (public vs. private), and larger sample sizes.

Conclusion

This study revealed the impact of exercise self-efficacy and peer support on university students' PA, suggesting that exercise self-efficacy is the main path to promoting university students' PA, followed by peer support. Peer support affects university students' PA not only through direct effects but also through indirect effects. This study suggests that female university students' peer support impacts PA more than males. This research finding provides ideas for more effective future development and guidance of physical exercise practice. When formulating physical exercise courses in the future, it is necessary to plan for more peer support for female college students to compensate for their inadequate exercise self-efficacy.

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 Sichuan University of Arts and Science (approval No. 2022SASULL–002). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JS and LG: conceptualization, data curation, writing—original draft preparation, and resources. JS: methodology and writing—review and editing. LG and JZ: investigation. All authors have read and agreed to the published version of the manuscript.

Funding

This research received funding from the Zigong City Health Humanities Center Project (JKYW-2021-18).

Acknowledgments

The authors thank the subjects for participating in this survey.

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

Agans, J. P., Su, S., and Ettekal, A. V. (2018). Peer motivational climate and character development: testing a practitioner-developed youth sport model. *J. Adolesc.* 62, 108–115. doi: 10.1016/j.adolescence.2017.11.008

Bagozzi, R. P., and Yi, Y. (1988). On the evaluation of structural equation models. *J Acad Mark Sci.* 16, 74–94. doi: 10.1007/BF02723327

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84, 191–215. doi: 10.1037//0033-295x.84.2.191

Barnett, F., and Spinks, W. L. (2007). Exercise self-efficacy of postmenopausal women resident in the tropics. *Maturitas* 58, 1–6. doi: 10.1016/j.maturitas.2007.04.003

Bassett, D. R. Jr. (2003). International physical activity questionnaire: 12-country reliability and validity. *Med. Sci. Sports Exerc.* 35:1396. doi: 10.1249/01.Mss.0000078923.96621.1d

Chen, H., Sun, H., and Dai, J. (2017). Peer support and adolescents' physical activity: the mediating roles of self-efficacy and enjoyment. *J. Pediatr. Psychol.* 42, 569–577. doi: 10.1093/jpepsy/jsw103

Cho, S. H., and Lee, H. (2013). Factors associated with physical activity among Chinese immigrant women. *J. Korean Acad. Nurs.* 43, 760–769. doi: 10.4040/jkan.2013.43.6.760

Cruz, A. B., Kim, M., and Kim, H. D. (2021). Physical education attitude of adolescent students in the philippines: importance of curriculum and teacher sex and behaviors. *Front. Psychol.* 12:658599. doi: 10.3389/fpsyg.2021.658599

Deng, H. B., Macfarlane, D. J., Thomas, G. N., Lao, X. Q., Jiang, C. Q., Cheng, K. K., et al. (2008). Reliability and validity of the IPAQ-Chinese: the guangzhou biobank cohort study. *Med. Sci. Sports Exerc.* 40, 303–307. doi: 10.1249/mss.0b013e31815b0db5

Dong, B. L. (2017). Investigation and analysis of the influence of health belief and social support on teenager physical exercise. *J. Phys. Educ.* 24, 115–122.

Fletcher, J. S., and Banasik, J. L. (2001). Exercise self-efficacy. *Clin. Excell. Nurse Practit. Int. J. NPACE* 5, 134–143.

Gerbing, D. W., and Anderson, J. C. (1988). An updated paradigm for scale development incorporating unidimensionality and its assessment. *J. Mark. Res.* 25, 186–192. doi: 10.1177/002224378802500207

Gong, L., and Sheng, J. (2022). The current health belief of exercise conditions of Chinese college students and ways of improvements: an analysis based on the health belief model. *Front. Psychol.* 13:906297. doi: 10.3389/fpsyg.2022.906297

Gristwood, J. (2011). Applying the health belief model to physical activity engagement among older adults. *Illuminare* 9, 59–71.

Gruber, K. J. (2008). Social support for exercise and dietary habits among college students. *Adolescence* 43, 557–575.

Guthold, R., Willumsen, J., and Bull, F. C. (2022). What is driving gender inequalities in physical activity among adolescents? *J. Sport Health Sci.* 11, 424–426. doi: 10.1016/j.jshs.2022.02.003

Hamilton, K., Warner, L. M., and Schwarzer, R. (2017). The role of self-efficacy and friend support on adolescent vigorous physical activity. *Health Educ. Behav.* 44, 175–181. doi: 10.1177/1090198116648266

Hong, J. T., Chen, S. T., Tang, Y., Cao, Z. B., Zhuang, J., Zhu, Z., et al. (2020). Associations between various kinds of parental support and physical activity among children and adolescents in Shanghai, China: gender and age differences. *BMC Public Health* 20:1161. doi: 10.1186/s12889-020-09254-8

Hopkins, C. S., Hopkins, C., Kanny, S., and Watson, A. (2022). A systematic review of factors associated with sport participation among adolescent females. *Int. J. Environ. Res. Public Health* 19:353. doi: 10.3390/ijerph19063353

Hosseini, H., Moradi, R., Kazemi, A., and Shahshahani, M. S. (2017). Determinants of physical activity in middle-aged woman in Isfahan using the health belief model. *J. Educ. Health Promot.* 6:26. doi: 10.4103/jehp.jehp_68_15

Kaushal, N., Preissner, C., Charles, K., and Knäuper, B. (2021). Differences and similarities of physical activity determinants between older adults who have and have not experienced a fall: testing an extended health belief model. *Arch. Gerontol. Geriatr.* 92:104247. doi: 10.1016/j.archger.2020.104247

Khan, A., and Uddin, R. (2020). Parental and peer supports are associated with an active lifestyle of adolescents: evidence from a population-based survey. *Public Health* 188, 1–3. doi: 10.1016/j.puhe.2020.08.024

Khan, S. R., Uddin, R., Mandic, S., and Khan, A. (2020). Parental and peer support are associated with physical activity in adolescents: evidence from 74 countries. *Int. J. Environ. Res. Public Health* 17:435. doi: 10.3390/ijerph17124435

Klint, K. A., and Weiss, M. R. (1987). Perceived competence and motives for participating in youth sports: a test of harter's competence motivation theory. *J. Sport Exerc. Psychol.* 9, 55–65. doi: 10.1123/jsp.9.1.55

Kulik, N. L., Fisher, E. B., Ward, D. S., Ennett, S. T., Bowling, J. M., and Tate, D. F. (2014). Peer support enhanced social support in adolescent females during weight loss. *Am. J. Health Behav.* 38, 789–800. doi: 10.5993/ajhb.38.5.16

Ling, J., Robbins, L. B., Resnicow, K., and Bakhoya, M. (2014). Social support and peer norms scales for physical activity in adolescents. *Am. J. Health Behav.* 38, 881–889. doi: 10.5993/ajhb.38.6.10

Luo, J., Tang, Y., Li, P., and Gong, L. Z. (2011). Relations between the extracurricular physical exercising behavior choices of teenagers in chongqing city and restricting factors. *J. Phys. Educ.* 18, 94–100. doi: 10.3969/j.issn.1006-7116.2011.06.020

Macfarlane, D. J., Lee, C. C., Ho, E. Y., Chan, K. L., and Chan, D. T. (2007). Reliability and validity of the Chinese version of IPAQ (short, last 7 days). *J. Sci. Med. Sport* 10, 45–51. doi: 10.1016/j.jsams.2006.05.003

McAuley, E., and Jacobson, L. (1991). Self-efficacy and exercise participation in sedentary adult females. *Am. J. Health Promot.* 5, 185–191. doi: 10.4278/0890-1171-5.3.185

Mirzayi, C., Ferris, E., Ozcebe, H., Swierad, E., Arslan, U., Ünlü, H., et al. (2021). Structural equation model of physical activity in Turkish schoolchildren: an application of the integrated behavioural model. *BMJ Open* 11:e046317. doi: 10.1136/bmjopen-2020-046317

Ouyang, Y., Wang, K., Zhang, T., Peng, L., Song, G., and Luo, J. (2019). The influence of sports participation on body image, self-efficacy, and self-esteem in college students. *Front. Psychol.* 10:3039. doi: 10.3389/fpsyg.2019.03039

Peterson, M. S., Lawman, H. G., Wilson, D. K., Fairchild, A., and Van Horn, M. L. (2013). The association of self-efficacy and parent social support on physical activity in male and female adolescents. *Health Psychol.* 32, 666–674. doi: 10.1037/a0029129

Rahmati-Najarkolaei, F., Tavafian, S. S., Gholami Fesharaki, M., and Jafari, M. R. (2015). Factors predicting nutrition and physical activity behaviors due to cardiovascular disease in tehran university students: application of health belief model. *Iran Red. Crescent Med. J.* 17:e18879. doi: 10.5812/ircmj.18879

Rajbhandari-Thapa, J., Metzger, I., Ingels, J., Thapa, K., and Chiang, K. (2022). School climate-related determinants of physical activity among high school girls and boys. *J. Adolesc.* 94, 642–655. doi: 10.1002/jad.12052

Ricardo, L. I. C., Wendt, A., Costa, C. D. S., Mielke, G. I., Brazo-Sayavera, J., Khan, A., et al. (2022). Gender inequalities in physical activity among adolescents from 64 Global South countries. *J. Sport Health Sci.* 11, 509–520. doi: 10.1016/j.jshs.2022.01.007

Sallis, J. F., Grossman, R. M., Pinski, R. B., Patterson, T. L., and Nader, P. R. (1987). The development of scales to measure social support for diet and exercise behaviors. *Prev. Med.* 16, 825–836. doi: 10.1016/0091-7435(87)90022-3

Sanz-Martín, D., Melguizo-Ibáñez, E., Ruiz-Tendero, G., and Ubago-Jiménez, J. L. (2022). An explanatory model of the relationships between physical activity, social support and screen time among adolescents. *Int. J. Environ. Res. Public Health* 19:463. doi: 10.3390/ijerph19127463

Seo, Y. J., and Ha, Y. (2019). Gender differences in predictors of physical activity among Korean college students based on the health promotion model. *Asian Pac. Isl. Nurs. J.* 4, 1–10. doi: 10.31372/20190401.1000

Shafieian, M., and Kazemi, A. (2017). A randomized trial to promote physical activity during pregnancy based on health belief model. *J. Educ. Health Promot.* 6:40. doi: 10.4103/jehp.jehp_19_15

Soleymanian, A., Niknami, S., Hajizadeh, E., Shojaeizadeh, D., and Montazeri, A. (2014). Development and validation of a health belief model based instrument for measuring factors influencing exercise behaviors to prevent osteoporosis in pre-menopausal women (HOPE). *BMC Musculoskelet Disord* 15:61. doi: 10.1186/1471-2474-15-61

Spence, J. C., Blanchard, C. M., Clark, M., Plotnikoff, R. C., Storey, K. E., and McCargar, L. (2010). The role of self-efficacy in explaining gender differences in physical activity among adolescents: a multilevel analysis. *J. Phys. Act Health* 7, 176–183. doi: 10.1123/jpah.7.2.176

Terwee, C. B., Bot, S. D., de Boer, M. R., van der Windt, D. A., Knol, D. L., Dekker, J., et al. (2007). Quality criteria were proposed for measurement properties of health status questionnaires. *J. Clin. Epidemiol.* 60, 34–42. doi: 10.1016/j.jclinepi.2006.03.012

Treiber, F. A., Baranowski, T., Braden, D. S., Strong, W. B., Levy, M., and Knox, W. (1991). Social support for exercise: relationship to physical activity in young adults. *Prev. Med.* 20, 737–750. doi: 10.1016/0091-7435(91)90068-f

Wang, J. (2019). The association between physical fitness and physical activity among Chinese college students. *J. Am. Coll. Health* 67, 602–609. doi: 10.1080/07448481.2018.1515747

Wang, T., Ren, M., Shen, Y., Zhu, X., Zhang, X., Gao, M., et al. (2019). The association among social support, self-efficacy, use of mobile apps, and physical activity: structural equation models with mediating effects. *JMIR Mhealth Uhealth* 7:e12606. doi: 10.2196/12606

World Health Organization [WHO] (2022). *Physical Activity*. Available online at: www.who.int/news-room/fact-sheets/detail/physical-activity (accessed October 5, 2022).

Wu, S., Feng, X., and Sun, X. (2020). Development and evaluation of the health belief model scale for exercise. *Int. J. Nurs. Sci.* 7, S23–S30. doi: 10.1016/j.ijnss.2020.07.006

Xue-Liu, L., and Mu, X. (2021). The positive effect of perceived exercise benefit and the negative effect of perceived severity of disease and weakness on college students' amount of exercise: the mediate and suppressor role of physical fitness evaluation self-efficacy. *Front. Psychol.* 12:762865. doi: 10.3389/fpsyg.2021.762865

Yang, S. (2016). Relationship between social support, self-efficiency and satisfaction of youth physical activity. *J. Wuhan Inst. Phys. Ed.* 50, 90–94. doi: 10.15930/j.cnki.wtxb.2016.02.015

frontiers | Frontiers in Psychology

TYPE Review
PUBLISHED 22 February 2023
DOI 10.3389/fpsyg.2023.1095238

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Morteza Taheri,
Imam Khomeini International University, Iran
Jovan Gardasevic,
University of Montenegro, Montenegro

*CORRESPONDENCE
Okba Selmi
✉ okbaselmii@yahoo.fr
Katsuhiko Suzuki
✉ katsu.suzu@waseda.jp

†These authors share last authorship

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

RECEIVED 10 November 2022
ACCEPTED 03 February 2023
PUBLISHED 22 February 2023

CITATION
Selmi O, Ouergui I, Muscella A, Levitt DE, Suzuki K and Bouassida A (2023) Monitoring mood state to improve performance in soccer players: A brief review.
Front. Psychol. 14:1095238.
doi: 10.3389/fpsyg.2023.1095238

Monitoring mood state to improve performance in soccer players: A brief review

Okba Selmi[1,2,3]*, Ibrahim Ouergui[1,2], Antonella Muscella[4], Danielle E. Levitt[5], Katsuhiko Suzuki[6]*† and Anissa Bouassida[1,2†]

[1]High Institute of Sports and Physical Education of Kef, University of Jendouba, El Kef, Tunisia, [2]Research Unit: Sportive Sciences, Health and Movement, El Kef, Tunisia, [3]High Institute of Sports and Physical Education, Ksar Said, University of Manouba, Tunis, Tunisia, [4]Department of Biological and Environmental Science and Technologies, University of Salento, Lecce, Italy, [5]Department of Kinesiology and Sport Management, Texas Tech University, Lubbock, TX, United States, [6]Faculty of Sport Sciences, Waseda University, Saitama, Japan

Introduction: Psychological aspects of sport are key in maintaining athlete motivation and make a difference in competitive outcomes. Adjustments to training may be necessary according to athletes' emotional state. Therefore, it is important to assess and quantify mood states throughout the season in team sports, including among soccer players. The Profile of Mood States (POMS) is a widely used questionnaire that assesses emotional states characterized by positive or negative feelings and can be administered repeatedly to assess changes in mood state. This review aims to assess and summarize the current literature on mood state variation in soccer players with a specific focus on training loads, training modalities, and competitive performance.

Methods: A literature search was systematically conducted and resulted in 156 records. After removing duplicates, items with irrelevant titles and abstracts were screened out, and full texts were then screened for relevance and compared with inclusion and exclusion criteria. The remaining 37 articles were included in the final qualitative synthesis.

Results: POMS scores were related to variability in training load, intensity of the training period, modality of training exercises, competitive performance and time of day in soccer players. Common recommendations include monitoring the mood state of soccer players during training sessions, matches, and throughout training periods to detect early signs of psychological disturbance and aid in optimizing high-level training performance.

Conclusion: The POMS allows for monitoring of players' psychological state, providing coaches with data to aid in adjusting acute program variables according to players' psychological states and improve performance. Results offer practical support for the use of a simple POMS measurement as part of an overall program to monitor the players' psychological states. Results also highlight how training choices (i.e., load and exercise modality) and competitive performance are related to mood states (i.e., tension, anger, confusion, depression, fatigue, and vigor).

KEYWORDS

soccer, affect, exercise training, psychology, athletic performance

1. Introduction

Optimization of sport performance is linked to multiple factors such as physical, technical, tactical, and cognitive skills. The importance of mental health as a factor in sport performance is becoming increasingly recognized, including among soccer players (Soylu et al., 2021). Mental health is a concept that includes emotional, psychological and social states of athletes and affects the way they feel, react, and behave (Souter et al., 2018; Russell et al., 2020). Among the many dimensions of mental health is mood state which may change in response to the daily and periodic challenges that soccer players face (Selmi et al., 2017). Additive stressors from soccer players' personal lives, wellbeing, and sport training can influence mood state (Yagmaee, 2021). It is clear that soccer performance is closely linked to mental health in general and to mood state specifically (Yagmaee, 2021).

It is well known that in the field of sport, mood state is affected by psychophysiological responses (Soylu et al., 2021) and influenced by various factors such as training modality (Selmi et al., 2017), training load (TL; Beykzade et al., 2011; Watson et al., 2017; Botelho et al., 2022), competitive performance (Filaire et al., 2001; Casanova et al., 2016) and motivation and concentration of athletes during training (Aydi et al., 2022). Therefore, sport psychologists have sought to develop and validate reliable tools and inventories to assess athletes' mood states (Filaire et al., 2001; Saidi et al., 2020). In fact, the validated Profile of Mood States (POMS) questionnaire has been widely used to assess mood state in different sport situations such as during individual training sessions, throughout training periods, and before or after competitions (Miranda et al., 2013; Saidi et al., 2020; Selmi et al., 2020). Additionally, this tool has been widely used to explore the relationship between training modalities, TL and athletes' psychological state (Lovell et al., 2010; Aydi et al., 2022). For that reason, it is suggested that psychological state should be assessed during training to control and prevent negative mood states that are related to training intensity and exercises' modalities.

Increased TL during intense training periods in soccer is associated with a lack of concentration, negative feelings, uncertainty, and mental fatigue (Smith et al., 2016), which are reflected by mood and behavior changes, increased anxiety and aggressiveness, indifference, irritability, and sleep disturbance (Selmi et al., 2020). Sleep quality is a key and vital factor which can affect athletes' mood state (Paryab et al., 2021). In fact, sleep loss is detrimental to vigor and attention and increases fatigue, confusion, depression, and tension (Benjamin et al., 2019, 2020). Moreover, sleep is essential to maintain adequate recovery and stress tolerance among soccer athletes, and needs increase with TL (De Morais Ferreira et al., 2022). Because of the potential implications of psychological aspects of sport, a great deal of attention has been focused on the impact of high TL on mood. Several studies have confirmed that mood disturbances increase during heavy training periods (Smith et al., 2016; Botelho et al., 2022) alongside physiological variations (Filaire et al., 2001; Silva et al., 2008). Based on this body of work, Smith et al. (2016) suggested that negative affective responses and reduced performance may be related to physical fatigue accumulation, while positive affective responses during the taper period were associated with positive physiological changes and higher performance (Filaire et al., 2001; Beykzade et al., 2011). This is likely due to fatigue reduction and recovery during taper which allow for improved physical performance (Schmikli et al., 2011).

Additionally, mood state variation has been associated with performance achievement or failure (Jones et al., 2010; Miranda et al., 2013; Casanova et al., 2016; Picoli and Bueno, 2022). Therefore, mood regulation strategies may be beneficial for the competitive performance among soccer players (Hashim et al., 2011; Bijukumar, 2021). Mood regulation is associated with training modalities and player motivation (Selmi et al., 2017). In fact, verbal encouragement, a form of motivational training, improved mood state and resulted in greater self-reported physical enjoyment among young soccer players (Aydi et al., 2022). Using the POMS to monitor players' mood state may allow the technical staff of the soccer teams to better adapt TL, improve programming and select motivational training exercises to maximize performance *via* improved mood state.

This brief review summarizes the current literature on mood state variation in soccer players in the following areas: (1) TL and training period; (2) exercises modality; (3) competitive performance; and time of day. Additionally, a discussion of the impact of training on mood state is presented. Practical applications and future research are suggested.

2. Materials and methods

2.1. Search strategy

This review included studies that examined the effect of training on mood state within soccer players. The literature search was performed using PubMed, Scopus, Web of Science, and Google Scholar and included articles published until August 10, 2022. The oldest article retrieved was published in 2001. Moreover, we performed manual searches of relevant journals and reference lists obtained from published articles. The following English terms and key words were searched using Boolean operators: "mood state" AND "soccer" combined with the key words "training load," "training period," "training exercise" and "performance"(i.e., "mood state" AND "soccer" AND "training load," "mood state" AND "soccer" AND "training period," "mood state" AND "soccer" AND "training exercise," and "mood state" AND "soccer" AND "performance"). The inclusion criteria for these articles were: (1) the original studies were published in English; (2) data concerning training load, training period, exercise training or performance; (3) players included soccer players; and (4) studies examined mood state. The exclusion criteria were: (1) studies that included sports other than soccer; (2) studies that did not include any of the parameters evaluated in this review; and (3) reviews, commentaries, interviews or expert opinions, posters, or book chapters (Figure 1).

Two authors independently extracted and reviewed study data to verify if a given study met the inclusion criteria. Disagreements between the two authors on the inclusion criteria were resolved by a third author with experience in the field.

2.2. Definition and measurement of mood state

According to Lane (2001), mood is a set of sensations varying in intensity and duration. Chennaoui et al. (2016) reported that emotional mood contributes to an athletes' likelihood of success or failure in relation to training. This concept refers to the change in emotional state. Athletes may think of this dichotomously and report

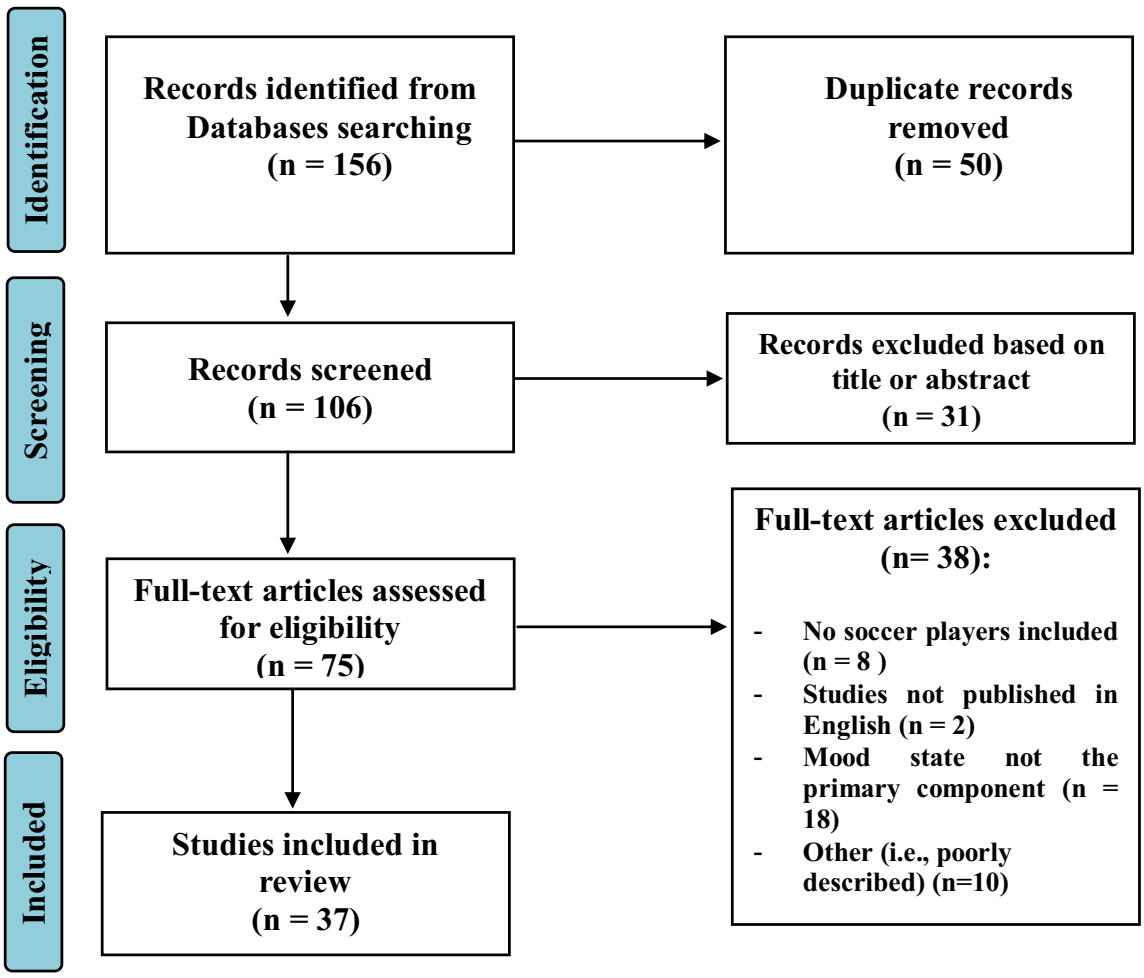


FIGURE 1
Flowchart describing the study selection process.

being in a good or bad mood characterized by overall positive or negative feelings, respectively (Selmi et al., 2020).

To identify practical assessments, researchers examined various psychological dimensions related to training that require less technology such as mood state questionnaires which have been actively researched in recent years (Saidi et al., 2020; Aydi et al., 2022; Picoli and Bueno, 2022). The profile of mood states (POMS) is a self-report questionnaire comprised of 65 items assessing seven mood states subscales (i.e., tension-anxiety, anger-hostility, confusion-bewilderment, depression-dejection, fatigue-inertia, vigor-activity, and interpersonal relationship; Table 1), with the interpersonal relationship subscale often being eliminated from measurement by researchers. Each item is rated on a 5-point Likert scale from 0 (not at all) to 4 (extremely) in response to questions such as "How are you feeling right now? (Aroian et al., 2007). The six subscales of POMS can be combined into a total mood disturbance (TMD) score by summing the (T) scores for the five negative mood subscales and subtracting the T score for positive mood state and adding a constant of 100 in order to prevent negative numbers.

Terry et al. (2003) published guidelines for the definition of each emotional state assessed by the POMS. According to this work, tension is characterized by sensations such as nervousness, apprehension, worry and anxiety. Anger is characterized by feelings that vary in intensity from annoyance or mild aggravation, fury, and irritation. Confusion described feelings of indecision associated with a decreased ability to control alertness and emotions. Depression is associated with a negative self-concept characterized by themes such as disappointment, deficiency, ineffectiveness, and self-blame. Fatigue is characterized by perception of mental and physical fatigue. Vigor represents the state of well-being, power, excitement, concentration, alertness, vitality, and strong ability to execute physical and mental effort. Finally, interpersonal relationships describe more of a trait than a specific state, but a strong score on this subscale is considered to indicate positive emotional state (Terry et al., 2003). These dimensions can be expressed in terms of state or trait depending on whether the instructions accompanying the form guide the participant to concentrate on their feelings at the moment, throughout the day or week of the assessment, or their usual feelings.

Some researchers have distinguished between high performers and low performers based on their pre-competition mood states (Filaire et al., 2001; Casanova et al., 2016). These studies reported that positive emotional state and successful athletic performance are strongly correlated. Specifically, the players who present lower tension, depression, anger, confusion and fatigue scores and higher vigor

TABLE 1 Summary of items making up each subscale.

Subscales	Item numbers	Total # of items	Range of scores
Tension-anxiety (TEN)	2, 10, 16, 20, 22*, 26, 27, 34, 41	9	0–36
Anger-hostility (ANG)	3, 12, 17, 24, 31, 33, 39, 42, 47, 52, 53, 57	12	0–48
Confusion-bewilderment (CONF)	8, 28, 37, 50, 54*, 59, 64	7	0–28
Fatigue-inertia (FAT)	4, 11, 29, 40, 46, 49, 65	7	0–60
Depression-dejection (DEP)	5, 9, 14, 18, 21, 23, 32, 35, 36, 44, 45, 48, 58, 61, 62	15	0–28
Vigor-activity (VIG)	7, 15, 19, 38, 51, 56, 60, 63	8	0–32
Interpersonal relationship (REL)	1,6, 13, 25, 30, 43, 55	7	0–28
Total Mood Disturbance (TMD)	(TEN + ANG + CONF + FAT + DEP) − VIG + 100	-	68–300

scores generally have more competitive success than players with the opposite profile as assessed by the POMS questionnaire. This positive profile has been called the "iceberg" profile (i.e., high vigor score and low scores for depression, tension, fatigue, confusion and anger) (Filaire et al., 2001; Casanova et al., 2016).

3. Results

3.1. The relationship between training loads, training periods, and mood state variation

During high-intensity training periods characterized by heavy TLs, athletes have usually reported significant mood changes (Filaire et al., 2001; Lovell et al., 2010; Picoli and Bueno, 2022). For example, Filaire et al. (2001) showed that mood disturbance increased progressively with higher TL. It has also been shown that acute fatigue during intense training periods was associated with worse mood state and decreased vigor (Lovell et al., 2010; Saidi et al., 2020). Similarly, Fields et al. (2021) reported higher intensities during soccer preseason were associated with more negative mood scores (i.e., anxiety, anger, depression, confusion, fatigue), while indicators of positive mood states (i.e., vigor) decreased. These results are in line with those reported by Filaire et al. (2001), which showed that mood disturbance increased with the training stimulus. Amstrup et al. (2002) examined the effects of sports season on mood states and found no change in POMS scores during the pre-season period. However, vigor decreased and fatigue and depression increased from the end of pre-season to mid-season. Additionally, Miranda et al. (2013) studied changes in mood across of10 weeks of training in young soccer players. This study showed that as training intensity increased throughout the training period, the mood state became more negative (Miranda et al., 2013). However, Silva et al. (2008) reported that POMS scores were stable after12 weeks of high training intensity, suggesting that athletes' mood states may be more vulnerable during extended periods of intense training.

The relationship between overtraining and mood state has also been investigated. Schmikli et al. (2011) reported a significant increase in depression and anger subscale scores and total mood disturbance (TMD) with overreaching in soccer players. Lovell et al. (2010) found that mood state shifted from more positive to more negative as the competitive season progressed, likely due to increasing TL and accumulating stress. Similarly, during a period of congested matches (10 games over 6 weeks) soccer players reportedly significantly increased fatigue, tension, anger and a decreased vigor compared to the non-congested period of match play (6 games over 6 weeks). They suggested that mood state disturbance is associated with increased physical and physiological load. Additionally, Botelho et al. (2022) showed significantly increased negative mood scores (i.e., tension, depression, anger, fatigue, confusion, and TMD) after7 weeks of intensive pre-season training in female soccer players, suggesting that training intensity increase may be associated with negative mood changes (Filaire et al., 2001). Results from these studies are consistent with the finding that substantial increases in training intensity may result in a decreased ability to concentrate and feelings of disorder, uncertainty, and mental fatigue (Djaoui et al., 2017). These changes in mood are also associated with poorer recovery state and well-being changes in soccer players (Selmi et al., 2020).

The tapering period, characterized by reduced training intensity, generally appears to have a positive effect on mood state. Beykzade et al. (2011) reported that after the tapering period, TMD, fatigue and depression decreased significantly compared to the beginning of the intense training period. Reducing the training intensity during the tapering period can produce a balance between effort and recovery which leads to mood regulation (Beykzade et al., 2011).

Regarding the study during Ramadan, the study by Baklouti et al. (2017) compared the effects of two small-sided game (SSG) training formats (4 × 4 min and 2 × 8 min) on mood state during Ramadan in male professional soccer players. The results indicated that Ramadan and not training increased subjective feelings of fatigue. Along the same lines, the study by Chtourou et al. (2011) which examined the effects of Ramadan fasting on RPE and mood state. They indicated that RPE and fatigue score were higher during Ramadan in comparison with before Ramadan.

Overall, results from studies using the POMS to assess mood state reveal that extended intense training is associated with more negative mood states, whereas periods of reduced training can be useful in restoring more positive mood state. However, short-term intense training may not negatively impact mood state. A summary of 13 studies examining the effects of both training intensity and periods on mood state variation is presented in Table 2.

3.2. Training exercises and mood state

Limited research has investigated how acute mood state changes with different training exercises in soccer. Those that have indicate

TABLE 2 Findings from studies examining mood variations with different training periods or intensities.

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Amstrup et al. (2002)	20, male, professional (20.0 ± 1.2 years)	Sports season	To monitor mood states (POMS) at the start and end of pre-season training, mid-season and at the end of competitive season	No change in POMS scores during the pre-season period decrease in vigor and increases in fatigue and depression from end of pre-season to mid-season	Mood disturbance at the mid-season with decline in vigor and increases in fatigue and depression
Baklouti et al. (2017)	24, male, professional (24 ± 4 years)	Ramadan	To compare the effects of two small-sided game (SSG) training formats (4 × 4 min (SSG-S) and 2 × 8 min (SSG-L)) on mood state and RPE	Compared to before Ramadan, fatigue score was higher at end of Ramadan. RPE measured during Ramadan were higher after SSG-L than SSG-S sessions	Ramadan and not training increased subjective feelings of fatigue
Beykzade et al. (2011)	15, male, amateur (25.0 ± 2.2 years)	Pre-season (5 weeks)	To assess the mood profile during pre-season preparatory	No significant change in mood after 4 weeks of progressive training load, except for fatigue score. After the taper period (1 week), fatigue and depression scores showed significant decrease compared to the beginning of the training period	Fatigue and depression have been shown to be more sensitive to the change of training load
Botelho et al. (2022)	24, female, elite (26.0 ± 3.7 years)	Preseason (7 weeks)	To investigate changes and correlations between mood states and various physiological stress markers	POMS scores (except vigor), testosterone, and cortisol concentrations, as well as CK, showed significant Changes after the preseason. Correlations were found between cortisol and tension, cortisol and confusion	Coaches and physical coaches can use these data to monitor, and control Training load and training programs, in particular throughout the preseason period
Chtourou et al. (2011)	20, male, young soccer players (17.6 ± 0.6 years)	Ramadan	To assess the effects of Ramadan fasting on RPE and mood state	RPE and fatigue score were higher during Ramadan in comparison with before Ramadan	RPE and feelings of fatigue were higher during Ramadan
Fields et al. (2021)	20, male, collegiate (20.3 ± 0.9 years)	Pre-season	To examine the relationship between external load and mood state during soccer preseason	Morning ratings of negative mood were positively predicted by previous day's afternoon practice high-speed distance. In addition, negative morning mood states inversely predicted high-speed distance, Total distance, and player load for that day's afternoon practice	Using POMS questionnaire with GPS may improve the understanding of physical and psychological responses
Lovell et al. (2010)	16, male, professional (25.0 ± 5.0 years)	Competitive season	To assess whether the demands of the modern English competitive soccer season would be reflected in the mood states	At the start of the season, the players had a positive mood state, however, as the season progressed, they showed a shift toward a negative mood state	The extended competitive season, increased training load and increase in stress lead to negative mood
Miranda et al. (2013)	13, male, youth players (17.0 ± 0.7 years)	At the beginning of the season (10 weeks)	To examine the influence of 10-week soccer training program on mood state	The positive score (i.e., vigor) was reduced, the negative scores (i.e., tension, depression, anger, fatigue, confusion and TMD) were increased	Mood disturbance is associated with long period of high training load (volume and intensity)
Silva et al. (2008)	15, male, professional (23.4 ± 2.5 years)	Competitive period (12 weeks)	To investigate the change of mood state in Brazilian soccer players during a training program	Decrease in vigor score in T3 (week 12) compared with T1 (week 0) and T2 (week 6)	The training program intensified between T2 and T3 led to the reduction of the positive mood score (vigor)

(Continued)

TABLE 2 (Continued)

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Saidi et al. (2020)	24, male, elite (19 to 22 years)	6 weeks after the beginning of the competitive period (12 weeks)	To analyze mood state in relation to changes in training and match exposure during a congested period of match play	A significant increase was found in fatigue, tension, anger and a significant decrease in vigor from the non-congested period of match play when the players played 6 games over 6 weeks to the congested period when the players played 10 games over 6 weeks	Mood state monitoring could be a practical and efficacy tool to verify the degree of preparedness for match play during a congested period
Schmikli et al. (2011)	77, male, young elite (16–21 years)	Competitive season	To examine the effects of performance decrement on mood during overreaching	The performance decrement group scored higher on depression and anger than controls	Disturbance in mood state is associated with the performance decrement of players during overreaching
Selmi et al. (2020)	24, male, professional (17.0 ± 0.2 years)	Pre-season (7 weeks)	To compare the effects of two intensified training period on mood state	Negative POMS scores increased (tension, anger, confusion, depression, fatigue and vigor decreased)	intensified training period affect negatively mood state

that intense training exercises can change mood state in soccer players (Selmi et al., 2017). In fact, Selmi et al. (2018) assessed mood responses to high-intensity interval training (HIIT) in soccer players, with the POMS questionnaire administered immediately before and within 5 min after training. Results indicated a significant increase in negative mood scores (i.e., anxiety, fatigue, and global mood score) and decrease in vigor score. Selmi et al. (2017) also reported that physical small-sided games (SSGs) induced significant improvements in mood state in professional soccer players. In the same study, both HIIT and SSG sessions induced similar physiological responses; in contrast, HIIT resulted in mood disturbance highlighted by increased tension, fatigue and TMD scores, whereas SSGs provided mood balance. The stability of POMS scores in this study may be due to athletes' motivation during preferred exercise modalities (i.e., exercises using the ball; Selmi et al., 2017). Similarly, Oliveira et al. (2009) reported that fatigue scores increased following a HIIT session in female soccer players. Broodryk et al. (2017) examined the effect of an anaerobic fatigue test (Yo-Yo Intermittent Recovery) on cortisol levels and mood state in female semi-professional soccer players and found significantly increased cortisol, psychological fatigue and TMD and decreased vigor. Sparkes et al. (2018) found perturbed mood state for up to 24 h after intensive SSG during the competitive period in professional soccer. Exercise motivation is associated with positive mood in soccer players and may be achieved using specific drills such as integrating the ball during physical tasks or the use of verbal encouragement by coaches (Aydi et al., 2022). Specifically, Aydi et al. (2022) showed that technical circuit dribbling drills with verbal coach encouragement improved mood state highlighted by decreased scores on negative mood subscales and increased vigor. Together, these studies suggest that verbal encouragement is an effective method to improve mood or prevent mood disturbances during training.

A summary of 5 studies investigating the relationships between exercise session characteristics and mood state variation is presented in Table 3.

3.3. Competitive performance and mood state

Previous studies have examined the relationship between mood state and performance using the POMS questionnaire (Filaire et al., 2001; Miranda et al., 2013). In fact, mood state in soccer is related to competitive performance in terms of win/draw/lose (Casanova et al., 2016). Studies with professional soccer players have shown that athletic performance can improve positive and decrease negative POMS subscale scores (Robinson and Howe, 1987; Filaire et al., 2001; Miranda et al., 2013). Furthermore, Silva et al. (2008) showed that when professional team presented an "iceberg" profile during the training program, with a fatigue score decrease from beginning to middle season, coinciding with the team's best performance during the season (50% of wins). However, decreased vigor score at the end compared to the beginning and middle of the season, corresponded with poor performance (33.3% wins; Silva et al., 2008). Similarly, Miranda et al. (2013) reported that the overall POMS score increased significantly in male youth soccer players after 10 weeks of training indicating greater TMD, and that the mood state disturbance was correlated with the team ranking in the championship. Mood state also appears to be related to match outcomes. Casanova et al. (2016) indicated that positive mood state (vigor) score increased after lost matches and anger score decreased after won matches during an official female association football tournament while "Iceberg" profiles were observed during all 5 matches regardless of outcome. Lowther and Lane (2002) indicated that vigor was associated with successful match performance and depression score were associated with poor match performance in a soccer team. Oliveira et al. (2009) examined the influence of match results on mood changes in professional female soccer players. They found more positive mood states among winners and more negative mood states among losers at the end of the matches, suggesting that overall mood state is related to match performance in female soccer players. Moreover, Dejongh et al. (2006) examined the relationship between in-season team

TABLE 3 Findings from studies examining relationships between training exercises and mood state.

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Aydi et al. (2022)	16, male, soccer specialist students (17.7 ± 0.5 years)	Mid-season (2 weeks)	To investigate the effects of verbal encouragement (VE) on mood state and physical enjoyment during a soccer dribbling circuit exercise (the Hoff circuit)	The circuit exercise without VE showed lower vigor and higher total mood disturbance and was associated with higher tension and fatigue, compared to the circuit exercise with VE	The soccer dribbling circuit exercise with VE condition resulted in positive mood state, compared to that of the soccer dribbling circuit exercise without VE
Broodryk et al. (2017)	47, female, semi-professional (22.0 ± 2.7 years)	Competitive training period	To examine the effects of anaerobic fatiguing test (5-m multiple shuttles run test) in mood state	Increase in fatigue and TMD from pre to post test. Decreased in vigor and confusion from pre to post test	The anaerobic fatiguing test can be perceived as a psychological stressor by female players
Selmi et al. (2017)	16, male, professional, (24.1 ± 0.9 years)	Competitive period	To compare the effects of high-intensity intermittent training (HIIT) versus small-sided games (SSG) on the mood state	The HIIT compared with SSG resulted in: an increased total mood disturbance fatigue, tension decreased positive mood (vigor)	SSG ensured mood balance while HIIT produced a mood disturbance
Selmi et al. (2018)	20, male, amateur (23.9 ± 0.9 years)	Competitive period	To examine the effects of HIIT on mood state and to show the relationship between RPE and POMS scores	HIIT leads to an increase in anxiety, fatigue, total mood disturbance and a decreased vigor. No correlation was found between POMS scores and RPE	HIIT causes negative mood changes that trainers should consider optimizing fitness and recovery
Sparkes et al. (2018)	16, male, professional (21 ± 2 years)	Competitive season	To characterize the mood response to a SSG exercises over 24 h	Immediate disturbances in mood following 42 min of SSG and + 2 h. On the following morning (+24 h), POMS scores had returned to baseline values	SSG exercises result in a perturbation in mood state for up to 24 h

TMD: total mood disturbance; SSG: small-sided games; HIIT: high-intensity interval training; RPE: ratings of perceived exertion.

performance and mood state in professional female soccer players. They showed that tension, depression, anger, and confusion scores were lower and vigor was higher when the team won indicating that poor performance was related to negative mood state in female players. In addition, Filaire et al. (2001) showed lower vigor scores when the performance of a professional male soccer team was below 50.0% wins. It is likely that competition success can lead to improved psychological states including more satisfaction, pleasure, and reduced anxiety, while the effects of defeat can produce poor well-being (Casanova et al., 2016). Alternatively, more negative mood state may decrease competitive performance.

A summary of 6 studies regarding the relationship between competitive performance and mood state variation is presented in Table 4.

3.4. The effect of training on mood regulation

Mood regulation strategies may benefit athletic performance (Hashim et al., 2011). In fact, strong athletic performance among soccer players is associated with high positive mood scores and low negative mood scores (Hashim et al., 2011; Bijukumar, 2021). Indeed, researchers have revealed several mood regulation strategies for soccer players (Selmi et al., 2017; Bijukumar, 2021). For example, Hashim et al. (2011) compared the effects of two different relaxation techniques, known as progressive muscle relaxation and autogenic relaxation on the mood of young soccer players and showed that these relaxation techniques induced equivalent beneficial mood responses and can be used to regulate mood state (Hashim et al., 2011). Akimoto et al. (2003) studied the effect of acupuncture treatment on the mood state in 12 women soccer players during the competition period. The results indicate that acupuncture treatment has a positive effect on mood regulation with improved positive mood and reduced negative mood scores. Other less obvious mood regulation strategies may also be effective, such as choices in training programming. For example, Progressive Muscle Relaxation training (PMR)decreased mood disturbance, anger, tension, and fatigue scores in university students (Bijukumar, 2021) suggesting positive impacts on mood state. This may be a worthwhile strategy to examine among soccer players. Selmi et al. (2017) showed that SSG, a training exercise that soccer players found more enjoyable and motivating, provided better mood state regulation compared to HIIT, a less preferred training strategy, despite similar training intensities. Likewise, previous studies have shown that using motivational training exercises can reduce negative emotions and improve mood in soccer players (Hashim et al., 2011; Aydi et al., 2022). Therefore, implementing relaxation training and selection of preferred training exercises could help to regulate the mood state of athletes (Hashim et al., 2011; Bijukumar, 2021).

TABLE 4 Findings from studies examining competitive performance and mood state.

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Casanova et al. (2016)	20, female, elite (22.9 ± 4.2 years)	Competitive period (5 matches)	To compare the mood state during an official female association football tournament (5 matches)	"Iceberg" profiles of POMS were observed during all the moments of evaluation (all matches), significant decrease in vigor score after loss matches and a significant decrease in anger score after win matches	Mood state variation is influenced by match performances
Dejongh et al. (2006)	32, female, professional (19.9 ± 2.0 years)	Competitive season	To quantify the mood state changes based on match results in female soccer athletes over seasonal play	Tension, depression, anger, vigor, fatigue, confusion increased concomitantly with match losses throughout seasonal play	Negative changes in mood states. May be due to the effect of defeats during the game and the strength of opponents
Filaire et al. (2001)	17, male, professional (23.1 ± 2.2 years)	In-season period	To investigate the relationship between mood state and competitive performance	Iceberg profiles of POMS were observed during periods, which coincided with successful performance. Decrease in vigor and an increase in tension and depression were observed during periods, which coincided with decreased performance	Change in mood is related to competitive performance
Lowther and Lane (2002)	32, male, collegiate (21.2 ± 2.1 years)	Competitive period	To examine relationships between mood state and performance in a soccer team on a match-by-match basis	Relationships showed that vigor were associated with successful performance. Depression score were associated with a poor performance	Mood state was related to performance
Miranda et al. (2013)	13, male, youth players (17.0 ± 0.7 years)	Competitive period	To determine the relationship of mood state profiles and competitive performance	Relationships showed that Positive mood state were associated with outcomes	Mood state was affected by win or loss outcomes
Oliveira et al. (2009)	33, female, professional (24.2 ± 4.7 years)	Competitive period	To investigate the change of mood state at winners and in losers at the end of the match	More positive mood state found in winners and more negative mood state found in losers at the end of the match	These results suggest that mood state responds to the contest challenges among females

A summary of 4 studies examining the relationship between training and mood regulation is presented in Table 5.

3.5. Time of day and mood state

Mood state in soccer players is related to time of day and to training time (e.g., morning versus evening training) (Chtourou et al., 2012, 2014; Masmoudi et al., 2016; Irandoust et al., 2019; Hsouna et al., 2021; Masmoudi et al., 2021). In male youth soccer players, depression, RPE scores, Hooper Index, and stress were higher in the afternoon than the morning (Masmoudi et al., 2016). In some studies, training in the morning improved mood state (Masmoudi et al., 2016; Irandoust et al., 2019), whereas Masmoudi et al. (2021) showed that only depression and vigor scores, but not anger, confusion, fatigue, inter-relation, or TMD were significantly worse when training at 17:00 h compared to 08:00 h. Across these studies, exercise/training in the morning boosts physical performance and physiological status including perceived energy levels that may have positive feedback effects and perpetuate improved mood. These studies also indicated that morning activities may also confer improved mental health status and productivity throughout the day. Dietary patterns, especially periods of fasting like Ramadan, may be particularly important for time-of-day studies to consider since fasting could impact mood and performance. Chtourou et al. (2012) observed that professional soccer players felt more fatigued in the evening versus morning during Ramadan. However, among youth soccer athletes, aerobic training during Ramadan had decreased anger, confusion, depression, fatigue, tension, and TMD, and increased vigor scores regardless of whether they trained in the morning or evening (Chtourou et al., 2014).

A summary of 4 studies examining the relationship between time of day and mood in soccer players is presented in Table 6.

4. Limitations and recommendations for further research

This work has assessed and summarized the current literature on mood state variation in soccer players with a specific focus on training loads, training modalities, and competitive performance. However, the study was not without limitations. This review only examined studies carried out in the context of soccer and not other sports

TABLE 5 Findings from studies examining the relationship between training and mood regulation.

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Akimoto et al. (2003)	21, female, elite (17.7 ± 1.4 years)	Competitive period	To examine the effect of acupuncture treatment on the mood state	POMS scores indicated a higher mental fatigue in the control group than in the acupuncture group	The acupuncture group suggests that acupuncture treatment had good effects on mood states during the competition period
Bijukumar (2021)	16, male, adolescent university level (15 to 18 years)	12 Sessions	To examine the effects of program of Progressive Muscle Relaxation Training (PMR) in the profile of mood states	PMR has made decreases in mood disturbance, anger, tension, and fatigue scores	PMR produce positive mood responses. This technique may be used to regulate players' mood states
Hashim et al. (2011)	16, male, youth (14.1 ± 1.3 years)	In-season	To examine the effects of relaxation training in regulate mood states	Relaxation training results in reductions in confusion, depression, fatigue, and tension scores	Relaxation training may be used to regulate mood states
Selmi et al. (2017)	16, male, professional (24.1 ± 0.9)	Competitive period	To examine the effect training exercise with ball on mood regulation compared to HIIT	No change in POMS scores during training exercise with ball. HIIT resulted in: an increased total mood disturbance fatigue, tension decreased positive mood (vigor)	SSG ensured mood balance while HIIT produced a mood disturbance

TABLE 6 Findings from studies examining time of day and mood regulation.

Study	Participant (number, sex, level, age)	Condition/ duration	Aim	Results	Findings
Chtourou et al. (2012)	10, male, junior (17 ± 0.5)	During Ramadan	To investigate the effect of timeofdayon mood states	Fatigue score significantly higher in the evening versus morning. Anger, confusion, and TMD scores were not significantly affected by the timeofday.	Fatigue recorded by the POMS questionnaire are higher in the afternoon during Ramadan
Chtourou et al. (2014)	30, male, young players(17.8 ± 0.5)	During Ramadan	To examine the effect of time-of-day on mood states	All subscales of mood such as anger, confusion, depression, fatigue, tension, vigor and TMD had a significant improvement following morning and evening aerobic training programs	Exercise at different times of the morning or evening can improve the mood state
Masmoudi et al. (2016)	10, male, children soccer players (14.6 ± 0.8 years)	In-season	To examine the effect of time-of-day on mood state	Negative mood (i.e., depression) significantly higher at 17:00 vs. 08:00 h	Depression recorded by the POMS questionnaire are higher in the afternoon
Masmoudi et al. (2021)	32, male, children soccer players (11 ± 0.7 years)	In-season	To investigate the effect of timeofday on mood state	Depression and vigor scores were significantly higher in the evening compared to the morning. However, anger, confusion, fatigue, inter-relation, and the TMD scores were not significantly affected by the time-of-day.	Positive mood was observed in the morning compared to the afternoon

disciplines. A comparison of the findings of the present study with those of other sports disciplines would be a valuable addition to the literature. Psychological responses during training for individual versus team sports would be particularly interesting. This study did not investigate the effects of Ramadan fasting on mood state since the training during Ramadan is very different from the other months of the year. Such fasting leads to physical, physiological, metabolic, and psychological changes. Moreover, this study did not examine effects of the environment (e.g., climate, altitude) on mood state. Environmental changes can also influence the physiological and

psychological aspects of sport. Finally, we did not include relationships between POMS scores and other psychological states such as physical enjoyment or motivation. Such measures would be a valuable addition for mood assessment in soccer players. Future investigations examining mood state should be conducted with other sports disciplines (individual and team sports), include other mental health dimensions, and examine the influence of environmental condition to extend the findings of the present work.

5. Conclusion

This review examined relationships between training load/period, training exercises, and competitive performance on mood state in soccer players. It offers practical support for the use of a simple POMS measurement as part of an overall program to monitor the players' psychological states. Results also highlighted how those training program (e.g., training load, training modality) and competitive performance are related to mood states (i.e., tension, anger, confusion, depression, fatigue, and vigor).

6. Practical applications

This review was conducted to summarize the current literature on the relationships between mood state in soccer players and: (1) TL and training period; (2) training exercises (e.g., modality); and (3) competitive performance. Methods of mood regulation also emerged and were examined. POMS is a simple, non-invasive, non-fatiguing, sensitive and effective measurement tool which can help coaches monitor the psychological state of soccer players. Mood state assessment can be useful in predicting mental fatigue and quantifying emotional state of players during training. It follows that the technical staff of soccer teams should bear in mind that an increase in TL (i.e., intensity and volume of training), fatigue accumulation and poor recovery negatively affect the mood state of players.

Monitoring mood state variation during training may also help predict player performance. This strategy could be useful for coaches to determine when to implement techniques to improve stress coping and to avoid potential negative impacts of extended periods of high TL such as anxiety and loss of concentration. Better identification of athletes' psychological states allows the technical staff to select programming and strategies to achieve better outcomes during training and competition.

Author contributions

All authors listed have made a substantial and intellectual contribution to the work, and approved it for publication.

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

Akimoto, T., Nakahori, C., Aizawa, K., Kimura, F., Fukubayashi, T., and Kono, I. (2003). Acupuncture, and responses of immunologic and endocrine markers during competition. *Med. Sci. Sports Exerc.* 35, 1296–1302. doi: 10.1249/01.MSS.0000078934.07213.25

Amstrup, T., Rysgaard, T., Johansen, J. V., Bangsbo, J., and Pedersen, P. K. (2002). Seasonal changes in heart rate variability and profile of mood states in professional soccer players. *Med. Sci. Sports Exerc.* 34:S198. doi: 10.1097/00005768-200205001-01118

Aroian, K. J., Kulwicki, A., Kaskiri, E. A., Templin, T. N., and Wells, C. L. (2007). Psychometric evaluation of the Arabic language version of the profile of mood states. *Res. Nurs. Health* 30, 531–541. doi: 10.1002/nur.20211

Aydi, B., Selmi, O., Souissi, M. A., Sahli, H., Rekik, G., Crowley-McHattan, Z. J., et al. (2022). The effects of verbal encouragement during a soccer dribbling circuit on physical and psychophysiological responses: an exploratory study in a physical education setting. *Child* 9:907. doi: 10.3390/children9060907

Baklouti, H., Rejeb, N., Aloui, A., Jaafar, H., Ammar, A., Chtourou, H., et al. (2017). Short versus long, small-sided game training during Ramadan in soccer players. *Phys. Ther. Sport* 24, 20–25. doi: 10.1016/j.ptsp.2016.10.002

Benjamin, C. L., Curtis, R. M., Huggins, R. A., Sekiguchi, Y., Adams, W. M., Arent, S. M., et al. (2019). Sleep quality effects mood, anxiety and disablement in division i national collegiate athletic association men's soccer players: 1623 board# 2 may 30 1: 30 PM-3: 30 PM. *Med. Sci. Sports Exerc.* 51, 442–443. doi: 10.1249/01.mss.0000561824.97520.c6

Benjamin, C. L., Curtis, R. M., Huggins, R. A., Sekiguchi, Y., Jain, R. K., McFadden, B. A., et al. (2020). Sleep dysfunction and mood in collegiate soccer athletes. *Sports Health* 12, 234–240. doi: 10.1177/1941738120916735

Beykzade, P., Farzanegi, P., Beykzade, H., Babaee, R., Robati, R., Jourkesh, M., et al. (2011). Monitoring of the pre-season preparatory training by the mood profile and physical performance in the male soccer players. *Res. Sport Sci. Q. Spring* 2, 1–7. doi: 10.5281/zenodo.6987350.svg

Bijukumar, K. (2021). Effect of progressive muscle relaxation training on profile of mood states of adolescent male football players. *Depress.* 9, 7–39.

Botelho, R., Abad, C. C. C., Spadari, R. C., Winckler, C., Garcia, M. C., and Guerra, R. L. F. (2022). Psychophysiological stress markers during preseason among elite female soccer players. *J. Strength Cond. Res.* 36, 1648–1654. doi: 10.1519/JSC.0000000000003702

Broodryk, A., Pienaar, C., Edwards, D., and Sparks, M. (2017). The psycho-hormonal influence of anaerobic fatigue on semi-professional female soccer players. *Physiol. Behav.* 180, 8–14. doi: 10.1016/j.physbeh.2017.07.031

Casanova, N., Palmeira-DE-Oliveira, A., Pereira, A., Crisóstomo, L., Travassos, B., and Costa, A. M. (2016). Cortisol, testosterone and mood state variation during an official female football competition. *J. Sports Med. Phys. Fitness* 56, 775–781. PMID: 26154730

Chennaoui, M., Bougard, C., Drogou, C., Langrume, C., Miller, C., Gomez-Merino, D., et al. (2016). Stress biomarkers, mood states, and sleep during a major competition: "success" and "failure" Athlete's profile of high-level swimmers. *Front. Physiol.* 7:94. doi: 10.3389/fphys.2016.00094

Chtourou, H., Briki, W., Hammouda, O., Aloui, A., Souissi, N., and Chaouachi, A. (2014). The effect of the time-of-day of training during Ramadan on soccer players' chronotype and mood states. *Sport Sci. Health* 10, 143–147. doi: 10.1007/s11332-014-0185-x

Chtourou, H., Hammouda, O., Chaouachi, A., Chamari, K., and Souissi, N. (2012). The effect of time-of-day and Ramadan fasting on anaerobic performances. *Int. J. Sports Med.* 33, 142–147. doi: 10.1055/s-0031-1286251

Chtourou, H., Hammouda, O., Souissi, H., Chamari, K., Chaouachi, A., and Souissi, N. (2011). The effect of ramadan fasting on physical performances, mood state and perceived exertion in young footballers. *Asian J. Sports Med.* 2, 177–185. doi: 10.5812/asjsm.34757

De Morais Ferreira, A. B., Ribeiro, B. L. L., dos Santos Batista, E., Dantas, M. P., and Mortatti, A. L. (2022). The influence of different training load magnitudes on sleep pattern, perceived recovery, and stress tolerance in young soccer players. *J. Strength Cond. Res.* 37, 10–1519. doi: 10.1519/JSC.0000000000004235

Dejongh, N. M., Meyers, M. C., Goodwin, B. G., Laurent, C. M., Lauffer, R., and Webb, C. (2006). "Mood states of ncaa division ii female soccer athlete's over seasonal play," in *American college of Sports Medicine Annual Meeting, Denver*.

Djaoui, L., Chamari, K., Owen, A. L., and Dellal, A. (2017). Maximal sprinting speed of elite soccer players during training and matches. *J. Strength Cond. Res.* 31, 1509–1517. doi: 10.1519/JSC.00000 00000 001642

Fields, J. B., Lameira, D. M., Short, J. L., Merrigan, J. M., Gallo, S., White, J. B., et al. (2021). Relationship between external load and self-reported wellness measures across a Men's collegiate soccer preseason. *J. Strength Cond. Res.* 35, 1182–1186. doi: 10.1519/JSC.0000000000003997

Filaire, E., Bernain, X., Sagnol, M., and Lac, G. (2001). Preliminary results on mood state, salivary testosterone:cortisol ratio and team performance in a professional soccer team. *Eur. J. Appl. Physiol.* 86, 179–184. doi: 10.1007/s004210100512, PMID: 11822478

Hashim, H. A., Hanafi, H., and Yusof, A. (2011). The effects of progressive muscle relaxation and autogenic relaxation on young soccer players' mood states. *Asian J. Sports Med.* 2, 99–105. doi: 10.5812/asjsm.34786

Hsouna, H., Boukhris, O., Hill, D. W., Abdessalem, R., Trabelsi, K., Ammar, A., et al. (2021). A daytime 40-min nap opportunity after a simulated late evening soccer match reduces the perception of fatigue and improves 5-m shuttle run performance. *Res. Sports Med.* 30, 1–14. doi: 10.1080/15438627.2021.1917400

Irandoust, K., Taheri, M., Chtourou, H., Nikolaidis, P. T., Rosemann, T., and Knechtle, B. (2019). Effect of time-of-day-exercise in group settings on level of mood and depression of former elite male athletes. *Int. J. Environ. Res. Public Health* 16:3541. doi: 10.3390/ijerph16193541

Jones, M. T., Matthews, T. D., Murray, M., Van Raalte, J., and Jensen, B. E. (2010). Psychological correlates of performance in female athletes during a 12 week off-season strength and conditioning program. *J. Strength Cond. Res.* 24, 619–628. doi: 10.1519/JSC.0b013e3181cc23c3

Lane, A. (2001). Relationships between perceptions of performance expectations and mood among distance runners: the moderating effect of depressed mood. *J. Sci. Med. Sport* 4, 116–128. doi: 10.1016/S1440-2440(01)80013-X

Lovell, G. P., Townrow, J., and Thatcher, R. (2010). Mood states of soccer players in the English leagues: reflections of an increasing workload. *Biol. Sport* 27, 83–88. doi: 10.5604/20831862.913072

Lowther, J., and Lane, A. (2002). Relationships between mood, cohesion and satisfaction with performance among soccer players. *Athletic Insight* 4, 57–69.

Masmoudi, L., Gharbi, A., Chtourou, H., and Souissi, N. (2016). Effect of time of day on soccer specific skills in children: psychological and physiological responses. *Biol. Rhythm. Res.* 47, 59–68. doi: 10.1080/09291016.2015.1073888

Masmoudi, L., Gharbi, A., H'Mida, C., Trabelsi, K., Boukhris, O., Chtourou, H., et al. (2021). The effects of exercise difficulty and time-of-day on the perception of the task and soccer performance in child soccer players. *Child* 8:793. doi: 10.3390/children 8090793

Miranda, R. E. E. P. C., Antunes, H. K. M., Pauli, J. R., Puggina, E. F., and da Silva, A. S. R. (2013). Effects of 10-week soccer training program on anthropometric, psychological, technical skills and specific performance parameters in youth soccer players. *Sci. Sports* 28, 81–87. doi: 10.1016/j.scispo.2012.02.005

Oliveira, T., Gouveia, M. J., and Oliveira, R. F. (2009). Testosterone responsiveness to winning and losing experiences in female soccer players. *Psychoneuroendocrinol.* 34, 1056–1064. doi: 10.1016/j.psyneuen.2009.02.006

Paryab, N., Taheri, M., H'Mida, C., Irandoust, K., Mirmoezzi, M., Trabelsi, K., et al. (2021). Melatonin supplementation improves psychomotor and physical performance in collegiate student-athletes following a sleep deprivation night. *Chronobiol. Int.* 38, 753–761. doi: 10.1080/07420528.2021.1889578

Picoli, R., and Bueno, J. L. O. (2022). Changes in present mood states of youth soccer players during the competition period. *In SciELO*. doi: 10.1590/SciELOPreprints.4397

Robinson, D. W., and Howe, B. L. (1987). Causal attribution and mood state relationships of soccer players in a sport achievement setting. *J. Sport Behav.* 21, 137–146. doi: 10.1136/bjsm.21.3.137

Russell, E. R., McCabe, T., Mackay, D. F., Stewart, K., MacLean, J. A., Pell, J. P., et al. (2020). Mental health and suicide in former professional soccer players. *J. Neurol. Neurosurg. Psychiatry* 91, 1256–1260. doi: 10.1136/jnnp-2020-323315

Saidi, K., Ben Abderrahman, A., Boullosa, D., Dupont, G., Hackney, A. C., Bideau, B., et al. (2020). The interplay between plasma hormonal concentrations, physical fitness, workload and mood state changes to periods of congested match play in professional soccer players. *Front. Physiol.* 11:835. doi: 10.3389/fphys.2020.00835. PMID: 32792977; PMCID: PMC7385323

Schmikli, S. L., Brink, M. S., de Vries, W. R., and Backx, F. J. (2011). Can we detect non-functional overreaching in young elite soccer players and middle-long distance runners using field performance tests? *Br. J. Sports Med.* 45, 631–636. doi: 10.1136/bjsm.2009.067462

Selmi, O., Ben Khalifa, W., Zouaoui, M., Azaiez, F., and Bouassida, A. (2018). High intensity interval training negatively affects mood state in professional athletes. *Sci. Sports* 33, e151–e157. doi: 10.1016/j.scispo.2018.01.008

Selmi, O., Haddad, M., Majed, L., Ben Khalifa, W., Hamza, M., and Chamari, K. (2017). Soccer training: high-intensity interval training is mood disturbing while small, sided games ensure mood balance. *J. Sports Med. Phys. Fitness* 58, 1163–1170. doi: 10.23736/S0022-4707.17.07292-9

Selmi, O., Ouergui, I., Castellano, J., Levitt, D., and Bouassida, A. (2020). Effect of an intensified training period on well-being indices, recovery and psychological aspects in professional soccer players. *Eur. Rev. Appl. Psychol.* 70:100603. doi: 10.1016/j.erap.2020.100603

Silva, A. S. R., Santhiago, V., Papoti, M., and Gobatto, C. A. (2008). Psychological, biochemical and physiological responses of Brazilian soccer players during a training program. *Sci. Sports* 23, 66–72. doi: 10.1016/j.scispo.2007.10.010

Smith, M. R., Coutts, A. J., Merlini, M., Deprez, D., Lenoir, M., and Marcora, S. M. (2016). Mental fatigue impairs soccer-specific physical and technical performance. *Med. Sci. Sports Exerc. Feb.* 48, 267–276. doi: 10.1249/MSS.0000000000000762

Souter, G., Lewis, R., and Serrant, L. (2018). Men, mental health and elite sport: a narrative review. *Sports Med. Open* 4:57. doi: 10.1186/s40798-018-0175-7

Soylu, Y., Arslan, E., and Kilit, B. (2021). Psychophysiological responses and cognitive performance: a systematic review of mental fatigue on soccer performance. *Int. J. Sport Stud. Health* 4:e124244. doi: 10.5812/intjssh.124244

Sparkes, W., Turner, A., Weston, M., Russell, M., Johnston, M., and Kilduff, L. (2018). Neuromuscular, biochemical, endocrine, and mood responses to small-sided Games' training in professional soccer. *J. Strength Cond. Res.* 32, 2569–2576. doi: 10.1519/JSC.0000000000002424

Terry, P. C., Lane, A. M., and Fogarty, G. J. (2003). Construct validity of the profile of mood states—adolescents for use with adults. *Psychol. Sport Exer.* 4, 125–139. doi: 10.1016/S1469-0292(01)00035-8

Watson, A., Brickson, S., Brooks, A., and Dunn, W. (2017). Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. *Br. J. Sports Med.* 51, 194–199. doi: 10.1136/bjsports-2016-096584

Yagmaee, F. (2021). Eight weeks of aerobic exercise and prescribed diet (low in carbohydrate and high protein) improve mental health in obese women. *Int. J. Sport Stud. Health* 4:e121345. doi: 10.5812/intjssh.121345

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 23 February 2023
DOI 10.3389/fpsyg.2023.1099254

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Peter Gröpel,
University of Vienna, Austria
Nicolas Benguigui,
Normandie Université, France

*CORRESPONDENCE
Xiao-Feng Zhu
✉ zhuxiaofeng@sus.edu.cn

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

RECEIVED 15 November 2022
ACCEPTED 06 February 2023
PUBLISHED 23 February 2023

CITATION
Jin P, Zhao Z-Q and Zhu X-F (2023) The relationship between sport types, sex and visual attention as assessed in a multiple object tracking task.
Front. Psychol. 14:1099254.
doi: 10.3389/fpsyg.2023.1099254

The relationship between sport types, sex and visual attention as assessed in a multiple object tracking task

Peng Jin[1,2], Zi-Qi Zhao[1] and Xiao-Feng Zhu[3]*

[1]Department of Physical Education, Southeast University, Nanjing, China, [2]Southeast University Research Institute of Sports Science, Nanjing, China, [3]School of Elite Sport, Shanghai University of Sport, Shanghai, China

This study was conducted to examine differences in visual attention according to sports type and sex. In total, 132 participants [open-skill sport athletes (basketball players), closed-skill sport athletes (swimmers), and non-athletes; *n* =22 men and 22 women each] aged 19–24years performed a multiple object tracking (MOT) task, which is a well-established paradigm for the assessment of visual attention. Visual tracking accuracy was affected by the sport type (p <0.001), being superior among basketball players than among swimmers and non-athletes, with no significant difference between the latter groups. It also varied by sex (p <0.001), being superior among males than among females. Significant interaction between the sport type and sex was observed (p <0.001), with male and female basketball players showing similar tracking accuracy. Our results demonstrate that open-skill sport activities strongly related to visual attention, as estimated by MOT task performance, and that sex plays a role in this performance. They also indicate that females might gain a greater visual attention advantage from open than from closed-skill sports participation, as long-term open-skill sports training appeared to minimize the sex difference in visual attention.

KEYWORDS

open skill sport, closed skill sport, multiple object tracking, visual attention, sex difference

Introduction

Visual attention has perhaps been the most active area of study in perceptual-cognitive research in the last several decades (Harris et al., 2020). Visual attention is widely accepted in psychology and can be described as the cognitive system's selection of a subset of relevant information for further processing (Meyerhoff and Papenmeier, 2020). It plays an important role in most activities of daily living, including assessments of traffic, work, and sports (Hüttermann and Memmert, 2017). In sports, athletes must continuously pay attention to the environment to execute timely and correct decisions (Walsh, 2014). This skill is especially critical in sports such as basketball, in which players are required to track the ball in dynamically changing and unpredictable situations while simultaneously monitoring the position of other players, including teammates and opponents on the court (Gallotta et al., 2020; Legault et al., 2022). Thus, the investigation of visual attention in a sports environment may provide a deeper understanding of the involved cognitive mechanisms to inform better performance of many real-life tasks.

Several studies have examined the relationship of sports participation to visual attention, and have yielded somewhat conflicting results; sports training has been found to have positive transfer effects on visual attention (Faubert, 2013; Zhang et al., 2021), whereas other studies do not find this (Memmert et al., 2009). Some of these discrepant findings may be because different types of sports activities may exert differential influences on visual attention (Gallotta et al., 2020). Thus, increasingly more investigations have focused on the relationship between the type of sports training and visual attention. Sports may be categorized into two types based on their cognitive demands: open skill sports and closed skill sports (Poulton, 1957; Ke et al., 2021). In open skill sports (e.g., basketball, tennis, squash, or boxing), participants are required to react and adapt in an unpredictable and dynamically changing environment. By contrast, closed skill sports (e.g., swimming, running, or cycling) are performed in an environment that is internally paced, predictable, and highly consistent (Gu et al., 2019; Coyne et al., 2021; Koch and Krenn, 2021). Regarding the different characteristic by type of sport, researchers have found that athletes in open skill sports show better performance in cognitive function (Wang et al., 2013), visuospatial attention (Tsai et al., 2016), and other cognitive tasks than have closed-skill sports athletes (Voss et al., 2010). Despite these clear sport type-related differences in cognitive abilities, however, evidence indicating which types of sport activity are associated with superior visual attention performance remains insufficient.

Sex differences in visual attention have also attracted research interest. Some studies have investigated sex differences in visual attention among the general population. For example, Roudaia and Faubert (2017) found that males showed superior visual attention compare with females in a visual tracking task, whereas Merritt et al. (2007) found no sex difference in visual selection task performance. Only a few studies have explored sex differences in visual attention in athletes, highlighting the demand for more study in this area. One study indicated that male athletes show superior cognition compare with female athletes (Lum et al., 2002), and Legault et al. (2022) reported a significant sex difference in visual tracking performance favoring male athletes. By contrast, another study reported no superior performance between male and female volleyball players on a visual selective attention task (Alves et al., 2013). Similarly, another study found no statistically significant sex difference on a visual spatial attention task among volleyball players (Notarnicola et al., 2014b). Thus, the existence of a sex difference in athletes' visual attention remains controversial; previous findings should be further confirmed and more investigation in this area is needed.

The multiple object tracking (MOT) task is a well-established paradigm used for investigating visual attention in laboratory research (Pylyshyn and Storm, 1988). In a classic MOT task, target and distractor objects are presented on a screen. A subset of the objects are cued as being target objects (typically by their changing color or flashing) for a short period of time. Thereafter, all objects move around on the screen for several seconds, and at the end of a given trail the observer is asked to identify the original target objects (Meyerhoff et al., 2017). The MOT task is considered to be one of the most popular and powerful tools for exploring the underlying mechanisms involved in visual attention, and the best method for the assessment of distributed, selective, and sustained attention skills (Qiu et al., 2018). Some previous studies demonstrating an expertise effect on performance in Mot task. In domains as varied as radar operator expertise (Allen et al., 2004), video-game expertise (Green and Bavelier, 2006), and sport expertise (Martín et al., 2017; Jin et al., 2020), all of these studies have used the MOT task to display that expertise in visual attention provides a greater advantages. In addition, the MOT task paradigm is similar to the requirements of an open skill sports situation (Mangine et al., 2014). In some open skill sports that have high cognitive demands, such as basketball, players have to react within continuously changing conditions. They need to concurrently focus not only on the ball and the field but also on the movement and position of opponents and teammates (Zarić et al., 2018). In contrast, closed skill sports, such as swimming, are performed in a predictable and stable environments (Koch and Krenn, 2021) that require less such cognitive activities and attention demands (Cooper et al., 2018; Gallotta et al., 2020). Therefore, it is reasonable to postulate that open skill sports athletes may exhibit performance on the MOT task superior to closed skill sports athletes owing to the nature of the type of sport. However, this remains controversial. For example, one study from Memmert et al. (2009) found that handball athletes show no better tracking accuracy on the MOT task than either track athletes or non-athletes. Thus, whether MOT task performance can be improved by engaging in a given type of sport remains unclear. In addition, there is a limited number of studies about sex differences in MOT task performance, in general and according to sports type (open-vs. closed-skill).

Thus, this study was conducted to examine whether there are differences between types of sport and between men and women in a visual attention task. The two main objectives were as follows: (1) to investigate possible differences in performance measures on the MOT task among athletes trained in an open skill sport, athletes trained in a closed skill sport, and non-athletes; and (2) to assess whether there is a sex difference in MOT task performance. Our hypotheses were twofold. The first hypothesis was that basketball athletes would exhibit better tracking accuracy performance on the MOT task than both athletes trained in swimming and non-athletes. Based on the literature we mentioned above (Alves et al., 2013; Notarnicola et al., 2014a), our second hypothesis was that sex differences for MOT task performance would be revealed only in non-athletes and swimmers, not in the basketball players.

Materials and methods

Participants

Sample size calculations were computed by analysis of variance (ANOVA) *F*-test and performed using G*Power 3.1.9.2 software. Using a medium effect size of 0.25, an alpha level of 0.05, and power of 0.80 (Cohen, 1992), the result indicated that a sample size of at least 158 participants was required. However, the number of participants in present study was slightly below the limit due to COVID-19 related restrictions at the time. Therefore, the final total sample encompassed 132 participants in our study. We recruited 44 open-skill sport athletes, 44 closed-skill sport athletes, and 44 non-athletes (22 men and 22 women each). The open skill sport athletes were recruited from eight China University Basketball Association (CUBA) teams. These athletes comprised 22 men

(mean age: 21.62 ± 2.07 years) with a mean of 9.46 (SD = 2.92) years of basketball training experience, and a mean of 12.36 (SD = 2.14) training hours per week as well as 22 women (mean age: 21.48 ± 1.92 years), with a mean of 9.17 (SD = 2.44) years of basketball training experience and a mean of 12.42 (SD = 2.37) training hours per week. All players were first-level national athletes. The closed skill sport athletes were com-posed of 22 men (mean age: 21.89 ± 2.32 years) with a mean of 10.05 (SD = 2.63) years of swim training experience, and a mean of 12.87 (SD = 1.82) training hours per week as well as 22 women (mean age: 21.36 ± 1.58 years), with a mean of 9.78 (SD = 1.53) years of swim training experience and a mean of 12.62 (SD = 2.37) training hours per week. All of these athletes were also first-level national athletes. The non-athlete group was composed of 22 men (mean age: 21.17 ± 1.28 years) and 22 women (mean age: 21.05 ± 1.41 years) who were college students and had never participated in open skill sports training or any other sports. All participants reported normal or corrected-to-normal levels of visual function. All participants received a verbal explanation of the research and experimental procedures. The study protocol was approved by the Ethics Committee of Shanghai University of Sport (No. 2015003SUS). All participants provided written informed consent prior to the start of the experiment. Each participant who completed the study received a small monetary compensation for their time.

Stimuli, apparatus, and procedure

The experiment was conducted on a ThinkPad (ThinkBook Plus 17) laptop running Windows 10. Visual stimuli were created using MATLAB R2016a (MathWorks, Natick, MA) and Psychtoolbox 3.0 software. Stimuli were presented on a 17-inch monitor with a resolution of 3,072 × 1,440 pixels and a refresh rate of 120 Hz. Individual participants were seated ~ 55 cm in front of the monitor of the laptop and were tested individually in a quiet room. The entire experiment consisted of 30 trials in two blocks separated by a 3-min rest period (total, ~ 12 min). Before the start of the formal session, the participants completed six practice trials to ensure that they were familiar with the procedure. At the beginning of each test block, the instruction "press the left mouse button to start the task" was presented on the screen. In each trial, a white fixation symbol (+) was displayed in the center of a gray background (visual field, 37.98 × 21.0°) for 2,000 ms, followed by the presentation of 10 white-field circles (0.65 diameter) for 1,000 ms. Four filled circles were highlighted blue and flickered three times for a total of 3 s to mark them as the targets. Thereafter, the target circles returned to white so that no cue remained to discriminate them from the untracked items (distractors). Next, the 10 filled circles moved in random directions at a constant speed of 10°/s, with the movement of each circle affected only by collisions (The dots changed their directions randomly when they reached the edge of the screen border. There were no extra constraints in the dots' trajectories hence there was the possibility that they crossing each other for an instant). After 8 s, the filled circles stopped moving. The participants were instructed to identify the targets by pressing a mouse button (Figure 1). Their responses also triggered the start of the next trial. The tracking accuracy recorded with all other study data in MATLAB R2016a (The Math Works).

Statistical analysis

The statistical analyses were performed using SPSS 23.0. A Univariate analysis of variance (UNIANOVA) was constructed with sex (male and female) and group (basketball players, swimmers, and college students) serving as independent variables and MOT task tracking accuracy serving as the dependent variable. The simple effects test was performed to identify any significant interaction and simple comparisons followed by Bonferroni correction was used. Effect sizes (Cohen's *f*) were calculated; $d = 0.10$ was considered to represent a small effect, $d = 0.25$ was considered to represent a medium' effect, and $d = 0.40$ was considered to represent a large effect $p < 0.05$ was considered to be significant. The tracking accuracy was calculated by determining the percentage of correctly selected targets across all experimental times for each participant. For example, if a participant identified all four targets 15 out of 30 times, the tracking accuracy was 50%.

Results

The means and standard deviations of the tracking accuracy for the groups of open skill sport and closed skill sport or college student of both sex are shown in Figure 2. For the dependent variable of tracking accuracy, our UNIANOVA results indicated significant main effects for sex, $F(1,126) = 42.329$, $p < 0.001$, $\eta_p^2 = 0.251$ and for group, $F(2,126) = 53.643$, $p < 0.001$, $\eta_p^2 = 0.460$ (see Table 1). Importantly, a significant interaction was also observed between sex and group, $F(2,126) = 7.874$, $p < 0.001$, $\eta_p^2 = 0.111$.

Further simple effects analyses showed that for sex, male basketball athletes ($M = 0.52$, SD = 0.09) had significantly better tracking accuracy than male swimming athletes ($M = 0.44$, SD = 0.08; $p < 0.01$, $d = 0.94$) and then male college students ($M = 0.43$, SD = 0.08; $p < 0.01$, $d = 1.06$). However, the difference in tracking accuracy between male swimming athletes and college students failed to reach statistical significance ($p = 0.26$). An analysis by group revealed that male swimmers ($M = 0.44$, SD = 0.08) had significantly better tracking accuracy than female swimmers ($M = 0.33$, SD = 0.04; $p < 0.01$, $d = 1.73$); similarly, the tracking accuracy among male college students ($M = 0.43$, SD = 0.08) was significantly higher than among female college students ($M = 0.30$, SD = 0.05; $p < 0.01$, $d = 1.94$). By contrast, there was no significant difference in tracking accuracy between male basketball athletes ($M = 0.52$, SD = 0.09) and female basketball athletes ($M = 0.50$, SD = 0.08; see Table 2; Figure 2).

Discussion

The purpose of this study was to determine whether visual attention as assessed in the MOT task by tracking accuracy performance varied by type of sport (closed skill vs. open skill) or by sex among first-level national athletes. The results provided evidence to support our hypothesis that open skill athletes (in this case, basketball players) exhibit performance on the MOT task superior to closed skill athletes (swimmers) and to non-athletes (non-athletic college students). However, there was no significant difference in performance on the MOT task between swimmers and non-athletes. The results of this study were also concordant with our hypothesis

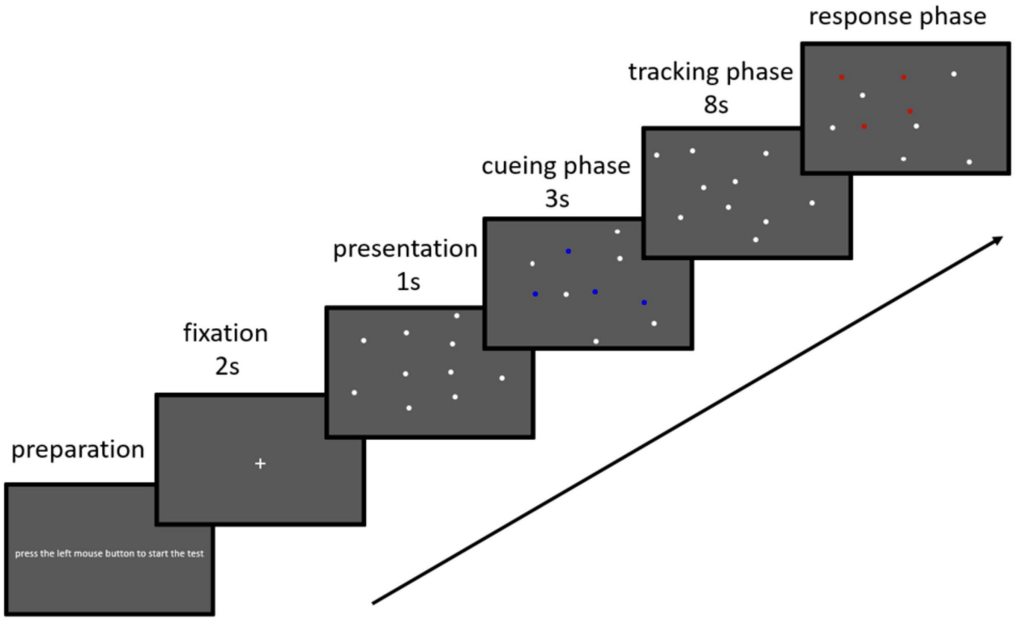


FIGURE 1
Schematic diagram of the visual stimuli presented in one trial of the multiple object tracking task. Ten filled white circles are presented on the screen. In each trial, four of the circles turn blue and flicker for 3s before turning back to white. The blue flickering circles indicate the targets for that trial. All 10 circles then move 10°/s for an 8-s tracking period. When the circles stop moving, the participants use a mouse to click over their choices for the target circles.

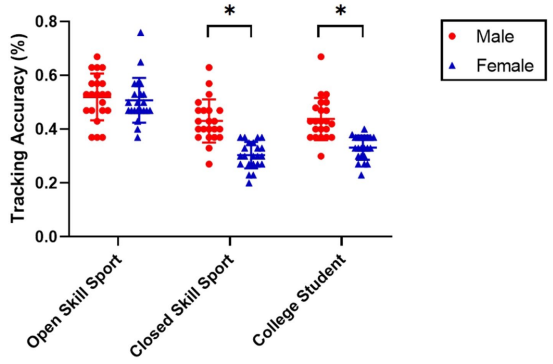


FIGURE 2
Comparison of the tracking accuracy between groups. *p<0.05.

TABLE 1 Univariate analysis of variance (UNIANOVA) results for between-subjects effects.

Source	SoS-III	*df*	Mean square	*F*	*p*	η_P^2
Corrected model	0.869[a]	5	0.174	33.073	<0.001	0.568
Intercept	23.504	1	23.504	4470.385	<0.001	0.973
Sex	0.223	1	0.223	42.329	<0.001	0.251
Group	0.564	2	0.282	53.643	<0.001	0.46
Sex × group	0.083	2	0.041	7.874	0.001	0.111
Error	0.662	126	0.005			
Total	25.036	132				
Corrected total	1.532	131				

Dependent variable = tracking accuracy. [a]$R2 = 0.568$ (adjusted $R2 = 0.550$). SoS-III, type III sum of squares; *df*, degrees of freedom.

regarding sex in that significant sex differences in tracking accuracy were observed for both the closed skill group and the non-athlete group. As expected, in the open skill sport group, we did not detect a difference between male basketball and female basketball players on tracking accuracy on the MOT task, a finding that has been little reported.

Regarding the differences by type of sport, we found that sport type is closely linked to visual attention, with tracking accuracies on the MOT task among basketball athletes being markedly better than those in both the closed skill sport group and the non-athlete group. A plausible explanation for this finding is that open skill athletes have to monitor numerous changing stimuli and continuously shifting positions to excel in their sport (Ong, 2017; Gökçe et al., 2021). In basketball, players have to allocate visual attention to track the targets of the ball, teammates, and opponents while inhibiting irrelevant information over time on the court. These tracking processes are similar to those used in the MOT task. In comparison, because closed skill sports take place in a predictable and relatively stable environment, there are fewer cognitive activities required and fewer demands on visual attention (Gu et al., 2019). Current evidence suggests that an enriched environment, such as basketball training, has positive effects on the brain (Qiu et al., 2019). Therefore, it is reasonable to suggest that the superior performance of the basketball players on tracking accuracy in the MOT task indicates that open skill sports activities may improve visual attention. This conclusion aligns

TABLE 2 Sex and group interactions.

Group	Sex	Mean difference	SE	p [a]	95% CI	
					Lower limit	Upper limit
Open skill sport	Male vs. Female	0.012	0.022	0.576	−0.031	0.056
Closed skill sport	Male vs. Female	0.127*	0.022	<0.001	0.084	0.171
College student	Male vs. Female	0.107*	0.022	<0.001	0.064	0.15

CI = confidence interval; SE, standard error.
Dependent variable = tracking accuracy. *The mean difference is significant at the.05 level. [a]Adjustment for multiple comparisons (least significant difference test, equivalent to no adjustments).

with recent trends in research showing that open skill sports athletes have better cognitive performance than closed skill sports athletes and non-athletes (Mohammadi et al., 2016; Holfelder et al., 2020).

We found no difference in the tracking accuracies between swimming athletes and non-athletes, suggesting that closed skill sports with low cognitive demands, such as aerobic exercise or resistance training, yields no greater abilities in visual attention (Diamond and Ling, 2019). The disagreement between our results and the previous finding that the sport type is unrelated to MOT task performance differences among handball players, track athletes, and non-athletes (Memmert et al., 2009) may be related to the MOT task structure. In the previous study, the MOT task had a lesser tracking load, with 7 objects (3 targets and 4 distractors) used instead of the 10 objects used in our study, which may not have provided sufficient sensitivity to detect a difference. It is also the reason why the tracking accuracy is low in comparison to other studies. Another explanation is that the object speed, in this study, the object speed is 10°/S, which is faster than other studies (Zhang et al., 2021), the previous research showed that tracking accuracy declines as object speed increases in the MOT task (Ma and Flombaum, 2013). Taken together, our findings extended those of previous studies and were consistent with our hypothesis that open skill sports athletes would exhibit visual attention as assessed in the MOT task superior to that of closed skill sports athletes.

The present study also found that the differences of tracking performance between male and female in the MOT task, with males demonstrating tracking accuracy superior to that of females in experimental groups. Our finding is consistent with existing research assessing visual attention on a MOT task (Roudaia and Faubert, 2017). Other studies using visual–spatial tasks (Notarnicola et al., 2014b), Silverman et al. (2007) have also shown that males demonstrate superior performance compared with females. This finding may be attributable to asymmetry in brain structures and the percentages of white vs. gray matter (Gur and Gur, 2017). Apart from potential biological factors, a difference in opportunities to participate in electronic video games and sports in daily life could result in the sex effects observed in the MOT task (Green et al., 2010). Another reason may be sociocultural environments; some findings have demonstrated a relationship between sex differences and national indices of gender equality for sustained attention (Riley et al., 2016; Roudaia and Faubert, 2017). Our findings thus extend previous research and further support the view that sex differences exist in visual attention.

We also found an interaction between group (open vs. closed skill sports athletes vs. non-athletes) and sex in the present study. A statistically significant sex difference was observed in tracking accuracy on the MOT task for the closed skill sport group (swimmers), whereas male basketball players did not show tracking accuracy performance superior to female basketball players (open skill sport). As far as we know, only a few studies have shown an absence of sex differences in visual attention abilities among open skill sports athletes. One recent study demonstrated that male basketball players did not exhibit better tracking accuracy than women basketball players on the MOT task (Jin and Fan, 2022). Two other studies also drew the same conclusion although they used different designs to assess visual attention in open skill sports athletes. One of those studies reported that athletes of an open skill sport (volleyball) showed no sex differences in the performance of a visual–spatial task (Notarnicola et al., 2014b). The other study also failed to find a statistically significant difference between female and male volleyball athletes in visual selective attention (Alves et al., 2013). A plausible explanation for these findings is that the athletes were participating in sports in which the environmental conditions for both men and women required similar perceptual skills (Mc Leod, 1987). Another possible explanation is that changes in hormone levels among women undergoing such sports training appears to get a higher advantage in related cognition function. Sex hormones have been shown to have a strong impact on performance in attention tasks (Holländer et al., 2005). Another study (Lord and Garrison, 1998) found that female basketball athletes who showed a greater benefit compare with female swimming and track athletes in spatial abilities had increased androgen levels. These findings could explain why sex differences only existed in the closed skill sports group, not in the open skill sports group.

The current study is the first, to our knowledge, to show that the sport type and sex affect visual tracking (MOT task) performance. However, some limitations must be taken into consideration. The main shortcoming was that the participating basketball players were not representative of the whole open-skill sport population. We recommend that future research be performed with athletes in a wider range of open-skill sports, in particular individual sports such as tennis and boxing. Furthermore, it is a cross-sectional design, not a Randomized Controlled trial. It is impossible for our study design to assign participants randomly, it is always possible that females need not necessarily gain advantage from open sport; maybe only those females with better MOT were able to remain in the sport over the years. Therefore, a longitudinal studies are needed to observe changes in open-and closed-skill athletes' visual attention abilities over time in the future study. Lastly, the small

sample size limits the generalizability of our study. We did not reach the sample size of 158 participants we expected, for the COVID-19 pandemic have made it difficult to recruit a larger number of participants, future study design will consider increasing the sample size to increasing the generalizability and validity of the results.

In conclusion, the current study demonstrates that open-skill sports athletes have visual tracking accuracy superior to that of closed-skill sport athletes and non-athletic college students on MOT task. This finding indicates that the cognitive requirements of the sports environment provided by open skill sports may transfer to enhanced visual attention abilities. The present study also revealed a sex difference in visual attention among non-athletes and among athletes in a closed skills sport, highlighting the need to control for sex in research comparing attentional tracking abilities across different participant groups. Additionally, no difference in tracking accuracy on the MOT task was found between female and male basketball athletes, supporting the idea that training in open skill sports may reduce sex differences in visual attention. These findings highlighting the necessary to control for sex in researches comparing visual tracking abilities in different participant groups, and also give sport psychology practitioners and coaches clues to be used in identifying athletes who might need to further improve this capacity.

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.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of Shanghai University of Sport. The patients/participants provided their written informed consent to participate in this study.

Author contributions

PJ and Z-QZ: conceptualization. X-FZ: methodology and supervision. PJ: writing—original draft. PJ and X–FZ: writing—review and editing. All authors contributed to the article and approved the submitted version.

Acknowledgments

Many thanks to all the coaches, players, college students and other staff members for their participation in the study. Our thanks also go to Thressa Smith for his language assistance and editing of the manuscript.

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

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1099254/full#supplementary-material

References

Allen, R., Mcgeorge, P., Pearson, D., and Milne, A. B. (2004). Attention and expertise in multiple target tracking. *Appl. Cogn. Psychol.* 18, 337–347. doi: 10.1002/acp.975

Alves, H., Voss, M. W., Boot, W. R., Deslandes, A., Cossich, V., Salles, J. I., et al. (2013). Perceptual-cognitive expertise in elite volleyball players. *Front. Psychol.* 4:36. doi: 10.3389/fpsyg.2013.00036

Cooper, S. B., Dring, K. J., Morris, J. G., Sunderland, C., Bandelow, S., and Nevill, M. E. (2018). High intensity intermittent games-based activity and adolescents' cognition: moderating effect of physical fitness. *BMC Public Health* 18, 1–14. doi: 10.1186/s12889-018-5514-6

Cohen, J. (1992). Statistical power analysis. *Curr. Dir. Psychol. Sci.* 1, 98–101. doi: 10.1111/1467-8721.ep10768783

Coyne, J. O., Coutts, A. J., Newton, R. U., and Haff, G. G. (2021). The influence of mental fatigue on sessional ratings of perceived exertion in elite open and closed skill sports athletes. *J. Strength Cond. Res.* 35, 963–969. doi: 10.1519/JSC.0000000000003980

Diamond, A., and Ling, D. S. (2019). Aerobic-exercise and resistance-training interventions have been among the least effective ways to improve executive functions of any method tried thus far. *Dev. Cogn. Neurosci.* 37:100572. doi: 10.1016/j.dcn.2018.05.001

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Sci. Rep.* 3, 1–3. doi: 10.1038/srep01154

Gallotta, M. C., Bonavolontà, V., Zimatore, G., Iazzoni, S., Guidetti, L., and Baldari, C. (2020). Effects of open (racket) and closed (running) skill sports practice on Children's attentional performance. *Open Sports Sci. J.* 13, 105–113. doi: 10.2174/1875399X02013010105

Gökçe, E., Güneş, E., Arı, F., Hayme, S., and Nalçacı, E. (2021). Comparison of the effects of open-and closed-skill exercise on cognition and peripheral proteins: a cross-sectional study. *PLoS One* 16:e0251907. doi: 10.1371/journal.pone.0251907

Green, C. S., and Bavelier, D. (2006). Enumeration versus multiple object tracking: the case of action video game players. *Cognition* 101, 217–245. doi: 10.1016/j.cognition.2005.10.004

Green, C. S., Li, R., and Bavelier, D. (2010). Perceptual learning during action video game playing. *Top. Cogn. Sci.* 2, 202–216. doi: 10.1111/j.1756-8765.2009.01054.x

Gu, Q., Zou, L., Loprinzi, P., Quan, M., and Huang, T. (2019). Effects of open versus closed skill exercise on cognitive function: a systematic review. *Front. Psychol.* 10:1707. doi: 10.3389/fpsyg.2019.01707

Gur, R. C., and Gur, R. E. (2017). Complementarity of sex differences in brain and behavior: from laterality to multimodal neuroimaging. *J. Neurosci. Res.* 95, 189–199. doi: 10.1002/jnr.23830

Harris, D. J., Wilson, M. R., Crowe, E. M., and Vine, S. J. (2020). Examining the roles of working memory and visual attention in multiple object tracking expertise. *Cogn. Process.* 21, 209–222. doi: 10.1007/s10339-020-00954-y

Holfelder, B., Klotzbier, T. J., Eisele, M., and Schott, N. (2020). Hot and cool executive function in elite-and amateur-adolescent athletes from open and closed skills sports. *Front. Psychol.* 11:694. doi: 10.3389/fpsyg.2020.00694

Holländer, A., Hausmann, M., Hamm, J. P., and Corballis, M. C. (2005). Sex hormonal modulation of hemispheric asymmetries in the attentional blink. *J. Int. Neuropsychol. Soc.* 11, 263–272. doi: 10.1017/S1355617705050319

Hüttermann, S., and Memmert, D. (2017). The attention window: a narrative review of limitations and opportunities influencing the focus of attention. *Res. Q. Exerc. Sport* 88, 169–183. doi: 10.1080/02701367.2017.1293228

Jin, P., and Fan, M. T. (2022). Team ball sport experience minimizes sex difference in visual attention. *Front. Psychol.* 13:987672. doi: 10.3389/fpsyg.2022.987672

Jin, P., Li, X., Ma, B., Guo, H., Zhang, Z., and Mao, L. (2020). Dynamic visual attention characteristics and their relationship to match performance in skilled basketball players. *PeerJ* 8:e9803. doi: 10.7717/peerj.9803

Ke, L., Lanlan, Z., Jian, Z., and Jianing, W. (2021). Comparison of open-skill and closed-skill exercises in improving the response inhibitory ability of the elderly: a protocol for a randomised controlled clinical trial. *BMJ Open* 11:e051966. doi: 10.1136/bmjopen-2021-051966

Koch, P., and Krenn, B. (2021). Executive functions in elite athletes–comparing open-skill and closed-skill sports and considering the role of athletes' past involvement in both sport categories. *Psychol. Sport Exerc.* 55:101925. doi: 10.1016/j.psychsport.2021.101925

Legault, I., Sutterlin-Guindon, D., and Faubert, J. (2022). Perceptual cognitive abilities in young athletes: a gender comparison. *PLoS One* 17:e0273607. doi: 10.1371/journal.pone.0273607

Lord, T. R., and Garrison, J. (1998). Comparing spatial abilities of collegiate athletes in different sports. *Percept. Mot. Skills* 86, 1016–1018. doi: 10.2466/pms.1998.86.3.101

Lum, J., Enns, J. T., and Pratt, J. (2002). Visual orienting in college athletes: explorations of athlete type and gender. *Res. Q. Exerc. Sport* 73, 156–167. doi: 10.1080/02701367.2002.10609004

Ma, Z., and Flombaum, J. I. (2013). Off to a bad start: uncertainty about the number of targets at the onset of multiple object tracking. *J. Exp. Psychol. Hum. Percept. Perform.* 39, 1421–1432. doi: 10.1037/a0031353

Mangine, G. T., Hoffman, J. R., Wells, A. J., Gonzalez, A. M., Rogowski, J. P., Townsend, J. R., et al. (2014). Visual tracking speed is related to basketball-specific measures of performance in NBA players. *J. Strength Cond. Res.* 28, 2406–2414. doi: 10.1519/JSC.0000000000000550

Martín, A., Sfer, A. M., D'Urso Villar, M. A., and Barraza, J. F. (2017). Position affects performance in multiple-object tracking in rugby union players. *Front. Psychol.* 8:1494. doi: 10.3389/fpsyg.2017.01494

Mc Leod, B. (1987). Sex, structured sport activity, and measurement of field dependence. *Percept. Mot. Skills* 64, 452–454. doi: 10.2466/pms.1987.64.2.452

Memmert, D., Simons, D. J., and Grimme, T. (2009). The relationship between visual attention and expertise in sports. *Psychol. Sport Exerc.* 10, 146–151. doi: 10.1016/j.psychsport.2008.06.002

Merritt, P., Hirshman, E., Wharton, W., Stangl, B., Devlin, J., and Lenz, A. (2007). Evidence for gender differences in visual selective attention. *Personal. Individ. Differ.* 43, 597–609. doi: 10.1016/j.paid.2007.01.016

Meyerhoff, H. S., and Papenmeier, F. (2020). Individual differences in visual attention: a short, reliable, open-source, and multilingual test of multiple object tracking in PsychoPy. *Behav. Res. Methods* 52, 2556–2566. doi: 10.3758/s13428-020-01413-4

Meyerhoff, H. S., Papenmeier, F., and Huff, M. (2017). Studying visual attention using the multiple object tracking paradigm: a tutorial review. *Atten. Percept. Psychophysiol.* 79, 1255–1274. doi: 10.3758/s13414-017-1338-1

Mohammadi, N., Rostami, R., and Alborzi, M. (2016). Visual skills of the female athletes in team and individual sports. *Ann. Appl. Sport Sci.* 4, 69–77. doi: 10.18869/acadpub.aassjournal.4.4.69

Notarnicola, A., Maccagnano, G., Pesce, V., Tafuri, S., Novielli, G., and Moretti, B. (2014a). Visual-spatial capacity: gender and sport differences in young volleyball and tennis athletes and non-athletes. *BMC. Res. Notes* 7:57. doi: 10.1186/1756-0500-7-57

Notarnicola, A., Maccagnano, G., Pesce, V., Tafuri, S., Novielli, G., and Moretti, B. (2014b). Visual-spatial capacity: gender and sport differences in young volleyball and tennis athletes and non-athletes. *BMC. Res. Notes* 7, 1–5. doi: 10.1186/1756-0500-7-57

Ong, N. (2017). Reactive stress tolerance in elite athletes: differences in gender, sport type, and competitive level. *Cognitie, Creier, Comportament/Cognition, Brain, Behavior* 21, 189–202. doi: 10.24193/cbb.2017.21.11

Poulton, E. (1957). On prediction in skilled movements. *Psychol. Bull.* 54, 467–478. doi: 10.1037/h0045515

Pylyshyn, Z. W., and Storm, R. W. (1988). Tracking multiple independent targets: evidence for a parallel tracking mechanism. *Spat. Vis.* 3, 179–197. doi: 10.1163/156856888X00122

Qiu, F., Pi, Y., Liu, K., Li, X., Zhang, J., and Wu, Y. (2018). Influence of sports expertise level on attention in multiple object tracking. *PeerJ* 6:e5732. doi: 10.7717/peerj.5732

Qiu, F., Pi, Y., Liu, K., Zhu, H., Li, X., Zhang, J., et al. (2019). Neural efficiency in basketball players is associated with bidirectional reductions in cortical activation and deactivation during multiple-object tracking task performance. *Biol. Psychol.* 144, 28–36. doi: 10.1016/j.biopsycho.2019.03.008

Riley, E., Okabe, H., Germine, L., Wilmer, J., Esterman, M., and DeGutis, J. (2016). Gender differences in sustained attentional control relate to gender inequality across countries. *PLoS One* 11:e0165100. doi: 10.1371/journal.pone.0165100

Roudaia, E., and Faubert, J. (2017). Different effects of aging and gender on the temporal resolution in attentional tracking. *J. Vis.* 17:1. doi: 10.1167/17.11.1

Silverman, I., Choi, J., and Peters, M. (2007). The hunter-gatherer theory of sex differences in spatial abilities: data from 40 countries. *Arch. Sex. Behav.* 36, 261–268. doi: 10.1007/s10508-006-9168-6

Tsai, C.-L., Wang, C.-H., Pan, C.-Y., Chen, F.-C., Huang, S.-Y., and Tseng, Y.-T. (2016). The effects of different exercise types on visuospatial attention in the elderly. *Psychol. Sport Exerc.* 26, 130–138. doi: 10.1016/j.psychsport.2016.06.013

Voss, M. W., Kramer, A. F., Basak, C., Prakash, R. S., and Roberts, B. (2010). Are expert athletes 'expert'in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Appl. Cogn. Psychol.* 24, 812–826. doi: 10.1002/acp.1588

Walsh, V. (2014). Is sport the brain's biggest challenge? *Curr. Biol.* 24, R859–R860. doi: 10.1016/j.cub.2014.08.003

Wang, C.-H., Chang, C.-C., Liang, Y.-M., Shih, C.-M., Chiu, W.-S., Tseng, P., et al. (2013). Open vs. closed skill sports and the modulation of inhibitory control. *PLoS One* 8:e55773. doi: 10.1371/journal.pone.0055773

Zarić, I., Dopsaj, M., and Marković, M. (2018). Match performance in young female basketball players: relationship with laboratory and field tests. *Int. J. Perform. Anal. Sport* 18, 90–103. doi: 10.1080/24748668.2018.1452109

Zhang, Y., Lu, Y., Wang, D., Zhou, C., and Xu, C. (2021). Relationship between individual alpha peak frequency and attentional performance in a multiple object tracking task among ice-hockey players. *PLoS One* 16:e0251443. doi: 10.1371/journal.pone.0251443

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 23 February 2023
DOI 10.3389/fpsyg.2023.1072709

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Md. Dilsad Ahmed,
Prince Mohammad bin Fahd University, Saudi Arabia
Nadhir Hammami,
University of Jendouba, Tunisia
Jiazhi Sheng,
School of Sports and Physical Education, China

*CORRESPONDENCE
Majed M. Alhumaid
malhumaid@kfu.edu.sa

†These authors have contributed equally to this work

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

RECEIVED 23 November 2022
ACCEPTED 06 February 2023
PUBLISHED 23 February 2023

CITATION
Alhumaid MM and Said MA (2023) Increased physical activity, higher educational attainment, and the use of mobility aid are associated with self-esteem in people with physical disabilities. *Front. Psychol.* 14:1072709. doi: 10.3389/fpsyg.2023.1072709

Increased physical activity, higher educational attainment, and the use of mobility aid are associated with self-esteem in people with physical disabilities

Majed M. Alhumaid [1*†] and Mohamed Ahmed Said [1,2†]

[1]Department of Physical Education, College of Education, King Faisal University, Al-Ahsa, Saudi Arabia, [2]Higher Institute of Sport and Physical Education of Kef, University of Jandouba, Jendouba, Tunisia

Background: High self-esteem can help people with disabilities overcome barriers and improve their mental health and well-being. This study sought to examine self-esteem levels among Saudis with physical disabilities based on socio-economic factors. It also aimed to determine the minimum weekly duration of physical activity performed by participants and examine its effects, along with those of other socio-economic factors, on participants' self-esteem.

Methods: A participant sample (N=582) consisting of Saudi individuals aged 33.78±9.81years with physical disabilities (males, n=289; females, n=293) was recruited to participate in this study. Levels of self-esteem were measured using the Arabic version of the Rosenberg Self-Esteem Scale.

Results: Compared to women, men demonstrated significantly higher levels of overall self-esteem, positive feelings, and negative feelings (p<0.01). The respondents' average levels of overall self-esteem (p<0.001), positive feelings (p<0.01), and negative feelings (p<0.001) also varied by type of physical disability. Wheelchair-using participants had the highest values for self-esteem and positive feelings; cane-using participants or those who did not use mobility aids had the lowest values. Weighted least squares regression showed that weekly physical activity was the factor that most affected self-esteem (β=0.002), followed by education level (β=0.115), then type of mobility device used (β=−0.07).

Conclusion: Increased weekly physical activity, higher education levels, and the use of mobility aids were the factors likely to improve the self-esteem of Saudis with physical disabilities.

KEYWORDS

quality of life, educational level, assistive devices, multiple sclerosis, cerebral palsy, physical activity

Introduction

A disability is a condition or function that is considered to be significantly reduced from the usual norm for an individual or group. The term is used to refer to a person's ability to function and includes physical, sensory, cognitive, and mental disorders, as well as mental illness and various types of chronic disease (Disabled World, 2022). The World Health Organization (2021)

stated that people with disabilities face barriers, stigma, and discrimination when accessing health and related services and strategies. These barriers often prevent people with disabilities from fully and effectively participating in society on an equal basis with others (Howard et al., 2022).

Up-to-date statistics indicate that in Saudi Arabia, the overall prevalence of disability was around 7.1%, of which 3.9% are affected by physical disabilities. These rates are expected to increase due to the continued increase in health risk factors such as obesity, physical inactivity, road accidents, and chronic diseases (Zahra et al., 2022). People with physical disabilities are sometimes stigmatized by their families, excluded from social gatherings, and sometimes are not authorized to receive family visits. The family perspective is based on simple notions of disability including helplessness, lifelong dependence, home isolation, poor quality of life, etc. (Al-Jadid, 2013).

High self-esteem (SE) can help people with disabilities overcome these barriers, simplify their daily lives, and improve their mental health and well-being. SE is usually defined as "the extent to which one prizes, values, approves, or likes oneself" or "the overall affective evaluation of one's own worth, value, or importance" (Blascovich and Tomaka, 1991, p. 115). The benefits of high SE fall into two categories: increased initiative and pleasant feelings. People with high SE report that they are more likable, more attractive, have better relationships, and make a better impression on others than people with low SE. Conversely, low SE is associated with anxiety, depression, suicide, alcoholism, aggression, antisocial behaviors, and criminality (Serafin et al., 2022).

Self-esteem in people with disabilities can be mediated and moderated by several factors, including the occurrence of SE (Ekeland et al., 2005), perceived stigma and social relationships (Zhang et al., 2014), socioeconomic status (Twenge and Campbell, 2002), and support from family members or others (Stark et al., 2017). In a literature review on gender and age differences in SE, Bleidorn et al. (2016) reported that men generally had significantly higher levels of SE than women. However, despite the huge gender differences in SE, men and women often follow similar life trajectories. For both sexes, SE is relatively high during childhood, declines during adolescence, increases gradually throughout adulthood, and then declines in old age (Trzesniewski et al., 2013). Thus, we propose the following hypothesis:

> *H1a*: Saudis with physical disabilities generally report lower levels of SE and men report significantly higher levels of SE than women.
>
> *H1b*: The level of SE of people with physical disabilities depends on their age.

Relevant studies have also shown that physical activity (PA) has many positive effects on the SE of people with disabilities as mobility and exercise improve a person's fitness and performance (Nemček, 2017). However, the extant literature indicates poor adherence to the prescription of PA among those with disabilities (Maynou et al., 2021). Liu et al.'s (2015) systematic review and meta-analysis identified that PA-based interventions were associated with significant improvements in overall personal achievement, self-concept, and SE. The authors also revealed that PA-based interventions are potentially important in mediating the effect of PA on SE and that such interventions produce more beneficial outcomes in school and gymnasium settings compared to other contexts. Ahn et al. (2021) also revealed that participation in sports activities increases the SE of individuals with disabilities, may help them overcome feelings of pain or sadness, and can positively influence their acceptance of their disability. Jung et al. (2022), in a four-year follow-up study assessing the impact of disability acceptance on SE in adults with disabilities, reported that uncompromising people with disabilities had reduced disability acceptance; moreover, when self-denial was maximized, there was a pathological risk of depression and suicide. It can also be accompanied by the social risks of selfish behavior and aggression. Therefore, it is necessary to care for people with disabilities to ensure that they have high SE by healthily accepting their disability, not only individually but also socially. Thus, we propose the following hypothesis:

> *H2a*: A greater amount of weekly PA is associated with a higher level of SE in participants with physical disabilities.

The literature also indicates that there is a significant and mostly positive relationship between SE and education level (Zhao et al., 2021; Al Awaji et al., 2022). However, Vialle et al.'s (2005) study on the relationship between SE and the achievement of gifted students is at odds with this assertion: It reported that there is no significant difference in SE between gifted and non-gifted students. Besides, the study found no relationship between SE and academic performance in the gifted group. Studies have also shown that SE is strongly linked to opportunities to make meaningful decisions (Nemček et al., 2014; Sandjojo et al., 2019). A greater level of independence has been related to increased feelings of happiness and satisfaction and a higher quality of life (Sandjojo et al., 2019). An independent person is usually someone who has high levels of SE and self-worth. Independence is essential in life and plays a substantial role in what a person achieves in school, work, and relationships. This leads to a sense of accomplishment that will improve how they view themselves. Le Breton (2004) argues that risky behaviors may have benefits because they are associated with the development of autonomy and survival without the benefit of parental protection. It can also be argued that risky behaviors can promote autonomy in adolescence and are believed to help in forming an identity. Thus, we propose the following hypothesis:

> *H2b*: Higher education level positively modulates SE among Saudis with physical disabilities.

Assistive devices are also widely regarded as powerful tools for increasing the independence of people with disabilities while simultaneously allowing them to participate in PAs and all tasks of daily living (Brown et al., 2011). By definition, assistive devices refer to products whose primary purpose is to support the functioning and independence of individuals with disabilities to promote their academic, social, and physical well-being (McNicholl et al., 2021). According to these authors, inadequate assistive device training, the inadequacy of assistive devices, the availability of external support, and the challenge of negotiating multiple sources of information can impede the effective use of assistive devices and thus limit individuals' engagement in the higher education environment. Therefore, choosing

the right assistive device is the key to effective assistance in all of these activities. Tamakloe and Agbenyega (2017) argued that assistive devices if used effectively, could create a positive environment for the independence and development of people with disabilities. Assistive devices allow people with disabilities to overcome their weaknesses by increasing the strength needed to reach their potential and improving their motivation (Robitaille, 2010). Although several studies indicate that technical assistance can improve the quality of life of people with disabilities, much less is said about the potential of everyday technical assistance to promote SE for these individuals (Nemček, 2021; Howard et al., 2022). This is a major omission, as assistive devices enable people to be more independent and engaged in PA through a wide range of participation, from observation to practice (Bryant and Bryant, 2011). Referring to the studies described above, we expect the following hypotheses:

> *H2c*: Mobility assistance correlates with SE in people with physical disabilities.
>
> *H2d*: The type of physical disability affects SE in people with physical disabilities.

This study sought to examine SE levels among Saudis with physical disabilities based on socio-economic factors such as gender, age, education level, type of physical disability, and the use of mobility aids. It also aimed to determine the minimum weekly duration of PA performed by participants and examine its effects, along with those of other socio-economic factors, on participants' SE.

Materials and methods

Participants and procedure

The Arabic version of the Rosenberg Self-Esteem Scale (RSES) (Rosenberg, 1965) was used to examine the SE of people with physical disabilities in Saudi Arabia. This version was previously translated from English by ALAhmari et al. (2019), and our research group studied its validity and reliability in a group of volunteer participants with disabilities ($N = 30$). The construct validity was assessed using exploratory factor analysis and principal component analysis, while the reliability was assessed by Cronbach's alpha. An electronic copy was then distributed through emails sent to representatives of the Association of Motor Disabled for Adult Mobility, located in the city of Riyadh, which caters to all Saudi people with physical disabilities. Some participants were also invited to participate in our study. Each email contained a Google Form link that led to a page with details about the study's objectives and instructions for participants. All participants voluntarily participated in the study, and informed consent was obtained by asking participants to click on the questionnaire to begin. Participants were informed that the questionnaire would take approximately 10 min to complete. The results were then uploaded ($N = 645$) and checked for accuracy, and incomplete or disputed questionnaires were discarded ($n = 63$). In total, the results from 582 participants (289 males and 293 females) aged 18–59 years were stored and analyzed. Ethical approval was granted by the Research Ethics Board of King Faisal University, Saudi Arabia (KFU-REC-2021-DEC-EA000307).

Reliability and validity of the Arabic version of the Rosenberg self-esteem scale

The analysis revealed two factors in the Arabic version of the RSES: (1) Factor 1, which included Items 1, 3, 4, 7, and 10, labeled as positive feelings, and (2) Factor 2, which included Items 2, 5, 6, and 9, labeled as negative feelings. The eighth item was removed because its load factor was <0.30, whereas the remaining nine items achieved an acceptable item-to-total correlation. The positive factor alone explained 27.70% of the total variance; however, combined with the second factor, it indicated a cumulative eigenvalue of approximately 53.5% of the total variance, indicating good validity of the scale. Cronbach's alpha was then calculated separately for the two factors and combined. The respective values were 0.79, 0.77, and 0.83, which indicated good reliability of the Arabic version of the RSES. Therefore, the validity and traceability were met, and the Arabic RSES was a reliable and valid measure of the SE of people with physical disabilities.

Measures

Sociodemographic factors and weekly physical activity

The demographic form was used to collect data on age, gender, educational level, type of physical disability, type of physical assistive device used, PA participation in units/week, and daily PA duration in minutes/unit. The last two items were measured on a 4-point Likert scale based on responses to two questions indicating whether or not the participant engaged in physical activity/exercise. The first question asked about the number of days per week, while the second question asked about the duration of PA in minutes per session. The responses were used to calculate the minimum weekly PA time in minutes by multiplying the lowest reported number of sessions performed per week by the lowest reported time in minutes per session (Strath et al., 2013). The scoring method used distinguished 4 levels of weekly physical practice by adding four times the product of the range divided by four to zero (<50 min/week, from 50 to <100 min/week, from 100 to <150 min/week, and ≥ 150 min/week). The Cronbach's alpha value of this study was 0.661 indicating an acceptable level of reliability (Taber, 2018).

Assessment of the level of self-esteem

The Arabic version of the RSES whose validity and reliability have been previously verified was used. RSES is a 10-point scale that measures overall SE by measuring positive and negative feelings about oneself. The scale is meant to be uni-dimensional and all questions are answered on a 4-point Likert-type scale ranging from "strongly agree" (4 points) to "strongly disagree" (1 point) for items 1, 3, 4, 7, and 10 and vice versa (4 points for "strongly disagree" and 1 point for "strongly agree") for items 2, 5, 6, 8, and 9. The RSES results have been interpreted differently in previous studies (Ryszewska-Łabędzka et al., 2022). In our study, we used the following scoring: the sum of all answers divided by 10 is taken as the participant's score differentiated into 4 levels by adding four times the product of the range divided by four to one: scores of 1.0–1.75 indicate low SE; scores of 1.76–2.50 indicate moderate SE; scores of 2.51–3.25 indicate high SE; and scores of 3.26–4.0 indicate very high SE. The 10 statements of the

questionnaire are as follows: (1) In general, I am satisfied with myself; (2) Sometimes I think I'm no good at all; (3) I feel that I have several good qualities; (4) I can do things as well as most people; (5) I feel that I do not have much to be proud of; (6) I feel useless sometimes; (7) I feel like a person of value, and that I am at least on an equal footing with others; (8) I wish I had more respect for myself; (9) In general, I tend to feel like a failure; and (10) I have a positive attitude toward myself.

Statistical analysis

The first objective of the research was addressed by calculating the mean and standard deviation of the components of the RSES based on socioeconomic factors. The normality of the data distribution was tested using the Kolmogorov–Smirnov test, which found nonnormal distributions for all dependent variables. Data were compared using the Mann–Whitney nonparametric *U* test and the Kruskal–Wallis test. The second objective of the research was analyzed using weighted least squares (WLS) regression to deal with inefficiency-based problems due to biased estimates and standard errors resulting from unequal variance observed (violation of homoscedasticity; Akari and Gündoğdu, 2013). The linear regression assumptions were examined by examining the scatterplots of the matrix, the normality of the residuals, the relationship between all the independent variables, and the variance inflation factor values. These were obtained by regression analysis with the SE score as the dependent variable. The residuals were normally distributed according to the results of the Kolmogorov–Smirnov test, and the highest variance inflation factor value was 1.266; therefore, multicollinearity was ruled out. Finally, the independent variables were not strongly correlated with each other; therefore, the linearity of the data was checked. Statistical analysis was performed with SPSS 26 (IBM, United States) using a significance level of $p < 0.05$.

Results

Demographic data

A total of 582 Saudi participants with physical disabilities completed the RSES questionnaire, and their data were stored and analyzed. There were 289 men (49.66%) and 293 women (50.34%) between the ages of 18 and 59 (33.78 ± 9.81 years), including 276 participants (47.42%) aged 18–31, 208 participants (35.74%) aged 32–45, and 98 participants (16.84%) aged 46–59. A total of 133 of the participants (22.85%) did not use mobility aids; however, 449 participants (77.15%) used mobility assistive devices, including 335 who used wheelchairs, 55 who used crutches, and 38 who used canes. Most of the participants (71.65%) reported having a secondary school diploma (36.08%) or university-level degree and above (35.57%), while the remainder had a primary (14.09%) or intermediate (14.26%) degree. Approximately 46% of the respondents also reported having types of physical disabilities other than those listed in the questionnaire (Others); however, polio was the most prevalent disability across the study population (23.02%), followed by cerebral palsy, spinal diseases, progressive muscular dystrophy, and multiple sclerosis, with prevalence values of 9.8, 9.28, 8.93, and 3.44%, respectively.

Self-esteem levels among participants with physical disabilities

Table 1 illustrates the SE levels of participants with disabilities stratified by the category of each independent variable. The results showed that the participants reported moderate overall SE (2.997 ± 0.516) levels, with moderately high positive feelings and low negative feelings. The participants' average SE levels on the positive feelings factor was 3.22 ± 0.57, while the mean SE level related to the negative feelings factor was 3.01 ± 0.72. Compared to female participants, male participants reported significantly higher levels of overall SE, positive feelings, and negative feelings ($p < 0.01$ for all). Regarding the participants' levels of education, the data showed that those who reported the lowest level of education (primary school) also reported the lowest levels of SE, positive feelings, and negative feelings ($p < 0.01$ for the intermediate level; $p < 0.001$ for the rest). No significant difference was found among the other groups stratified by level of education. The respondents' average levels of overall SE ($p < 0.001$), positive feelings ($p < 0.01$), and negative feelings ($p < 0.001$) also varied by type of physical disability. The lowest values were observed in participants with multiple sclerosis and, to a lesser extent, in those with cerebral palsy; however, the highest values were noted in participants with poliomyelitis (Table 1). Importantly, significant differences ($p < 0.001$) were observed when comparing the positive feelings factor and the total scale among participants stratified by the type of mobility aid used. Participants using wheelchairs had the highest values of SE and positive feelings, while those using canes or those who did not use mobility aids had the lowest values. The levels of negative feelings did not differ significantly among groups stratified by the type of mobility assistive device used.

Physical activity levels according to sociodemographic variables

Figure 1 shows the total PA level and its subdomains. The level of PA in men was statistically higher than that in women (Kruskal–Wallis test, $p < 0.001$). A significantly shorter PA duration was also observed in the group of participants with a primary education level compared to the other three groups stratified by level of education ($p < 0.001$). No significant differences were noted between groups stratified by age category or by type of disability (Figure 1). However, multiple comparisons showed that participants using crutches as physical assistive devices were significantly more active than those using wheelchairs ($p < 0.01$) and those who did not use mobility aids ($p < 0.001$).

Self-esteem at different levels of physical activity

According to the World Health Organization's (2020) PA recommendations for adults with disabilities, only 13.23% of the surveyed population achieved the required weekly amount of PA (150–300 min/week; Figure 2). However, 74.91% of the participants reported practicing PA for less than 50 min/week, 8.25% reported practicing PA for 50 to <100 min/week, and 3.61% reported practicing PA for 100 to <150 min/week. The data also showed that participants

TABLE 1 Exploring the overall self-esteem and positive and negative feelings scores for independent variables (N=582).

			Positive feelings score	Z/H	p	Negative feelings score	Z/H	p	Self-esteem score	Z/H	p
Age (years)KW											
1	18–31	276	3.25 (0.58)	3.819	NS	2.96 (0.77)	3.577	NS	2.98 (0.55)	1.915	NS
2	32–45	208	3.15 (0.57)			3.04 (0.66)			2.98 (0.48)		
3	46–59	98	3.24 (0.54)			3.11 (0.66)			3.06 (0.49)		
Gender [MW]											
Male		289	3.28 (0.57)	−2.615	0.009	3.11 (0.76)	−3.778	0.001	3.06 (0.51)	−3.097	0.002
Female		293	3.15 (0.57)			2.92 (0.66)			2.94 (0.51)		
Educational level[KW]											
1	Primary	82	2.96 (0.59) ♣,†††,♠♠♠	19.939	0.001	2.72 (0.63)♣♣,†††,♠♠♠	21.168	0.001	2.76 (0.50)♣,†††,♠♠♠	23.055	0.001
2	Intermediate	83	3.21 (0.44)			3.00 (0.56)			2.97 (0.36)		
3	Secondary	210	3.22 (0.63)			3.08 (0.79)			3.02 (0.56)		
4	University level and above	207	3.30 (0.52)			3.07 (0.70)			3.08 (0.50)		
Type of physical disability[KW]											
1	Cerebral palsy	57	3.05 (0.63)♦♦,¶	17.584	0.004	2.78 (0.69) ♣♣,♦♦♦,¶	40.801	0.001	2.78 (0.56)♣♣,♦♦♦,¶¶	35.527	0.001
2	Spinal disease	54	3.21 (0.57)			3.13 (0.58)			3.09 (0.50)		
3	Progressive muscular dystrophy	52	3.10 (0.60)			2.84 (0.73)			2.89 (0.49) ♣,♦♦		
4	Sclerosis multiplex	20	2.87 (0.55) ♣,¶¶			2.51 (0.39)♣♣♣,†,♦♦♦,¶¶			2.65 (0.31)♣♣,♦♦♦,¶¶		
5	Poliomyelitis	134	3.32 (0.49) ††,♠			3.25 (0.68)†††,¶¶			3.13 (0.45)¶		
6	Others	265	3.24 (0.58)			2.99 (0.74)			3.00 (0.53)		
Mobility assistive device[KW]											
1	With	Wheelchair 356	3.23 (0.58)	1.983	NS	3.13 (0.65)††,♠♠♠	24.014	0.001	3.05 (0.52)††,♠♠♠	17.769	0.001
2		Crutches 55	3.19 (0.50)			3.01 (0.83)♠			2.99 (0.55)		
3		Cane 38	3.15 (0.62)			2.74 (0.76)			2.86 (0.43)		
4	Without (independent)	133	3.18 (0.56)			2.80 (0.77)			2.89 (0.51)		

[MW]The Mann–Whitney U Test was used; [KW]The Kruskal–Wallis Test was used. Z/H, Z score or H-Value. ♣ < 0.05, ♣♣ < 0.01, ♣♣♣ < 0.001 differs from subgroup 2; † < 0.05, †† < 0.01, ††† < 0.001 differs from subgroup 3; ♠ < 0.05, ♠♠ < 0.01, ♠♠♠ < 0.001 differs from subgroup 4; ♦ < 0.05, ♦♦ < 0.01, ♦♦♦ < 0.001 differs from subgroup 5; ¶ < 0.05, ¶¶ < 0.01, ¶¶¶ < 0.001 differs from subgroup 6.

who were physically active for less than 50 min/week had the lowest levels of SE and positive and negative feelings. No significant differences were observed among the other groups (Figures 3A–C).

Predictors of self-esteem

Weighted least squares regression showed that a significant regression pattern was identified among participants with physical disabilities, with r-squared values of 0.138 for positive feelings, 0.143 for negative feelings, and 0.161 for overall SE (Table 2). Therefore, the regression analysis results indicated that the independent variables accounted for 13.8, 14.3, and 16.1% of the variation in the SE levels of the participants for the positive feelings factor, negative feelings factor, and the total scale, respectively. Variance inflation factor values varied between 1.041 and 1.33 for all predictors, indicating a lack of collinearity in the results and therefore sufficient statistical significance. Of note, age, gender, and disability type were not labeled as potential covariates and were considered regressors of overall SE, positive feelings, and negative feelings. This is due to the lack of correlation (or weak correlation) observed between these variables and the dependent variables, and the negligible effects of these parameters on the regression results. Indeed, the WLS was calculated four consecutive times for each dependent variable and each time gender, age, or disability type was subtracted with no noticeable

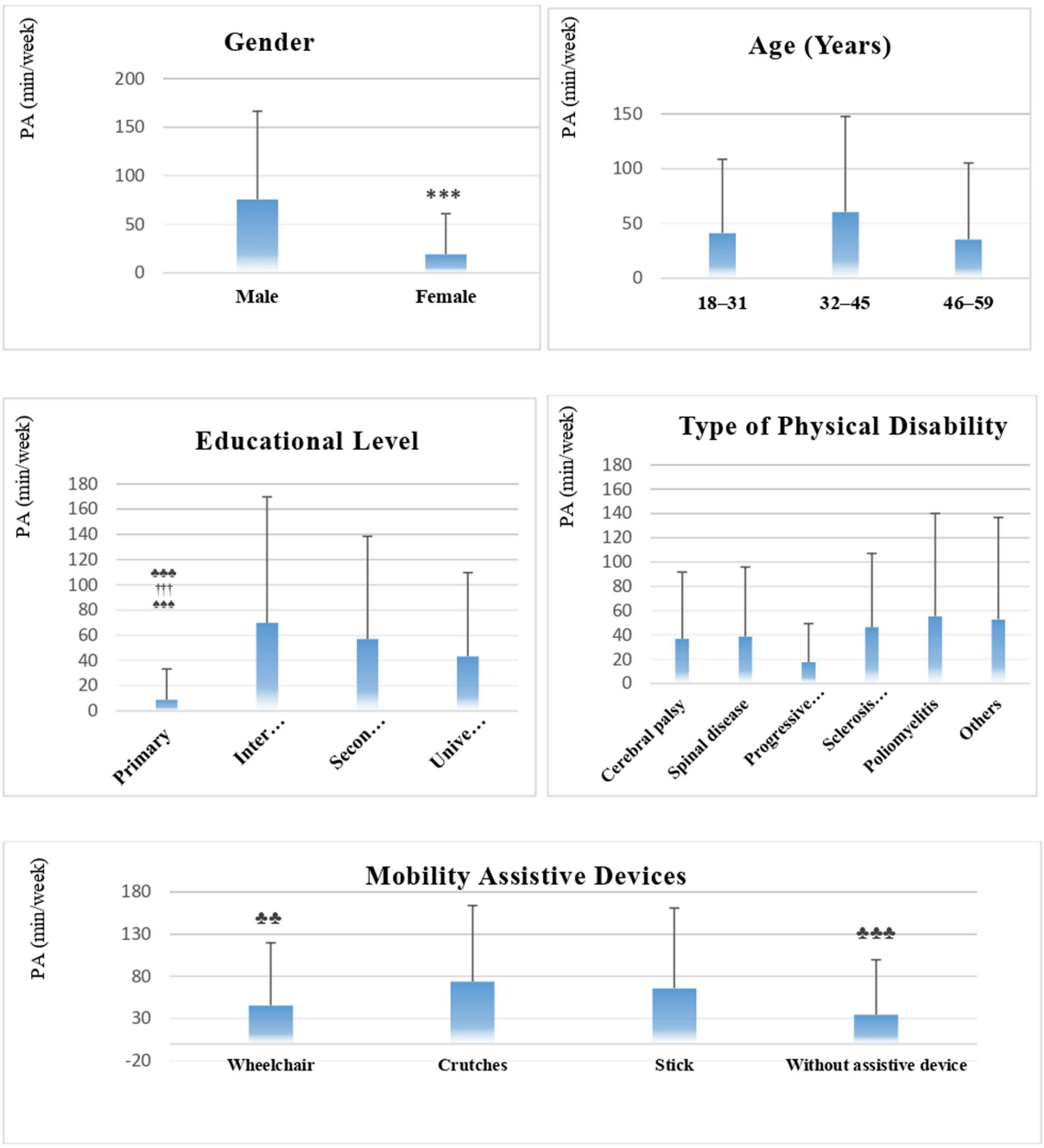


FIGURE 1
Weekly physical activity levels according to sociodemographic variables in Saudi participants with physical disabilities (N=582). PA, physical activity. ***<0.001 differs from subgroup 1; ♣♣<0.01, ♣♣♣<0.001 differs from subgroup 2; †††<0.001 differs from subgroup 3; ♠♠♠<0.001 differs from subgroup 4.

change in the association of the other regressors with the dependent variables (Supplementary Material).

Table 2 shows the extent, direction, and strength of the relationships between individual predictors and levels of overall SE, positive feelings, and negative feelings in the overall sample. Note that the scores for the items related to negative feelings were reversed during data processing. Weekly PA, as the first predictor of positive beta scores, suggested that participants with physical disabilities could increase their levels of SE and its two related subdomains (positive feelings factor and negative feelings factor) by increasing their amount of weekly PA. The β values were 0.002 for all groups. Educational level ($\beta = 0.115$; $p < 0.001$), as the second predictor that achieved positive beta scores, suggested that participants with higher levels of education had higher levels for SE and its subdomains. The type of physical disability was the third factor that positively impacted SE and the magnitude of positive and negative feelings, suggesting that

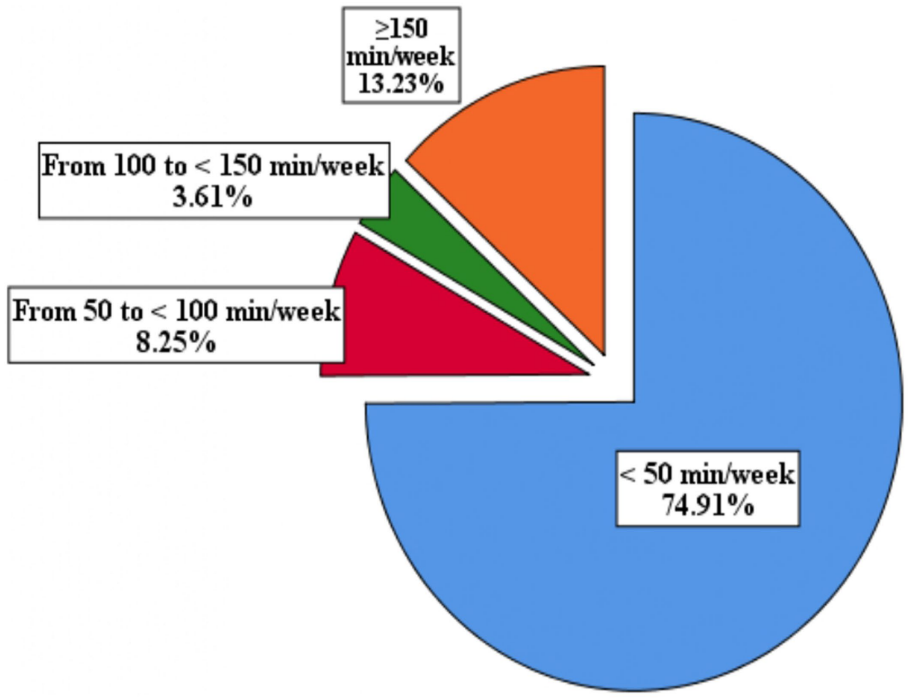


FIGURE 2
Exploration of weekly physical activity duration in Saudi participants with physical disabilities (*N*=582).

participants with polio had the highest SE, while those with sclerosis multiplex and cerebral palsy had the lowest. The values of β were 0.029, 0.033, and 0.029, respectively. The type of mobility aid used also had an impact on SE but returned only negative feelings. The β scores were −0.07 and −0.153, respectively, indicating that participants who used wheelchairs had the highest levels of SE and negative feelings; however, those who used canes or did not use mobility aids had the lowest scores.

Discussion

The purpose of this study was to examine the levels of SE among Saudis with physical disabilities and, at the same time, to select and highlight the factors that most enhance positive feelings and overall SE and reduce negative feelings. The results showed that Saudis with physical disabilities reported moderate overall SE, with significant inferiority among women compared to men and among participants with primary education compared to those with higher levels of education. There was no effect of age on the participants' SE. Extensive research has identified that gender and age have clear effects on the level of SE (Bleidorn et al., 2016). Regardless of cohort, sample, or measure, men tend to have higher SE than women, and regardless of gender, all individuals show an increase in SE from late adolescence to middle adulthood before it narrows in old age. The reported effect size is almost the same at all life stages, varying from low to moderate, except in adolescence where it tends to increase slightly. These two effects are now considered the most established findings in the SE literature (Trzesniewski et al., 2013; Orth and Robins, 2014). These studies also suggest that gender differences are determined, at least in part, by universal mechanisms that reflect both universal sociocultural factors and genetic biological processes that transcend culture and context (Gao et al., 2020; Liu, 2022). Moderate global SE, which was slightly higher than that in our study [2.997 (0.516) vs. 3.14 (0.56)], was also reported in 292 Saudi people with disabilities, with a clear male superiority over females. Narimani and Mousazadeh (2010) also reported lower SE scores in people with physical disabilities than in those without disabilities and in men than in women. Heydari et al. (2009), examining SE levels between students with and without disabilities, found that SE and life satisfaction were lower in people with physical disabilities than in those without physical disabilities. Nemček (2016) also confirmed lower SE in a group of sedentary people with disabilities compared to a comparable group of healthy people. However, contrary to our results, this author surveyed people with different types of disabilities and found no significant gender differences in SE scores, but the mean scores showed higher SE in females than in males (Nemček, 2013).

The lower levels of SE in people with disabilities can be explained by noting that body limb defects and injuries are important determining factors in the structure of human personality, so scientists know that self-depreciation is a consequence of personality defects and disorders. Therefore, based on Adler's psychological principles, any factor that robs a person of their pride and SE can be a major factor causing senseless emotions. Such a factor can turn a person into a mentally ill and insane person. These results show that SE is lower in people with disabilities (Narimani and Mousazadeh, 2010). Regarding gender differences, Twenge and Campbell (2002) suggested that one reason for the differences between men and women is that women's participation in forced labor has increased significantly over time. While women have increasingly pursued professional careers in recent decades, the changes for men during this time have been more subtle. Men's participation in the labor force has not changed, so they

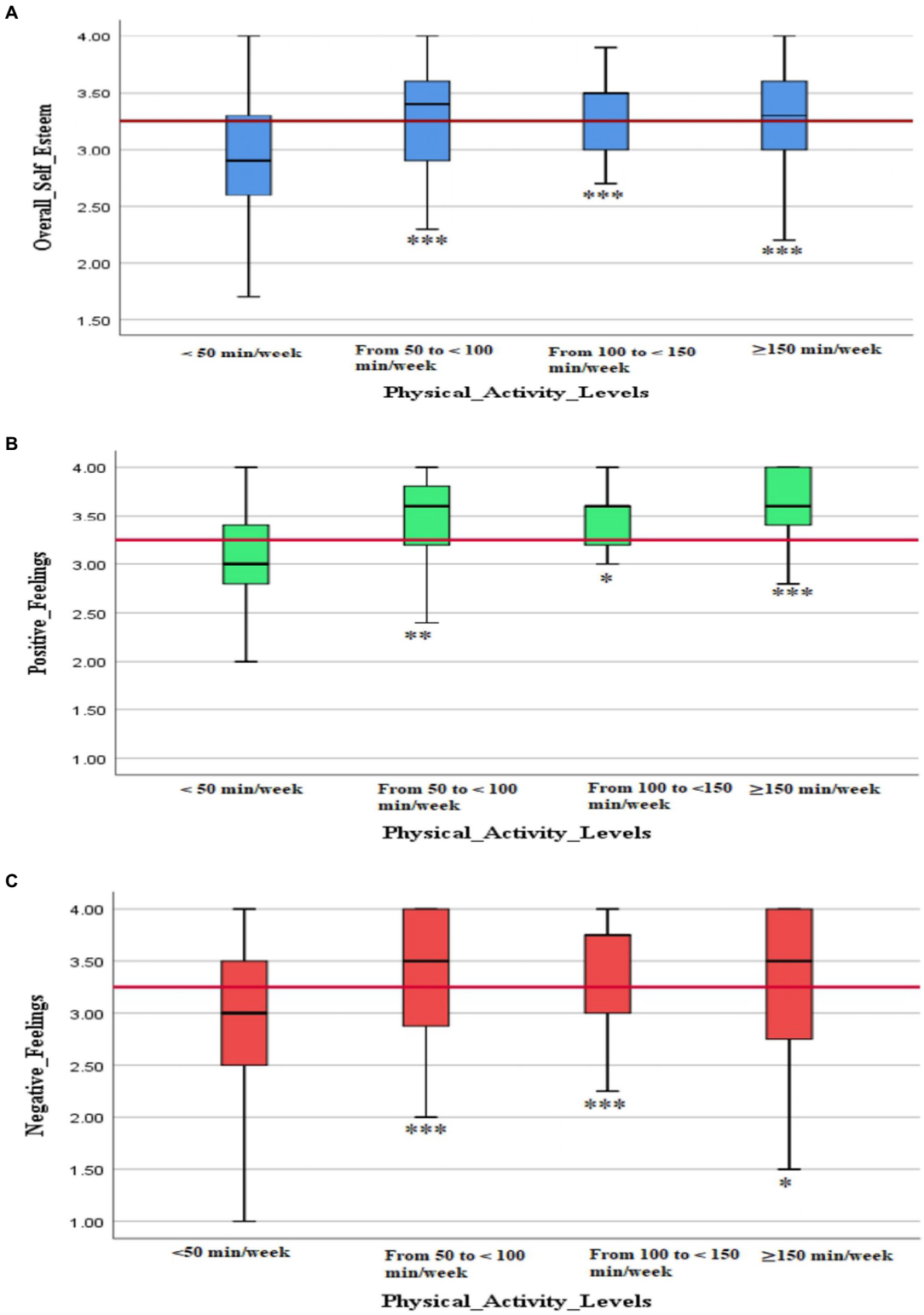


FIGURE 3
Levels of overall self-esteem **(A)** and positive **(B)** and negative **(C)** feelings according to the weekly physical activity level in Saudi participants with physical disabilities (*N*=582). *<0.05, **<0.01, ***<0.001 differs from subgroup 1.

no longer dominate occupations as they used to. In addition, men have given up the role of breadwinner, as fewer and fewer men are solely responsible for supporting their families. These shifts in gender roles have increased the psychological centrality of socioeconomic status to women's SE and decreased it for men's SE. It is important to note that only beginning in 2017 were Saudi women allowed to drive

TABLE 2 Weighted least squares regression models for the effect of sociodemographic factors and weekly physical activity on the levels of overall self-esteem and positive and negative feelings among Saudi participants with physical disabilities (N=582).

		Unstandardized coefficients		R^2	t	Sig.	95.0% CI for β		VIF
		β	Std. error				Lower bound	Upper bound	
Overall self-esteem	(Constant)	2.498	0.144	0.161	17.328	0.001	2.215	2.781	
	Gender	0.011	0.045		0.256	NS	−0.076	0.099	1.306
	Age (years)	0.002	0.002		0.978	NS	−0.002	0.006	1.159
	Type of physical disability	0.029	0.012		2.469	0.014	0.006	0.052	1.041
	Educational level	0.115	0.019		5.908	0.001	0.077	0.153	1.096
	Mobility assistive device	−0.07	0.016		−4.39	0.001	−0.101	−0.038	1.111
	Weekly Physical Activity	0.002	0.000		6.162	0.001	0.001	0.002	1.213
Positive feelings	(Constant)	2.883	0.163	0.138	17.671	0.001	2.563	3.204	
	Gender	−0.015	0.051		−0.306	NS	−0.115	0.084	1.33
	Age (years)	−0.003	0.002		−1.232	NS	−0.008	0.002	1.141
	Type of physical disability	0.029	0.013		2.196	0.028	0.003	0.055	1.052
	Educational level	0.101	0.023		4.429	0.001	0.056	0.146	1.089
	Mobility assistive device	−0.034	0.018		−1.889	NS	−0.07	0.001	1.122
	Weekly physical activity	0.002	0.000		6.493	0.001	0.001	0.002	1.245
Negative feelings	(Constant)	2.442	0.196	0.143	12.455	0.001	2.057	2.827	
	Gender	0.060	0.062		0.967	NS	−0.061	0.181	1.289
	Age (years)	0.004	0.003		1.47	NS	−0.001	0.01	1.15
	Type of physical disability	0.033	0.015		2.124	0.034	0.002	0.063	1.049
	Educational level	0.133	0.026		5.167	0.001	0.082	0.183	1.107
	Mobility assistive device	−0.153	0.024		−6.517	0.001	−0.2	−0.107	1.094
	Weekly physical activity	0.002	0.000		4.753	0.001	0.001	0.003	1.235

Age, gender, and disability type were considered as regressors. NS, not significant; VIF, variance inflation factor.

vehicles and access government services such as education and health care without requiring the consent of a male guardian. This may partly explain the lower SE of Saudi women compared to men, but this is likely to change in the future.

The Social Model of Disability (Oliver, 1983) suggests that to improve the quality of life of people with disabilities, we must first change societal attitudes (Hughes and Paterson, 2006). This includes removing stigma and reducing social inequalities while empowering people with disabilities. In this sense, PA was considered an important factor that can improve SE in people with disabilities, although research shows that the participation rates of people with physical disabilities remain lower than those of older comparison groups without disabilities. Hollis et al. (2020) found that less than half (45.2%) of US adults with motor disabilities engaged in aerobic PA, and 39.5% met one or both PA guidelines. The same data collected from Americans in 1997 revealed that compared to 16% of people without disabilities, only 12% of people with disabilities engaged in moderate PA for at least 30 min a day, 5 days a week. If only leisure-time PA was considered, the difference between people with and without disabilities was even greater: 56 and 36%, respectively, engaged in no leisure-time PA (U.S. Department of Health and Human Services, 2000). Alfermann and Stoll (2000) reported a significant association between PA and higher levels of SE in healthy middle-aged adults. In a longitudinal cohort study among kindergarten to fourth-grade females, Noordstar et al. (2016) found that changes in global SE were significantly associated with perceived athletic proficiency and moderate-to-vigorous PA. Recently, Romero et al. (2022) reported on the positive effects of endurance and strength exercises on SE in male college students. There was a statistically significant relationship between exercise

frequency and SE, while the relationship between exercise type and SE was not significant.

Nevertheless, the association between PA and SE in people with physical disabilities remains unclear (Jalayondeja et al., 2016). Crawford et al. (2008) found that high fitness levels in people with physical disabilities affect the likelihood of returning to as-normal-as-possible community life. These authors also noted that highly active people with physical disabilities participated more in recreational and social activities than inactive non-disabled people. In contrast, Gutierrez et al. (2007) examined the association between subjective quality of life, PA, and community involvement among 80 paraplegic subjects with shoulder pain, and found a weak correlation between PA, quality of life, and community involvement. Also, Jalayondeja et al. (2016) revealed that while PA did not significantly explain the quality of life, 34.7% of the quality of life was explained by SE. These authors also found that those with disabilities who reported good quality of life engaged in high-intensity PA compared to those who reported a fair to poor quality of life.

Importantly, the results of the present study showed that among Saudi Arabians with physical disabilities, there was a positive association between participation in PA and SE. Our results showed that at least 40 min/week of PA resulted in significant improvements in the levels of positive feelings and overall SE and, to a lesser extent, in the level of negative feelings. Moreover, and in accordance with the practical recommendations required by different health organizations, a minimum of 150 min/week of PA provides more benefits for SE and its components. Participation in PA appears to be a critical predictor of SE. In other words, people with physical disabilities who are physically active tend to report higher levels of SE than those who are inactive. This finding largely supports the work of other studies on different types of disabilities reaching a consensus that exercise can effectively improve the SE of people with disabilities (Yan et al., 2019; Shang et al., 2021). Nemček et al. (2014) found that the differences between active and sedentary people with disabilities show that those who preferred active lifestyles and played sports (elite and all levels of sports) were happier with their lives than those who did not exercise. Therefore, it has been recognized that to promote these benefits for people with disabilities, work must be directed toward increasing opportunities for their participation in PA and sports (Groff et al., 2009). This is particularly important given the societal shift from segregation to inclusion for people with physical disabilities and can therefore be further facilitated through PA and sports. It is believed that people with disabilities can also benefit from physically active lifestyles. People's health states and secondary health problems can lead to problems in everyday life (disability). Such functional problems and, in particular, mobility problems can be positively influenced by a physically active lifestyle and thus reduce disabilities. In addition, secondary health and functioning problems in people with disabilities that could be prevented or reduced by a physically active lifestyle include the risk of coronary artery disease, type 2 diabetes mellitus, osteoporosis, osteoarthritis, colon cancer, high blood pressure, decreased balance, decreased health-related fitness, spasticity, weight problems including obesity, depression, urinary tract infections, decreased SE, impaired ability to have normal social interactions and increased dependence on others. This shows that a physically active lifestyle is probably even more important for the health and well-being of people with disabilities than for the general population (van der Ploeg and Bull, 2020). In contrast, other studies have shown much smaller and even non-significant associations between PA and SE among people with disabilities. According to Bondár et al. (2020), these inconsistent findings likely reflect the methodological differences between the studies mainly in terms of the conceptual measures of SE and the prescribed activity types, intensities, and durations of PA.

The literature also supports our claim that SE is associated with the level of education. Bano et al. (2015) compared the levels of SE in students with and without disabilities and found that both groups of participants had high levels of SE. The result also showed that disability and gender did not significantly affect the students' levels of SE. The study concluded that education plays an important role in improving students' SE and eliminating gender-related stigma. The study also concluded that the provision of education can lead students with disabilities to recognize, accept and use their skills. This will also increase their value in their ranking (Bano et al., 2015). Previous studies have also shown that higher levels of education lead to a better quality of life, especially regarding psychology and the environment (Jani et al., 2020). Naturally, a higher education level is likely to help people with disabilities understand their rights, gain a higher level of respect, find better jobs, and improve their interpersonal relationships (Singal et al., 2015). In general, education improves SE and well-being by providing access to non-alienated economic and labor resources; this increases feelings of control over life, as well as access to stable social relationships such as marriage, which increases social support (Addabbo et al., 2016). In contrast, Jalayondeja et al.'s (2016) study of the associations between quality of life, education, PA, and SE found that quality of life was explained by SE and daily life, but was not significantly related to education level. The differences may be explained by the fact that all the participants were in vocational education and training at school. The authors also reported that all respondents who reported having a good quality of life claimed that they were satisfied with education and training that matched their skills and interests for their future careers.

The type of physical disability and the assistive device used can also affect SE scores. The lowest SE among our participants was found in patients with multiple sclerosis or cerebral palsy, while the highest was found in participants with polio. Participants who used wheelchairs also had higher SE and positive feelings than those who used other assistive devices. According to Miyahara and Piek (2011), people with physical disabilities may be concerned about their functional disabilities, body structure, and appearance, which may not conform to sociocultural norms. Therefore, a physical disability is considered an obstacle to development. The inconsistency of the impact of physical disabilities on people with disabilities could be explained by the multidimensional interactive model of self-concept, which takes multiple dimensions of the self and the socio-cultural impact on the individual into account. From this perspective, self-perceptions in several domains could be interpreted as reflecting, or at least being influenced by, the sociocultural values in each dimension. Jung et al. (2022) found that low disability acceptance contributed to low SE. On the Disability Acceptance Scale, adults who were struggling with their disability were more likely to have low SE. This may be because hiding the limitations of their disability made them more aware of their alienation. To overcome their sense of inferiority, they refused to accept their disability by distorting reality or fooling themselves, resulting in low SE. The greater the distortion process, the greater the disability and the greater the resulting integration difficulties. Disability paradox theory refers to

people who are satisfied with themselves, can achieve their life goals, and enjoy a high quality of life despite or because of a disability. People who respond better to their disability have higher levels of SE, social participation, and quality of life (Brown et al., 2011). In other words, whether people with disabilities can hide their disability affects their disability acceptance and SE. Therefore, the acceptance of a disability requires that people avoid devaluing a person because of their disability, hiding the disability out of shame, and overestimating the disability. It is about recognizing the discomfort caused by the disability and trying to find and accept the reality and limitations that it brings (Jung et al., 2022).

The results of this study should be interpreted with some limitations in mind. First, although the research team made several efforts to minimize bias by making the Arabic version of the RSES clear and readable for all people, the team was unable to exclude responses or recall biases that may have affected the results. Second, regarding the different types of physical disabilities assessed, five types were identified (cerebral palsy, spinal diseases, progressive muscular dystrophy, multiple sclerosis, and poliomyelitis), while the rest were grouped under the heading "Other," in which almost half of the participants were included. It is necessary to examine the impact of other specific disability types on SE. Focusing on other disability types may show implications beyond those found in our study for the types of disabilities already identified. Finally, the questionnaire was used as an indirect method to assess PA participation and duration, which does not exclude the possibility of recall bias and social desirability results. In addition, it was difficult to distinguish among the PA patterns the participants engaged in (aerobics, muscular strengthening, or a combination of aerobics and strengthening). Using direct measurement methods such as pedometers or motion sensors can provide much greater accuracy, mainly depending on the type and intensity of the PA performed (Hollis et al., 2020).

Conclusion

The data showed that the participants reported moderate levels of overall SE. Compared to women, men demonstrated significantly higher levels of overall SE, positive feelings, and negative feelings. Participants with the lowest level of education (i.e., primary school) also reported the lowest levels of SE, positive feelings, and negative feelings. The respondents' average levels of overall SE, positive feelings and negative feelings also varied depending on the type of physical disability and the type of mobility device used. WLS regression analysis noted that the factors influencing positive feelings included weekly PA, the level of education, and the type of physical disability; factors influencing negative feelings included weekly PA, the type of mobility assistance device, the level of education, and the type of physical disability; and factors influencing overall SE included weekly PA, the level of education, the type of mobility aid used, and the type of physical disability. More attention should be also given to participants with multiple sclerosis and cerebral palsy, and appropriate tools should be provided to all participants who need them.

The results of the present study may provide useful guidelines for the Saudi Arabian Ministry of Sport and other related organizations and associations for people with physical disabilities in terms of raising awareness of the importance of weekly PA for people with disabilities.

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 Research Ethics Committee at King Faisal University, Saudi Arabia (protocol code KFU-REC-2021-DEC-EA000307, approved on 21 December 2021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

This research was funded by the Deanship of Scientific Research, King Faisal University, Saudi Arabia, grant number GRANT1276. The funder had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Acknowledgments

The authors are grateful to all subjects who gave their time and effort to participate in this research project.

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.

The reviewer NH declared a shared affiliation with the author MS to the handling editor at the time of review.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1072709/full#supplementary-material

References

Addabbo, T., Sarti, E., and Sciulli, D. (2016). Disability and life satisfaction in Italy. *Appl. Res. Qual. Life* 11, 925–954. doi: 10.1007/s11482-015-9412-0

Ahn, H., Lee, K., and So, Y. (2021). The mediating effect of disability acceptance in individuals with spinal cord injury participating in sport for all. *Int. J. Environ. Res. Public Health* 18:10883. doi: 10.3390/ijerph182010883

Akari, M., and Gündoğdu, S. (2013). A comparison of weighted least square estimation and ordinary least square estimation for analysing weight-length relationship of Por's goatfish (Upeneus pori ben-Tuvia & Golani, 1989) in Iskenderun Bay. *J. Appl. Biol. Sci.* 7, 46–50.

Al Awaji, N., Zaidi, U., Awad, S. S., Alroqaiba, N., Aldhahi, M. I., Alsaleh, H., et al. (2022). Moderating effects of self-esteem on the relationship between communication anxiety and academic performance among female health college students during the COVID-19 pandemic. *Int. J. Environ. Res. Public Health* 19:13960. doi: 10.3390/ijerph192113960

ALAhmari, T., Alomar, A. Z., ALBeeybe, J., Asiri, N., ALAjaji, R., ALMasoud, R., et al. (2019). Associations of self-esteem with body mass index and body image among Saudi college-age females. *Eat. Weight Disord.* 24, 1199–1207. doi: 10.1007/s40519-017-0471-0

Alfermann, D., and Stoll, O. (2000). Effects of physical exercise on self-concept and well-being. *Int. J. Sport Psychol.* 31, 47–65.

Al-Jadid, M. S. (2013). Disability in Saudi Arabia. *Saudi Med. J.* 34, 453–460.

Bano, H., Anjum, N., and Pasha, S. (2015). Differences in self-esteem of university students with and without disability. *J. Educ. Res.* 18, 114–124.

Blascovich, J., and Tomaka, J. (1991). "Measures of self-esteem" in *Measures of Personality and Social Psychological Attitudes*. eds. J. P. Robinson, P. R. Shaver and L. S. Wrightsman (New York: Academic Press), 115–160.

Bleidorn, W., Arslan, R. C., Denissen, J. J. A., Rentfrow, P. J., Gebauer, J. E., Potter, J., et al. (2016). Age and gender differences in self-esteem—a cross-cultural window. *J. Pers. Soc. Psychol.* 111, 396–410. doi: 10.1037/pspp0000078

Bondár, R. Z., di Fronso, S., Bortoli, L., Robazza, C., Metsios, G. S., and Bertollo, M. (2020). The effects of physical activity or sport-based interventions on psychological factors in adults with intellectual disabilities: a systematic review. *J. Intellect. Disabil. Res.* 64, 69–92. doi: 10.1111/jir.12699

Brown, D. J., McHugh, D., Standen, P., Evett, L., Shopland, N., and Battersby, S. (2011). Designing location-based learning experiences for people with intellectual disabilities and additional sensory impairments. *Comput. Educ.* 56, 11–20. doi: 10.1016/j.compedu.2010.04.014

Bryant, D. P., and Bryant, B. R. (2011). *Assistive Technology for People With Disabilities*. London: Pearson Higher Education.

Crawford, A., Hollingsworth, H. H., Morgan, K., and Gray, D. B. (2008). People with mobility impairments: physical activity and quality of participation. *Disabil. Health J.* 1, 7–13. doi: 10.1016/j.dhjo.2007.11.004

Disabled World. (2022) Disabilities: Definition, types and models of disability. Disabled World. Available at: www.disabled-world.com/disability/types/ (Accessed July 11, 2022)

Ekeland, E., Heian, F., and Hagen, K. B. (2005). Can exercise improve self-esteem in children and young people? A systematic review of randomized controlled trials. *Br. J. Sports Med.* 39, 792–798. doi: 10.1136/bjsm.2004.017707

Gao, W., Ping, S., and Liu, X. (2020). Gender differences in depression, anxiety, and stress among college students: a longitudinal study from China. *J. Affect. Disord.* 263, 292–300. doi: 10.1016/j.jad.2019.11.121

Groff, D. G., Lundberg, N. R., and Zabriskie, R. B. (2009). Influence of adapted sport on quality of life: perceptions of athletes with cerebral palsy. *Disabil. Rehabil.* 31, 318–326. doi: 10.1080/09638280801976233

Gutierrez, D. D., Thompson, L., Kemp, B., and Mulroy, S. J.Physical Therapy Clinical Research Network, & Rehabilitation Research and Training Center on Aging-Related Changes in Impairment for Persons Living with Physical Disabilities (2007). The relationship of shoulder pain intensity to quality of life, physical activity, and community participation in persons with paraplegia. *J. Spinal Cord Med.* 30, 251–255. doi: 10.1080/10790268.2007.11753933

Heydari, A., Mashak, R., and Darvishi, H. (2009). Compare of the self-efficacy, loneliness, fear of success and satisfaction in physically disabled students with normal students in Ahvaz Islamic Azad University. *New Find Psychol.* 10, 7–26.

Hollis, N. D., Zhang, Q. C., Cyrus, A. C., Courtney-Long, E., Watson, K., and Carroll, D. D. (2020). Physical activity types among US adults with mobility disability, behavioral risk factor surveillance system, 2017. *Disabil. Health J.* 13:100888. doi: 10.1016/j.dhjo.2020.100888

Howard, J., Fisher, Z., Kemp, A. H., Lindsay, S., Tasker, L. H., and Tree, J. J. (2022). Exploring the barriers to using assistive technology for individuals with chronic conditions: a meta-synthesis review. *Disabil. Rehabil. Assist. Technol.* 17, 390–408. doi: 10.1080/17483107.2020.1788181

Hughes, B., and Paterson, K. (2006). "The social model of disability and the disappearing body: towards a sociology of impairment" in *Overcoming Disabling Barriers*. ed. L. Barton (Oxford: Routledge), 101–117.

Jalayondeja, C., Jalyondeja, W., Suttiwong, J., Sullivan, P. E., and Nilanthi, D. L. (2016). Physical activity, self-esteem, and quality of life among people with physical disability. *Southeast Asian J. Trop. Med. Public Health* 47, 546–558.

Jani, R., Alias, A. A., and Tumin, M. (2020). Persons with disabilities' education and quality of life: evidence from Malaysia. *Int. J. Incl. Educ.* 26, 753–765. doi: 10.1080/13603116.2020.1726511

Jung, Y. H., Kang, S. H., Park, E. C., and Jang, S. Y. (2022). Impact of the acceptance of disability on self-esteem among adults with disabilities: a four-year follow-up study. *Int. J. Environ. Res. Public Health* 19:3874. doi: 10.3390/ijerph19073874

Le Breton, D. (2004). Risk taking behaviours among young people. *Bulletin de l'Academie Nationale de Medicine* 188, 1313–1321.

Liu, C. (2022). Research on the influence of college students' participation in sports activities on their sense of inferiority based on self-esteem and general self-efficacy. *Front. Psychol.* 13:994209. doi: 10.3389/fpsyg.2022.994209

Liu, M., Wu, L., and Ming, Q. (2015). How does physical activity intervention improve self-esteem and self-concept in children and adolescents? Evidence from a Meta-Analysis. *PLoS One* 10:e0134804. doi: 10.1371/journal.pone.0134804

Maynou, L., Hernández-Pizarro, H. M., and Errea Rodríguez, M. (2021). The Association of Physical (in) activity with mental health. Differences between elder and younger populations: a systematic literature review. *Int. J. Environ. Res. Public Health* 18:4771. doi: 10.3390/ijerph18094771

McNicholl, A., Casey, H., Desmond, D., and Gallagher, P. (2021). The impact of assistive technology use for students with disabilities in higher education: a systematic review. *Disabil. Rehabil. Assist. Technol.* 16, 130–143. doi: 10.1080/17483107.2019.1642395

Miyahara, M., and Piek, J. (2011). "Physical disabilities and self-esteem" in *Encyclopedia of Adolescence*. ed. R. J. R. Levesque (New York, NY: Springer).

Narimani, M., and Mousazadeh, T. (2010). Comparing self-esteem and self-concept of handicapped and normal students. *Procedia Soc. Behav. Sci.* 2, 1554–1557. doi: 10.1016/j.sbspro.2010.03.234

Nemček, D. (2013). "Life satisfaction of people with disabilities" in *Theory and Practice in Adapted Physical Activity* (Olsztyń, Poland: Olsztyńska szkola wyższa Im. Józefa Rusieckiego), 46.

Nemček, D. (2016). Life satisfaction of people with disabilities: a comparison between active and sedentary individuals. *Journal of Physical Education and Sport* 16, 1084–1088. doi: 10.7752/jpes.2016.s2173

Nemček, D. (2017). Self-esteem in people with physical disabilities: differences between active and inactive individuals. *Acta Fac. Educ. Phys. Univ. Comen.* 57, 34–47. doi: 10.1515/afepuc-2017-0004

Nemček, D. (2021). Sport participation differences in the self-esteem of people with physical disabilities using assistive technology. *AIP Conf. Proc.* 2343:100005. doi: 10.1063/5.0047751

Nemček, D., Labudová, J., and Oršulová, N. (2014). Self-esteem in people with disabilities. *Acta Fac. Educ. Phys. Univ. Comen.* 54, 33–42.

Noordstar, J. J., Van der Net, J., Jak, S., Helders, P. J., and Jongmans, M. J. (2016). Global self-esteem, perceived athletic competence, and physical activity in children: a longitudinal cohort study. *Psychol. Sport Exerc.* 22, 83–90. doi: 10.1016/j.psychsport.2015.06.009

Oliver, M. (1983). *Social Work with Disabled People (Practical Social Work)*. London: Macmillan.

Orth, U., and Robins, R. W. (2014). The development of self-esteem. *Curr. Dir. Psychol. Sci.* 23, 381–387. doi: 10.1177/0963721414547414

Robitaille, S. (2010). *The Illustrated Guide to Assistive Technology and Devices*. New York, NY: Demos Medical Publishing.

Romero, I., Kaye, A., Poulin, C., and Petersen, M. E. (2022). An analysis of the effects of frequency and type of physical activity on self-esteem in adolescent males. *Georgetown Sci. Res. J.* 2, 42–52. doi: 10.48091/gsr.v2i2.42

Rosenberg, M. (1965). *Society and the Adolescent Self-Image*. Princeton, NJ: Princeton University Press.

Ryszewska-Łabędzka, D., Tobis, S., Kropińska, S., Wieczorowska-Tobis, K., and Talarska, D. (2022). The Association of Self-Esteem with the level of independent functioning and the primary demographic factors in persons over 60 years of age. *Int. J. Environ. Res. Public Health* 19:1996. doi: 10.3390/ijerph19041996

Sandjojo, J., Gebhardt, W. A., Zedlitz, A. M. E. E., Hoekman, J., den Haan, J. A., and Evers, A. W. M. (2019). Promoting Independence of people with intellectual disabilities: a focus group study perspectives from people with intellectual disabilities, legal representatives, and support staff. *J. Policy Prac. Intellect. Disabil.* 16, 37–52. doi: 10.1111/jppi.12265

Serafin, L., Strząska-Kliś, Z., Kolbe, G., Brzozowska, P., Szwed, I., Ostrowska, A., et al. (2022). The relationship between perceived competence and self-esteem among novice nurses–a cross-sectional study. *Ann. Med.* 54, 484–494. doi: 10.1080/07853890.2022.2032820

Shang, Y., Xie, H. D., and Yang, S. Y. (2021). The relationship between physical exercise and subjective well-being in college students: the mediating effect of body image and self-esteem. *Front. Psychol.* 12:658935. doi: 10.3389/fpsyg.2021.658935

Singal, N., Mahama Salifu, E., Iddrisu, K., Casely-Hayford, L., and Lundebye, H. (2015). The impact of education in shaping lives: reflections of young people with disabilities in Ghana. *Int. J. Incl. Educ.* 19, 908–925. doi: 10.1080/13603116.2015.1018343

Stark, L., Asghar, K., Meyer, S., Yu, G., Bakemore, T., Poulton, C., et al. (2017). The effect of gender norms on the association between violence and hope among girls in the Democratic Republic of the Congo. *Global Mental Health* 4:E1. doi: 10.1017/gmh.2016.31

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., et al. (2013). Guide to the assessment of physical activity: clinical and research applications: a scientific statement from the American Heart Association. *Circulation* 128, 2259–2279. doi: 10.1161/01.cir.0000435708.67487.da

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Res. Sci. Educ.* 48, 1273–1296. doi: 10.1007/s11165-016-9602-2

Tamakloe, D., and Agbenyega, J. S. (2017). Exploring preschool teachers' and support staff's use and experiences of assistive technology with children with disabilities. *Australas. J. Early Childhood* 42, 29–36. doi: 10.23965/AJEC.42.2.04

Trzesniewski, K., Donnellan, B., and Robins, R. W. (2013). "Development of self-esteem" in *Self-Esteem*. ed. V. Zeigler-Hill (New York, NY: Psychology Press), 60–79.

Twenge, J. M., and Campbell, W. K. (2002). Self-esteem and socioeconomic status: a meta-analytic review. *Personal. Soc. Psychol. Rev.* 6, 59–71. doi: 10.1207/S15327957PSPR0601_3

U.S. Department of Health and Human Services. (2000). *Healthy People 2010: Understanding and Improving Health. 2nd Edn*. Washington, DC: U.S. Government Printing Office.

van der Ploeg, H. P., and Bull, F. C. (2020). Invest in physical activity to protect and promote health: the 2020 who guidelines on physical activity and sedentary behaviour. *Int. J. Behav. Nutr. Phys. Act.* 17:145. doi: 10.1186/s12966-020-01051-1

Vialle, W. J., Heaven, P. C. L., and Ciarrochi, J. V. (2005). The relationship between self-esteem and academic achievement in high ability students: evidence from the Wollongong youth study. *Australas. J. Gifted Educ.* 14, 39–45. doi: 10.21505/ajge.2015.0013

World Health Organization. (2020). Guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization. Available at: https://apps.who.int/iris/bitstream/handle/10665/336656/9789240015128-eng.pdf?sequence=1&isAllowed=y (Accessed July 15, 2022)

World Health Organization. (2021). Disability and health. Available at: https://www.who.int/health-topics (Accessed July 12, 2022)

Yan, J., Li, Q., Zhang, Z. K., Wang, B. Y., and Zhu, F. S. (2019). The influence of extracurricular physical exercise on the physical self-esteem and self-confidence of elementary students. *Sports Sci.* 40, 100–104. doi: 10.13598/j.issn1004-4590.2019.02.012

Zahra, A., Hassan, M. S., Park, J. H., Hassan, S. U., and Parveen, N. (2022). Role of environmental quality of life in physical activity status of individuals with and without physical disabilities in Saudi Arabia. *Int. J. Environ. Res. Public Health* 19:4228. doi: 10.3390/ijerph19074228

Zhang, L., Wentao, L., Liu, B., and Xie, W. (2014). Self-esteem as mediator and moderator of the relationship between stigma perception and social alienation of Chinese adults with disability. *Disabil. Health J.* 7, 119–123. doi: 10.1016/j.dhjo.2013.07.004

Zhao, Y., Zheng, Z., Pan, C., and Zhou, L. (2021). Self-esteem and academic engagement among adolescents: a moderated mediation model. *Front. Psychol.* 12:690828. doi: 10.3389/fpsyg.2021.690828

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 14 March 2023
DOI 10.3389/fpsyg.2023.1098861

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Josie Booth,
University of Edinburgh, United Kingdom
Rosa Maria Angulo-Barroso,
California State University, Northridge, United States

*CORRESPONDENCE
Simon B. Cooper
✉ simon.cooper@ntu.ac.uk

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

RECEIVED 15 November 2022
ACCEPTED 13 February 2023
PUBLISHED 14 March 2023

CITATION
Gilbert LM, Dring KJ, Williams RA, Boat R, Sunderland C, Morris JG, Nevill ME and Cooper SB (2023) Effects of a games-based physical education lesson on cognitive function in adolescents. *Front. Psychol.* 14:1098861. doi: 10.3389/fpsyg.2023.1098861

Effects of a games-based physical education lesson on cognitive function in adolescents

Luke M. Gilbert, Karah J. Dring, Ryan A. Williams, Ruth Boat, Caroline Sunderland, John G. Morris, Mary E. Nevill and Simon B. Cooper*

Sport, Health, and Performance Enhancement (SHAPE) Research Centre, Department of Sport Science, School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom

Despite the importance of physical education (PE) lessons for physical activity in adolescents, the acute cognitive responses to PE lessons have not been explored; a gap in the literature that this study addresses. Following familiarisation, 76 (39 female) adolescents (12.2±0.4 y) completed two trials (60min games-based PE lesson and 60min academic lesson) separated by 7-d in a counterbalanced, crossover design. Attention, executive function, working memory, and perception were assessed 30min before, immediately post, and 45min post-lesson in both trials. Participants were split into high-and low-fit groups based on a gender-specific median split of distance run on the multi-stage fitness test. Furthermore, participants were split into high and low MVPA groups based on a gender-specific median split of MVPA time (time spent >64% HR max) during the PE lesson. Overall, a 60min games-based PE lesson had no effect on perception, working memory, attention, or executive function in adolescents (all p >0.05) unless MVPA time is high. The physical activity-cognition relationship was moderated by MVPA, as working memory improved post-PE lesson in adolescents who completed more MVPA during their PE lesson (time*trial*MVPA interaction, p <0.05, partial η^2 =0.119). Furthermore, high-fit adolescents displayed superior cognitive function than their low-fit counterparts, across all domains of cognitive function (main effect of fitness, all p <0.05, partial η^2 0.014–0.121). This study provides novel evidence that MVPA time moderates the cognitive response to a games-based PE lesson; and emphasises that higher levels of fitness are beneficial for cognitive function in adolescents.

KEYWORDS

physical education, physical activity, cognition, intensity, fitness

Introduction

Chief Medical Officer guidance states that young people aged 5–18 years should participate in an average of 60 min per day moderate-to-vigorous physical activity (MVPA) to enhance health and well-being (UK Chief Medical Officers, 2019); yet recent data suggest that only 44.6% of children and adolescents in England achieve these recommendations (Sport England, 2021). Given the large proportion of time that young people spend in school, schools present a unique opportunity to assist young people in meeting the daily physical activity recommendations (Hills et al., 2015). Consequently, schools are often designated as a promising environment for increasing physical activity in *all* young people, irrespective of their background (Slingerland

et al., 2012; van Slujis et al., 2021). Within the school environment, as it is compulsory in most Western school systems, physical education (PE) lessons have been identified as an important source of physical activity (Fairclough and Stratton, 2005) and provide adolescents with the opportunity to achieve the recommended 60 min of MVPA per day (Hills et al., 2015). Physical activity opportunities provided by PE lessons are of particular significance for the least active students (Fairclough and Stratton, 2005), with evidence that 30% of adolescents from Western Europe derive all of their daily MVPA from PE lessons (Westerstahl et al., 2005); suggesting that PE lessons are indeed the only form of MVPA for some adolescents (Association for Physical Education, 2020).

Despite the significance of PE as an opportunity for adolescents to participate in MVPA (Zhou and Wang, 2019), the time allocated for PE (and physical activity more broadly) in the school curriculum has often been reduced to accommodate increased instructional time for academic subjects (Rasberry et al., 2011; van den Berg et al., 2016). In the UK for example, the prioritisation of academic subjects is illustrated by a 13% reduction in the number of taught hours for PE since 2011/12; during which time mathematics, English, and science have increased by 13, 11, and 14%, respectively (National Statistics, 2021). However, the reduction in teaching hours for PE is somewhat counterintuitive given that physical activity is positively associated with cognition and academic achievement (Sneck et al., 2019; Garcia-Hermoso et al., 2021). Furthermore, evidence suggests that increasing PE time does not negatively impact academic achievement, even when less time is dedicated to subjects other than PE (Rasberry et al., 2011); thus, reducing PE time (and subsequently physical activity) could be counter-productive for enhancing academic achievement and cognitive function.

Cognitive function can be defined as a variety of brain-mediated functions and processes (Schmitt et al., 2005). These functions allow us to perceive, evaluate, store, manipulate, and use information from external (e.g., environment) and internal (e.g., experiences, memory) sources, before responding to this information (Schmitt et al., 2005). Cognitive functions are clustered into the six domains of executive function, memory, attention, perception, language, and psychomotor functions (Schmitt et al., 2005). A recent meta-analysis by Haverkamp et al. (2020) concluded that acute exercise interventions improved cognitive outcomes (Hedges' $g = 0.31$). Specifically, processing speed ($g = 0.39$), attention ($g = 0.34$) and inhibition (a component of executive function; $g = 0.32$), were enhanced in adolescents following physical activity. This is of importance given that these cognitive domains are the foundation of academic ability (Esteban-Cornejo et al., 2015), Furthermore, as adolescence is a critical stage for the development of cognitive function (Romeo and McEwen, 2006), and a period during which cognitive function and academic achievement are a key focus of the education sector, physical activity opportunities in schools are of particular importance for this population.

The positive effects of physical activity on cognitive function are influenced by several factors such as physical fitness (Garcia-Hermoso et al., 2021), the characteristics of the physical activity (intensity, duration, and modality) and the domain of cognitive function assessed (Williams et al., 2019). Despite the influence of these moderating factors, running is the most common exercise modality in research examining the acute effects of physical activity on adolescent cognitive function. Whilst running appears to be an effective modality (e.g., Budde et al., 2010; Cooper et al., 2012; 2016), it does not reflect typical activity patterns in adolescents (Rowlands et al., 2008) and does not foster long-term adherence (Howe et al., 2010). Recent research has attempted to replicate the high-intensity and intermittent activity patterns that are preferred by adolescents (Bailey et al., 1995) and has demonstrated the positive acute effects of games-based activity (such as basketball) on subsequent cognitive function (Cooper et al., 2018). The positive influence of games-based activity, an activity that requires cognitive engagement, is consistent with the belief that cognitively engaging physical activities elicit a greater effect on subsequent cognitive function (Crova et al., 2014). However, previous studies that have examined games-based activities have done so through direct intervention of researchers and the provision of a games-based activity that was not delivered within the PE curriculum. The applicability of such findings to curriculum delivered PE lessons is thus unknown. Therefore, developing an understanding of the activity patterns of PE, and how PE influences subsequent cognitive function, is an important gap in existing research that should be addressed.

Previous research investigating PE in adolescents has primarily focussed on the activity volume, intensity, and patterns (Fairclough and Stratton, 2005; Slingerland et al., 2011; Hollis et al., 2017; Lyyra, et al., 2017; Mooses et al., 2017; Cheung, 2019; Zhou and Wang, 2019; Wallace et al., 2020); with no examination of the acute cognitive response to a single PE lesson in adolescents. Whilst a recent systematic review and meta-analysis concluded that there were no statistically significant effects of secondary PE interventions on cognitive function in adolescents (i.e., aged >11 years; Garcia-Hermoso et al., 2021), the review was only able to analyse the effect of chronic (> 12 weeks) PE interventions on adolescent cognitive function due to a paucity of research that has examined the acute cognitive responses to a single bout of PE.

To date, the only study to investigate the acute cognitive response to a single PE lesson was conducted in primary school-aged children (aged 8–9 years) and reported no effect of a single PE lesson on memory and attention, when compared to no physical activity (Pirrie and Lodewyk, 2012). However, as the PE lesson, through various activities, required students to undertake 20 min of MVPA by moving around the room performing specific movements (e.g., hopping), it was not reflective of the national curriculum for PE (Department for Education, 2013) or a typical PE lesson. Additionally, cognitive function testing was not administered simultaneously for all participants, with testing ranging from 10 min to 60 min post lesson. The timing of post-exercise cognitive function testing is an important consideration given that this timing has been shown to moderate the subsequent effects on cognition (e.g., Cooper et al., 2018; Hatch et al., 2021). Therefore, the lack of control of this key variable in previous work limits the conclusions that can be drawn regarding the acute effects of a PE lesson on subsequent cognitive function.

Therefore, the primary aim of the study was to examine the acute effects of a curriculum-based PE lesson on subsequent cognitive function in adolescents. A secondary aim was to quantify the physical activity characteristics of a game-based PE lesson, given that these activity patterns are likely to influence the subsequent effects on cognition. Finally, the third aim was to analyse whether there was a moderating effect of physical fitness, or the amount of MVPA completed during the lesson, on subsequent cognitive performance.

Materials and methods

Participant characteristics

To estimate our sample size, an *a priori* power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007). For a repeated measures approach (two groups, three measurements; two-tailed test; $\alpha = 0.05$, power = 0.80), and a small effect size of 0.14 [based on the previous work by Cooper et al. (2018)], the minimum sample size was n = 84. Subsequently, eighty-five young people (aged 12–13 years) were recruited to participate in the study. However, nine participants failed to complete the study due to absence from school for one of the experimental trials. Therefore, a total of 76 participants completed the study (37 male, 39 female). During familiarisation, all participants underwent anthropometric measures of height, body mass, sitting height, waist circumference and skinfold thickness. A Leicester Height Measure (Seca, Germany), accurate to 0.1 cm, was used to measure height and a Seca 770 digital scale (Seca, Germany), accurate to 0.1 kg, was used to measure body mass. An estimation of maturity offset was made by measuring sitting height, to subsequently estimate years from peak height velocity using methods previously described (Moore et al., 2015). Body mass index (BMI) was calculated and subsequently age-and gender-specific centiles for BMI were derived based on national reference values (Cole et al., 2000). Four skinfold sites were measured (triceps, subscapular, supraspinale, and front thigh) using previously described methods, as a marker of body composition (Dring et al., 2018). Participants were split into high-fit and low-fit groups based on a gender-specific median split of distance run on the multi-stage fitness test (as per previous research (Cooper et al., 2018; Williams et al., 2020)). Likewise, participants were split into high MVPA and low MVPA groups based on the gender-specific median split on MVPA time during the PE lesson. Descriptive participant characteristics are presented in Table 1.

Study design

Following approval from the institution's ethical advisory committee (approval number SST-659), participants were recruited from a secondary school in the East Midlands, UK. As per the guidelines for school-based research, head teacher consent was gained. Additionally, written informed consent from parents/guardians and a health screen questionnaire were completed for each participant; this determined each participant's eligibility for participation by screening for health conditions which may be affected by participation (e.g., exercise-induced asthma). Participants also provided their written assent to participate in the study.

The study employed a randomised, order-balanced, crossover, within-subjects design, consisting of two main experimental trials (PE lesson and academic lesson). A familiarisation took place ~7 d before the first main trial, whereby the protocol of the study was explained to the participants, and they were provided with the opportunity to practice and become familiar with the procedures to be used, including the cognitive function tests. The procedures of the study were also provided to parents/guardians before the study *via* both written information and a phone call from a member of the research team. Opportunities were provided for participants/parents/guardians to ask questions to clarify any aspect of the study they did not fully understand.

To assess physical fitness participants completed the multi-stage fitness test (MSFT; Ramsbottom et al., 1988) during the familiarisation trial. The MSFT involves progressive 20 m shuttle runs in time with an audio signal, until volitional exhaustion or the point at which participants could not maintain the required running speed to keep time with the audio signal. The MSFT commenced at a speed of 8.0 $km \cdot h^{-1}$, increased by 1.0 $km \cdot h^{-1}$ to 9.0 $km \cdot h^{-1}$ for stage two, and increased by 0.5 $km \cdot h^{-1}$ for every completed stage thereafter. To monitor heart rate throughout the MSFT (and record maximum heart rate upon completion), participants were fitted with a chest-worn heart rate monitor (Firstbeat Team Sport System; Firstbeat Technologies Ltd., Finland). To encourage maximum effort from the participants, the research team provided verbal encouragement and participants were paced by an experienced member of the research team familiar with the test. Performance on the MSFT was determined by the total distance covered (m). Using a gender-specific median split of distance ran on the MSFT, participants were split into high-fit and low-fit groups [as per previous research (Cooper et al., 2018; Williams et al., 2020)].

TABLE 1 Participant characteristics for the group overall, as well as for the high-and low-fit groups, and high and low MVPA groups.

Variable	Overall	High-fit (n=38)	Low-fit (n=38)	*p* value [a]	High-MVPA (n=35)	Low-MVPA (n=36)	*p* value [b]
Age (y)	12.2 ± 0.4	12.2 ± 0.4	12.2 ± 0.4	0.695	12.2 ± 0.4	12.2 ± 0.4	0.959
Height (cm)	157.3 ± 8.1	157.9 ± 7.7	156.7 ± 8.5	0.547	156.6 ± 7.4	158.0 ± 9.1	0.484
Body mass (kg)	49.0 ± 10.3	46.3 ± 7.1	51.6 ± 12.2	0.025*	47.6 ± 9.7	51.2 ± 11.1	0.159
Body mass index (BMI; $kg \cdot m^2$)	19.7 ± 3.4	18.5 ± 1.8	20.9 ± 4.0	0.002*	19.3 ± 3.1	20.4 ± 3.6	0.175
BMI percentile	64.5 ± 25.7	56.9 ± 22.0	71.6 ± 27.1	0.012*	61.2 ± 28.1	70.7 ± 22.5	0.120
Waist circumference (cm)	66.8 ± 8.1	63.6 ± 4.6	69.7 ± 9.6	< 0.001*	66.1 ± 8.0	68.4 ± 8.2	0.242
Sum of 4 skinfolds (mm)	64.2 ± 24.7	54.5 ± 16.4	73.4 ± 27.8	< 0.001*	61.5 ± 23.2	68.1 ± 27.1	0.273
Maturity offset [c]	−0.30 ± 0.91	−0.26 ± 0.89	−0.36 ± 0.93	0.645	−0.44 ± 0.93	−0.20 ± 0.86	0.245
MSFT distance (m)	880 ± 320	1,100 ± 260	660 ± 180	< 0.001*	900 ± 300	860 ± 340	0.655

Abbreviations: MSFT Multi-Stage Fitness Test

[a]comparison between high and low fit, independent samples *t*-test.

[b]comparison between high and low MVPA during the PE trial, independent samples *t*-test.

[c]calculated using the method of Moore et al. (2015).

*significant difference ($p < 0.05$) between high and low fit groups.

As outlined in Figure 1, 60 min following breakfast, participants attended either a 60 min PE lesson or a 60 min academic lesson. A battery of cognitive functions tests were completed 30-min pre-, immediately post-and 45-min post-each lesson.

Pre-trial control

The evening before their first experimental trial, participants consumed a meal of their choice and repeated this for their subsequent experimental trial. Subsequently, participants were asked to fast from 10 pm the evening before each experimental trial. To maintain euhydration, water was allowed *ad libitum* during this time. Additionally, for 24 h prior to each experimental trial participants were also asked to avoid any unusually vigorous physical activity. Parents/guardians were contacted by telephone the evening prior to each experimental trial to ensure compliance with these requirements. All participants followed the pre-trial requirements. On the morning of each experimental trial, participants reported to the school (between 8:45 am and 8:55 am) and consumed a standardised breakfast consisting of cornflakes, milk, and toast; providing 1.5 g carbohydrate per kg of body mass, identical to the breakfast of Williams et al. (2020). A standardised breakfast was provided to control for the potential of breakfast and exercise to interact and affect cognitive function in young people (Cooper et al., 2015).

Lesson protocol

The single-gender PE lessons consisted of a 60 min football session, completed outdoor on a rubber crumb pitch. Football was selected as the activity given its popularity among young people and within the PE curriculum. A single researcher was present during the PE lesson to facilitate heart rate and GPS data collection and to provide a description of the lesson. The single researcher present played no active part in the lesson, and they did not interact with the participants or teacher. The PE lessons consisted of a warm-up, skill-based drills, and small-sided games. All lessons were delivered by the participants' normal PE teacher and the research team did not influence the nature or focus of the session. Throughout both experimental trials, participants were fitted with a heart rate monitor (Firstbeat Team Sport System; Firstbeat Technologies Ltd., Finland). Heart rate was monitored continuously throughout both trials. Maximum heart rate and average heart rate were recorded for each trial. Participants were removed from analyses where heart rate data was incomplete or missing (n = 5), thus 71 participants were included for heart rate analysis. For the PE trial only, participants were also fitted with a PlayerTek Global Position System (GPS) unit (Catapult Sports, Melbourne, Australia). The units were placed outside and left stationary to enable an accurate number of satellite signals to be obtained (> 6 satellites). Once satellite signals were obtained, units were placed between the scapulae using an elasticated shoulder harness. The mean satellite signal strength was 9 ± 1 and horizontal dilution of precision was 1.00 ± 0.16. Participants were removed from analyses where GPS data was incomplete or missing (n = 13), thus 63 participants were included for GPS analysis. Variables of interest were total distance covered (m) and distance covered at low (<9 $km \cdot h^{-1}$), moderate (9–13 $km \cdot h^{-1}$), and high-speed (>13 $km \cdot h^{-1}$) (based on the speed zones of previous research; Randers et al., 2014). MVPA time was calculated as the percentage of the timetabled lesson time spent above 64% HR max, in accordance with ACSM guidelines (American College of Sports Medicine, 2017). For the academic lesson, participants attended their timetabled 60 min lesson in mathematics (n = 32), geography (n = 16), philosophy and ethics (n = 13), or personal development (n = 14); as per their normal school timetable. As outlined in Figure 1, both trials followed a time-matched protocol, with the only difference being the lesson attended (i.e., PE or academic).

Cognitive function tests

The battery of cognitive function tests lasted approximately 12 min and consisted of the Stroop test, Sternberg paradigm, and visual search task; completed in that order on a laptop computer (Lenovo ThinkPad T450; Lenovo, Hong Kong). Preceding each cognitive function test and level, the instruction was presented on the screen to each participant and participants completed 3–6 practice stimuli to re-familiarise with the test, negating any potential learning effects; data for these practice stimuli were discarded. The battery of cognitive function tests were completed in silence, in a classroom, and participants were separated such that they could not interact during the tests. To minimise external disturbances, participants wore sound cancelling headphones and the room lights were dimmed to enhance screen visibility. For all cognitive function tests, participants were instructed to respond as quickly and accurately as possible. This testing procedure has been previously used successfully in a similar study population (e.g., Cooper et al., 2018; Williams et al., 2020). For each cognitive function test, the variables of interest were response time (ms) of correct responses and the proportion (%) of correct responses made. To prevent the influence of unusually slow or fast responses on the analyses, response times were filtered in accordance

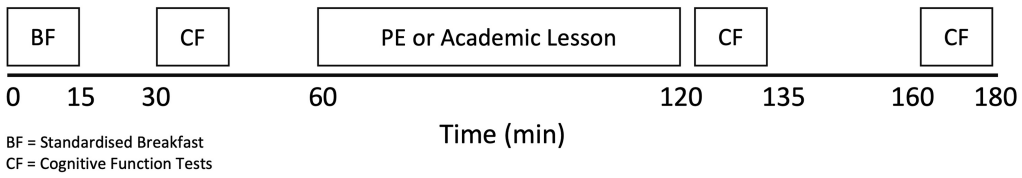


FIGURE 1
Experimental protocol.

with procedures previously conducted (Cooper et al., 2018), with minimum (< 100 ms) and maximum (2,000–10,000 ms, depending on task complexity) response time cut-offs applied.

Stroop test

To measure selective attention and executive function, the Stroop test was administered (Miyake et al., 2000). The Stroop test consists of two levels, simple and complex. Both levels of the Stroop test involved a test word being presented in the centre of the laptop screen, with a target and a distractor randomly presented on the left and right sides of the screen. Using the appropriate arrow key (left or right), participants were instructed to select their responses. For the simple level, the test word, target word and distractor word were all presented in a white font; a total of 20 stimuli were presented. On the complex level (colour-interference) there were 40 stimuli, with the participant selecting the colour the word was written in rather than the word itself (e.g., if 'green' was written in blue font, the correct response would be blue). Choices remained on the screen until the participant responded, with an inter-stimulus interval of 1 s.

Sternberg paradigm

The Sternberg paradigm is a commonly used test that measures the domain of working memory (Sternberg, 1969). The test consists of three levels of ascending complexity that utilise a different working memory load (one, three or five items). The one item level consisted of 16 test stimuli and the number '3' is always the target. Whereas on the three and five item levels, the target is three (e.g., 'A F P') or five (e.g., 'B E H R V') randomly generated letters, respectively; with each containing 32 test stimuli. At the start of each level, the target items were displayed along with instructions to press the right arrow key if a target item was presented and the left arrow key otherwise. The correct response was counterbalanced between the left and right arrow keys for each level. On all levels, the choice stimuli were presented in the centre of the screen, with an inter-stimulus interval of 1 s.

Visual search

The visual search test comprised two levels; simple and complex. When completing both levels of the visual search test, participants were instructed to press the space key as soon as they could detect a triangle on the screen. Following each response, a new target would appear following a random delay (minimum 500 ms delay). The simple level assessed simple visuomotor speed and required participants respond to 20 targets, which were triangles drawn in solid green lines on a black background. For the complex level, participants responded to 40 targets. The additional complex visual processing component of a background distractor was introduced, induced by random moving dots on the screen (to induce the distracting visual effect of a flickering background, a new set of distractor dots were re-drawn on the screen every 250 ms). Target triangles were initially drawn with just a few visible dots of each line, and the density of these points increased linearly with time until the participants responded.

Statistical analysis

Response time and accuracy analyses for the cognitive function tests were conducted using R (www.r-project.org). Analyses were conducted using a two-way (trial*time) repeated measures analysis of variance (ANOVA) for each test level, as each level requires a different level of cognitive processing. Prior to analyses, response times were log transformed to exhibit the right-hand skew, typical of human response times. To assess the moderating effect of fitness and MVPA on the exercise-cognition relationship, three-way (trial*time*fitness and trial*time*MVPA) repeated measures analysis of variance (ANOVA) were conducted for each variable from the cognitive function tests. Collinearity between fitness and MVPA time was assessed using Spearman's rank-order correlation. Where statistically significant three-way interactions existed, post-hoc two-way (trial * time) ANOVA were conducted separately for high-and low-fit adolescents (for trial * time * fitness interactions) and high-and low-MVPA adolescents (for trial * time * MVPA interactions). For all statistically significant effects, partial eta squared effect sizes are included and interpreted as per convention (i.e., 0.01: small; 0.06: medium; 0.14: large).

Maximum heart rate, average heart rate, total distance covered, and distance covered at low, moderate, and high speed during the PE lesson were compared between groups (high-*vs* low-fit; high-*vs* low-MVPA) using SPSS (version 28; SPSS Inc., Chicago, IL., USA) using independent samples t-tests. All data are presented as mean ± standard error of the mean (SEM), unless stated otherwise. Statistical significance was accepted as $p < 0.05$.

Results

Lesson characteristics

Descriptive data for the PE lessons are presented in Table 2. During the PE lessons, time spent in MVPA ($p = 0.445$), average heart rate ($p = 0.093$), total distance covered ($p = 0.094$), and the distance covered at low (<9 km·h^{-1}; $p = 0.181$), moderate (9–13 km·h^{-1}; $p = 0.096$), and high (>13 km·hr.$^{-1}$; $p = 0.200$) speeds were similar between the high and low fit adolescents. However, the maximum heart rate during the PE lessons was significantly higher for the high fit adolescents when compared to low fit adolescents (high-fit; 200 ± 8 beats·min^{-1}, low fit; 195 ± 11 beats·min^{-1}; $t_{(69)} = 0.768$, $p = 0.046$, $d = 0.48$). Furthermore, during the PE lesson, total distance ($p = 0.807$), and the distance covered at low ($p = 0.398$), moderate ($p = 0.884$), and high ($p = 0.290$) speeds were similar between the high and low MVPA adolescents. There was no relationship between fitness and MVPA time during the PE lesson ($r_s = 0.130$, $p = 0.281$).

Cognitive function tests

Data for each of the cognitive function tests, across both trials, are displayed in Table 3 (overall), Table 4 (split by fitness group) and Table 5 (split by MVPA group).

TABLE 2 Descriptive data and inferential statistics for the PE lessons overall, as well as for the high fit and low fit groups, and the high MVPA and low MVPA groups.

Variable	Overall	High-fit	Low-fit	*p* value [a]	High-MVPA	Low-MVPA	*p* value [b]
MVPA [% total time]	67 ± 14	68 ± 15	65 ± 13	0.445	78 ± 5	56 ± 11	
Average heart rate [beats·min^{-1}]	149 ± 12	151 ± 12	146 ± 12	0.093	157 ± 8	140 ± 9	< 0.001**
(% HR max)	72 ± 6	73 ± 6	70 ± 6		75 ± 4	67 ± 4	
Maximum heart rate [beats·min^{-1}]	197 ± 10	200 ± 8	195 ± 11	0.046*	204 ± 7	191 ± 9	< 0.001**
(% HR max)	95 ± 5	96 ± 4	94 ± 5		98 ± 3	92 ± 4	
Total distance [km]	2.49 ± 0.46	2.58 ± 0.44	2.39 ± 0.47	0.094	2.47 ± 0.47	2.50 ± 0.48	0.807
Distance at low speed [km]	1.88 ± 0.26	1.92 ± 0.21	1.84 ± 0.29	0.181	1.85 ± 0.28	1.90 ± 0.25	0.398
Distance at moderate speed [km]	0.41 ± 0.16	0.44 ± 0.17	0.37 ± 0.16	0.096	0.41 ± 0.16	0.41 ± 0.18	0.884
Distance at high speed [km]	0.20 ± 0.12	0.22 ± 0.13	0.18 ± 0.11	0.200	0.21 ± 0.12	0.18 ± 0.13	0.290

Data presented as mean ± SD.
[a]comparison between high and low fit, independent samples t-test.
[b]comparison between high and low MVPA during the PE trial, independent samples t-test.
*significant difference ($p < 0.05$) between high and low fit groups.
**significant difference ($p < 0.05$) between high and low MVPA groups.

Stroop test

Response times

Response times on the simple level of the Stroop test were similar between the PE and academic lesson trials (main effect of trial, $p = 0.811$), but did get quicker across the morning (main effect of time, $F_{(2,148)} = 23.79$, $p < 0.001$, partial $\eta^2 = 0.077$). Additionally, response times on the simple level of the Stroop test were quicker overall in high-fit adolescents (main effect of fitness, $F_{(1,74)} = 141.73$, $p < 0.001$, partial $\eta^2 = 0.067$); and in those who spent less time in MVPA during the PE lesson (main effect of MVPA, $F_{(1,69)} = 40.70$, $p < 0.001$, partial $\eta^2 = 0.021$). However, the pattern of change in response times was similar between trials (trial * time, $p = 0.823$); and the pattern of change was not affected by fitness (trial * time * fitness, $p = 0.476$) or MVPA time (trial * time * MVPA, $p = 0.416$).

Overall, response times on the complex level of the Stroop test were quicker on the academic lesson trial than on the PE lesson trial (main effect of trial, $F_{(1,74)} = 38.59.4$, $p < 0.001$, partial $\eta^2 = 0.008$) and got quicker across the morning (main effect of time, $F_{(2,148)} = 33.39$, $p < 0.001$, partial $\eta^2 = 0.078$). Furthermore, response times on the complex level of the Stroop test were quicker overall in high-fit adolescents when compared to low-fit adolescents (main effect of fitness, $F_{(1,74)} = 294.11$, $p < 0.001$, partial $\eta^2 = 0.074$); and in those who spent more time during the PE lesson in MVPA compared to those who spent less time in MVPA (main effect of MVPA, $F_{(1,69)} = 106.52$, $p < 0.001$, partial $\eta^2 = 0.034$). However, the pattern of change in response times was similar between the academic lesson and PE lesson trials (trial * time, $p = 0.232$); and was not affected by fitness (trial * time * fitness, $p = 0.933$) or the time spent in MVPA (trial * time * MVPA, $p = 0.128$).

Accuracy

Accuracy on the simple level of the Stroop test was similar between trials (main effect of trial, $p = 0.691$); however, accuracy did improve across the morning (main effect of time, $F_{(2,148)} = 10.13$, $p < 0.001$, partial $\eta^2 = 0.119$). Additionally, accuracy for the simple level of the Stroop test was not affected by fitness (main effect of fitness, $p = 0.849$) or MVPA (main effect of MVPA, $p = 0.946$). The pattern of change in accuracy was similar between the academic lesson trial and the PE lesson trial (trial * time, $p = 0.129$); and it was not affected by time spent in MVPA during the PE lesson (trial * time * MVPA, $p = 0.483$) or fitness (trial * time * fitness, $p = 0.269$).

Overall, accuracy on the complex level of the Stroop test was similar between trials (main effect of trial, $p = 0.120$) and did not change across the morning (main effect of time, $p = 0.351$). Additionally, accuracy for the complex level of the Stroop test was not affected by fitness (main effect of fitness, $p = 0.220$) or MVPA time during the PE lesson (main effect of MVPA, $p = 0.150$). Furthermore, the pattern of change in accuracy was similar between trials (trial * time, $p = 0.987$); and it was not affected by MVPA (trial * time * MVPA, $p = 0.946$) or fitness (trial * time * fitness, $p = 0.746$).

Sternberg paradigm

Response times

Overall, response times on the one item level of the Sternberg paradigm were quicker in the academic lesson trial than PE trial (main effect of trial, $F_{(1,74)} = 4.20$, $p = 0.04$, partial $\eta^2 = 0.006$) and got quicker across the morning (main effect of time, $F_{(2,148)} = 19.45$, $p < 0.001$, partial $\eta^2 = 0.122$). Additionally, response times on the one item level of the Sternberg paradigm were quicker overall in high-fit adolescents (main effect of fitness, $F_{(1,74)} = 175.84$, $p < 0.001$, partial $\eta^2 = 0.121$); and in those who spent less time in MVPA compared to those who spent more time in MVPA during the PE lesson (main effect of MVPA, $F_{(1,69)} = 73.11$, $p < 0.001$, partial $\eta^2 = 0.052$). The pattern of change in response times was similar between trials (trial * time, $p = 0.114$) and not affected by MVPA (trial * time * MVPA, $p = 0.191$). However, there was a trial * time * fitness interaction ($F_{(2,148)} = 3.88$, $p = 0.021$, partial $\eta^2 = 0.017$; Figure 2). Upon further inspection, in high fit adolescents the improvement in response times across the morning was greater on the academic trial (trial * time, $F_{(2,72)} = 6.80$, $p = 0.001$, partial $\eta^2 = 0.089$; Figure 2A); whilst in low fit adolescents the pattern of change in response times was similar between the PE and academic trial (trial * time, $p = 0.746$).

10.3389/fpsyg.2023.1098861

TABLE 3 Cognitive function data across the academic and PE trials.

Test	Level	Variable	Academic trial			PE trial		
			Pre-exercise	Immediately post-exercise	45min post-exercise	Pre-exercise	Immediately post-exercise	45min post-exercise
Stroop test	Simple	Response time [ms]	811 ± 20	766 ± 18	773 ± 20	800 ± 17	770 ± 18	768 ± 18
		Accuracy [%]	97.6 ± 0.5	95.7 ± 0.7	94.6 ± 0.9	97.4 ± 0.4	95.7 ± 0.7	96.2 ± 0.6
	Complex	Response time [ms]	1,103 ± 33	1,032 ± 30	1,037 ± 29	1,111 ± 26	1,068 ± 24	1,065 ± 25
		Accuracy [%]	93.0 ± 1.2	92.2 ± 1.0	92.3 ± 1.0	94.1 ± 0.7	93.3 ± 0.6	93.3 ± 0.7
Sternberg paradigm	One item	Response time [ms]	560 ± 15	510 ± 10	525 ± 13	549 ± 13	529 ± 13	533 ± 12
		Accuracy [%]	92.3 ± 1.6	93.3 ± 0.9	93.4 ± 0.8	95.1 ± 0.7	94.8 ± 0.7	94.8 ± 0.7
	Three item	Response time [ms]	674 ± 15	661 ± 14	663 ± 14	697 ± 14	681 ± 15	664 ± 14
		Accuracy [%]	93.5 ± 0.9	93.4 ± 0.6	92.7 ± 0.8	93.2 ± 1.3	93.1 ± 0.7	93.4 ± 0.9
	Five item	Response time [ms]	847 ± 19	796 ± 19	771 ± 19	840 ± 19	779 ± 17	793 ± 17
		Accuracy [%]	92.0 ± 0.7	88.0 ± 1.3	87.5 ± 1.4	90.2 ± 1.2	89.3 ± 1.2	86.9 ± 1.3
Visual search	Simple	Response time [ms]	591 ± 8	585 ± 6	590 ± 7	587 ± 8	594 ± 8	592 ± 8
		Accuracy [%]	89.4 ± 2.3	91.3 ± 1.7	89.8 ± 2.0	92.6 ± 2.1	93.3 ± 1.9	90.3 ± 2.4
	Complex	Response time [ms]	1,633 ± 46	1,580 ± 43	1,551 ± 42	1711 ± 38	1,574 ± 40	1,593 ± 44
		Accuracy [%]	92.4 ± 1.3	91.9 ± 1.4	92.6 ± 1.0	94.5 ± 1.2	92.7 ± 1.8	91.0 ± 2.1

Data are mean ± SEM.

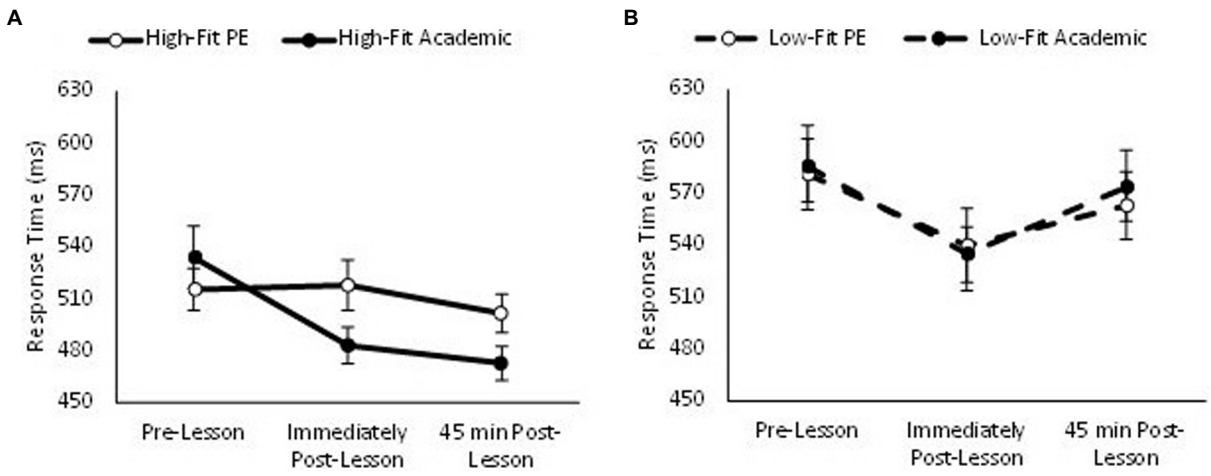


FIGURE 2
Response times across the morning on the one item level of the Sternberg paradigm on the PE and academic lesson trials for the high-fit (trial * time, $p = 0.001$; **A**) and low-fit (trial * time, $p = 0.746$; **B**) groups (trial * time * fitness, $p = 0.021$).

Response times on the three item level of the Sternberg paradigm were quicker in the academic lesson trial than PE trial (main effect of trial, $F_{(1,74)} = 13.07$, $p = 0.001$, partial $\eta^2 = 0.041$) and got quicker across the morning (main effect of time, $F_{(2,148)} = 10.13$, $p < 0.001$, partial $\eta^2 = 0.044$). Response times on the three item level of the Sternberg paradigm were also quicker overall in high-fit adolescents when compared to low-fit adolescents (main effect of fitness, $F_{(1,74)} = 260.28$, $p < 0.001$, partial $\eta^2 = 0.100$), and were influenced by MVPA, with high MVPA adolescents demonstrating a greater reduction in response times when compared with low MVPA adolescents (main effect of MVPA, $F_{(1,69)} = 31.28$, $p < 0.001$ partial $\eta^2 = 0.012$). Furthermore, response time improved immediately post-lesson in both trials, with a tendency for further improvement 45 min post-lesson in the PE trial, this did not reach statistical significance (trial * time, $F_{(2,148)} = 2.97$, $p = 0.052$). Additionally, the pattern of change in response times was not affected by fitness (trial * time * fitness, $p = 0.745$). However, the pattern of change in response time across the morning was affected by the amount of MVPA completed in the PE lesson (time * trial * MVPA, $F_{(2,138)} = 3.10$, $p = 0.045$, partial $\eta^2 = 0.025$; Figure 3). Upon further inspection, whilst response times improved across the

10.3389/fpsyg.2023.1098861

TABLE 4 Cognitive function data across the academic and PE trials for the high and low fitness groups.

Test	Level	Variable	Participant Group	Academic trial			PE trial		
				Pre-exercise	Immediately post-exercise	45min post-exercise	Pre-exercise	Immediately post-exercise	45min post-exercise
Stroop test	Simple	Response time [ms]	Low Fitness	840 ± 32	812 ± 30	834 ± 33	830 ± 29	805 ± 29	807 ± 30
			High Fitness	781 ± 23	721 ± 18	713 ± 19	770 ± 16	735 ± 21	729 ± 16
		Accuracy [%]	Low Fitness	97.6 ± 0.6	96.3 ± 0.9	95.0 ± 1.0	97.5 ± 0.5	95.0 ± 1.1	95.6 ± 0.8
			High Fitness	97.5 ± 0.7	95.0 ± 1.1	94.2 ± 1.4	97.2 ± 0.5	96.3 ± 0.7	96.6 ± 0.7
	Complex	Response time [ms]	Low Fitness	1,167 ± 48	1,095 ± 45	1,123 ± 44	1,160 ± 44	1,107 ± 39	1,126 ± 40
			High Fitness	1,039 ± 43	968 ± 37	951 ± 32	1,063 ± 24	1,030 ± 28	1,004 ± 28
		Accuracy [%]	Low Fitness	91.3 ± 2.0	91.1 ± 1.8	91.5 ± 1.5	93.5 ± 1.3	92.4 ± 0.8	92.9 ± 1.1
			High Fitness	94.6 ± 1.0	93.2 ± 0.8	93.1 ± 1.1	94.6 ± 0.6	94.1 ± 0.8	93.6 ± 0.7
Sternberg paradigm	One item	Response time [ms]	Low Fitness	586 ± 24	535 ± 15	574 ± 22	581 ± 21	540 ± 21	563 ± 20
			High Fitness	534 ± 18	483 ± 11	473 ± 10	515 ± 12	518 ± 15	502 ± 11
		Accuracy [%]	Low Fitness	91.2 ± 1.7	93.4 ± 1.2	92.1 ± 1.3	94.4 ± 1.1	94.4 ± 1.1	95.2 ± 0.9
			High Fitness	93.4 ± 2.6	93.1 ± 1.4	94.8 ± 1.1	96.0 ± 0.8	95.2 ± 0.8	94.4 ± 1.0
	Three item	Response time [ms]	Low Fitness	715 ± 21	692 ± 22	701 ± 23	727 ± 23	706 ± 21	689 ± 19
			High Fitness	630 ± 20	628 ± 16	623 ± 13	665 ± 14	654 ± 19	638 ± 18
		Accuracy [%]	Low Fitness	94.1 ± 0.9	93.7 ± 0.8	93.4 ± 1.1	92.1 ± 2.5	92.4 ± 1.1	92.5 ± 1.5
			High Fitness	93.0 ± 1.5	93.2 ± 0.9	91.9 ± 1.3	94.3 ± 0.8	93.8 ± 0.9	94.3 ± 0.9
	Five item	Response time [ms]	Low Fitness	863 ± 23	817 ± 28	786 ± 30	871 ± 31	796 ± 27	776 ± 26
			High Fitness	830 ± 31	774 ± 24	755 ± 22	808 ± 22	761 ± 21	810 ± 22
		Accuracy [%]	Low Fitness	91.4 ± 1.0	87.3 ± 1.7	86.0 ± 2.0	88.5 ± 2.2	88.1 ± 1.8	85.3 ± 2.2
			High Fitness	92.6 ± 0.8	88.6 ± 1.9	89.2 ± 1.9	91.9 ± 1.1	90.5 ± 1.5	88.6 ± 1.5
Visual search	Simple	Response time [ms]	Low Fitness	605 ± 11	596 ± 10	587 ± 11	600 ± 12	601 ± 12	603 ± 10
			High Fitness	576 ± 10	574 ± 7	593 ± 8	573 ± 10	586 ± 11	580 ± 12
		Accuracy [%]	Low Fitness	87.3 ± 3.9	90.6 ± 2.8	91.0 ± 1.8	92.0 ± 3.2	93.6 ± 2.5	89.1 ± 3.5
			High Fitness	91.6 ± 2.2	92.0 ± 2.0	88.5 ± 3.7	93.2 ± 2.6	93.1 ± 2.9	91.4 ± 3.3
	Complex	Response time [ms]	Low Fitness	1,620 ± 62	1,579 ± 64	1,551 ± 62	1758 ± 51	1,586 ± 62	1,656 ± 70
			High Fitness	1,647 ± 70	1,580 ± 59	1,551 ± 56	1,661 ± 56	1,562 ± 50	1,525 ± 51
		Accuracy [%]	Low Fitness	91.8 ± 2.1	92.3 ± 1.9	92.7 ± 1.3	95.4 ± 1.6	90.1 ± 3.1	88.0 ± 3.5
			High Fitness	93.1 ± 1.6	91.4 ± 2.1	92.5 ± 1.6	93.6 ± 1.8	95.4 ± 1.5	94.2 ± 2.0

Data are mean ± SEM.

morning on the PE trial in those who completed more MVPA during the PE lesson (trial * time, $F_{(2,68)} = 4.41$, $p = 0.012$, partial $\eta^2 = 0.063$; Figure 3A), the pattern of change in response times across the morning was similar between the PE and academic trials for those who completed less MVPA (trial * time, $p = 0.443$; Figure 3B).

Overall, response times on the five item level of the Sternberg paradigm were similar between the academic lesson trial and the PE lesson trial (main effect of trial, $p = 0.693$), but response times got quicker across the morning (main effect of time, $F_{(2, 148)} = 34.98$, $p < 0.001$, partial $\eta^2 = 0.157$). Additionally, response times on the five item level were quicker overall in high-fit adolescents when compared to low-fit adolescents (main effect of fitness, $F_{(1,74)} = 26.15$, $p < 0.001$, partial $\eta^2 = 0.014$); and were influenced by MVPA time during the PE lesson (main effect of MVPA, $F_{(1,69)} = 12.76$, $p < 0.001$, partial $\eta^2 = 0.005$) as high MVPA adolescents had quicker response time overall. Whilst the pattern of change in response times was similar between the academic lesson and PE lesson trials (trial * time, $p = 0.071$), and it was not affected by MVPA (trial * time *

10.3389/fpsyg.2023.1098861

TABLE 5 Cognitive function data across the academic and PE trials for the high and low MVPA groups.

Test	Level	Variable	Participant Group	Academic trial			PE trial		
				Pre-exercise	Immediately post-exercise	45min post-exercise	Pre-exercise	Immediately post-exercise	45min post-exercise
Stroop test	Simple	Response time [ms]	Low MVPA	790 ± 23	746 ± 23	748 ± 27	775 ± 22	742 ± 20	744 ± 18
			High MVPA	834 ± 35	782 ± 30	795 ± 32	810 ± 28	785 ± 32	778 ± 31
		Accuracy [%]	Low MVPA	97.9 ± 0.6	96.5 ± 0.9	93.9 ± 1.0	96.7 ± 0.6	95.6 ± 1.1	95.4 ± 0.9
			High MVPA	97.1 ± 0.9	94.3 ± 1.2	95.0 ± 1.6	97.7 ± 0.5	95.6 ± 1.0	96.6 ± 0.8
	Complex	Response time [ms]	Low MVPA	1,066 ± 38	994 ± 41	992 ± 36	1,064 ± 30	1,022 ± 25	1,027 ± 34
			High MVPA	1,138 ± 57	1,086 ± 47	1,075 ± 49	1,143 ± 42	1,097 ± 44	1,095 ± 40
		Accuracy [%]	Low MVPA	94.5 ± 1.0	93.2 ± 1.0	93.4 ± 0.8	94.9 ± 0.6	93.3 ± 0.8	93.8 ± 0.7
			High MVPA	90.5 ± 2.3	91.2 ± 1.9	90.6 ± 1.9	92.9 ± 1.4	93.1 ± 1.0	92.3 ± 1.2
Sternberg paradigm	One item	Response time [ms]	Low MVPA	543 ± 21	503 ± 13	506 ± 17	517 ± 13	505 ± 14	518 ± 15
			High MVPA	591 ± 28	512 ± 17	539 ± 21	567 ± 22	539 ± 18	543 ± 18
		Accuracy [%]	Low MVPA	89.7 ± 3.0	93.4 ± 1.2	93.9 ± 1.3	94.9 ± 1.1	94.3 ± 1.1	94.8 ± 0.9
			High MVPA	94.1 ± 1.2	92.3 ± 1.7	92.3 ± 1.2	95.7 ± 0.9	95.2 ± 1.0	94.3 ± 1.0
	Three item	Response time [ms]	Low MVPA	655 ± 22	673 ± 22	644 ± 16	673 ± 18	669 ± 21	662 ± 20
			High MVPA	688 ± 22	658 ± 22	676 ± 22	713 ± 22	684 ± 19	663 ± 20
		Accuracy [%]	Low MVPA	93.4 ± 1.4	94.1 ± 0.8	93.5 ± 1.0	94.1 ± 1.0	92.1 ± 1.2	94.0 ± 0.8
			High MVPA	93.3 ± 1.1	92.5 ± 1.0	91.3 ± 1.4	91.6 ± 2.7	93.2 ± 0.9	92.1 ± 1.7
	Five item	Response time [ms]	Low MVPA	842 ± 29	800 ± 27	773 ± 26	797 ± 23	766 ± 24	792 ± 24
			High MVPA	858 ± 29	793 ± 28	762 ± 30	874 ± 31	802 ± 26	786 ± 26
		Accuracy [%]	Low MVPA	91.6 ± 0.9	89.2 ± 1.8	89.5 ± 1.6	91.0 ± 1.2	88.1 ± 1.9	88.3 ± 1.8
			High MVPA	92.2 ± 0.9	86.4 ± 1.9	85.1 ± 2.4	89.0 ± 2.3	90.7 ± 1.4	85.4 ± 2.1
Visual search	Simple	Response time [ms]	Low MVPA	595 ± 11	602 ± 10	581 ± 7	598 ± 13	597 ± 12	606 ± 12
			High MVPA	585 ± 11	568 ± 7	601 ± 12	576 ± 9	591 ± 12	580 ± 11
		Accuracy [%]	Low MVPA	89.0 ± 3.6	90.0 ± 3.1	88.3 ± 3.4	92.3 ± 2.8	94.3 ± 2.2	92.1 ± 3.2
			High MVPA	88.9 ± 3.4	92.6 ± 1.8	90.4 ± 2.7	94.4 ± 2.6	95.3 ± 2.3	87.9 ± 4.0
	Complex	Response time [ms]	Low MVPA	1,653 ± 69	1,657 ± 60	1,560 ± 56	1,666 ± 53	1,533 ± 62	1,616 ± 64
			High MVPA	1,613 ± 66	1,525 ± 61	1,537 ± 66	1753 ± 58	1,604 ± 56	1,589 ± 67
		Accuracy [%]	Low MVPA	91.4 ± 2.0	90.3 ± 2.3	92.4 ± 1.4	92.0 ± 2.4	91.8 ± 2.4	87.2 ± 3.8
			High MVPA	94.2 ± 1.6	93.4 ± 1.8	92.5 ± 1.7	97.4 ± 0.6	93.6 ± 2.9	95.4 ± 1.4

Data are mean ± SEM.

MVPA, $p = 0.203$); the pattern of change in response times was significantly affected by fitness (trial * time * fitness, $F_{(2,148)} = 3.76$, $p = 0.023$, partial $\eta^2 = 0.028$; Figure 4). Upon further inspection, response times improved immediately and 45 min following the PE lesson in high fit adolescents when compared to the academic trial (trial * time, $F_{(2,72)} = 6.59$, $p = 0.001$, partial $\eta^2 = 0.093$; Figure 4A). However, there was no difference in the change in response times between the PE and academic trials in the low fit adolescents (trial * time, $p = 0.863$).

Accuracy

Accuracy on the one item level of the Sternberg paradigm was similar between the PE and academic trials (main effect of trial, $p = 0.839$), but did improve across the morning (main effect of time, $F_{(2,148)} = 6.86$, $p = 0.011$, partial $\eta^2 = 0.002$). In addition, accuracy on the one item level of the Sternberg paradigm was not different between low and high-fit adolescents (main effect of fitness, $p = 0.297$). Neither was accuracy affected by MVPA when comparing those adolescents with a high MVPA against those with low MVPA in the PE lesson

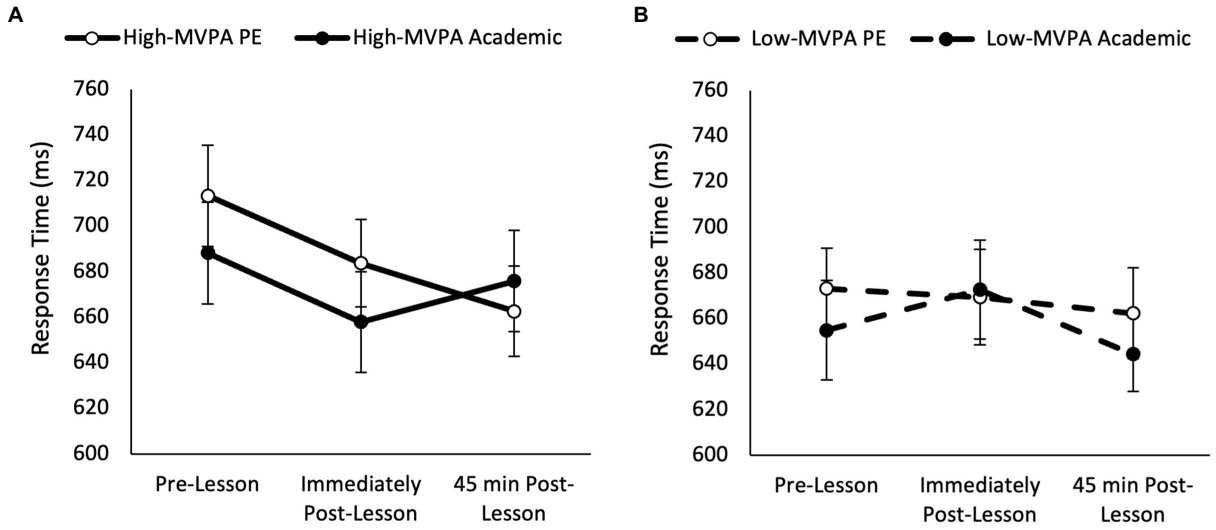


FIGURE 3
Response times across the morning on the three item level of the Sternberg paradigm on the PE and academic lesson trials for the high MVPA (trial * time, $p = 0.012$; **A**) and low MVPA (trial * time, $p = 0.443$; **B**) groups (trial * time * MVPA, $p = 0.045$).

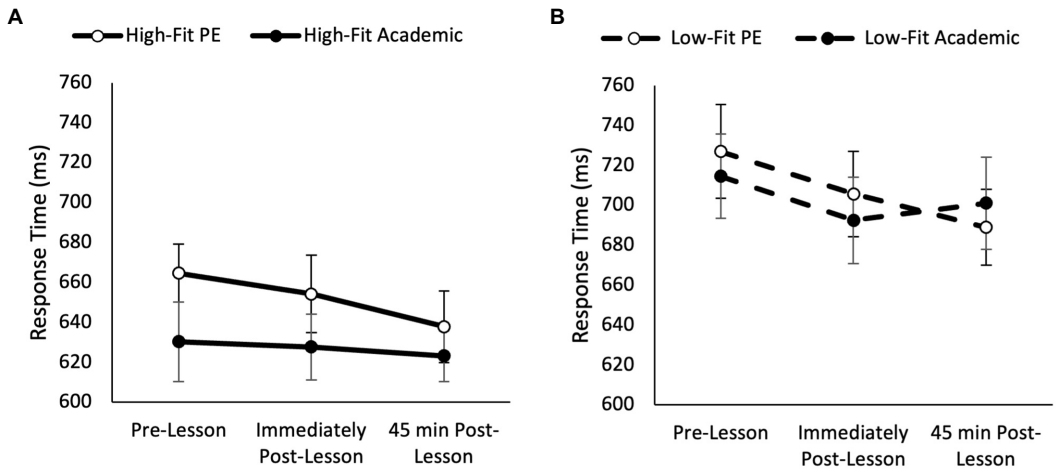


FIGURE 4
Response times across the morning on the five item level of the Sternberg paradigm on the PE and academic lesson trials for the high-fit (trial * time, $p = 0.001$; **A**) and low-fit (trial * time, $p = 0.863$; **B**) groups (trial * time * fitness, $p = 0.023$).

(main effect of MVPA, $p = 0.774$). The pattern of change was similar between trials (trial * time, $p = 0.659$) and was not affected by fitness (time * trial * fitness, $p = 0.453$) or MVPA during the PE lesson (trial * time * fitness, $p = 0.312$).

Overall, on the three item level of the Sternberg paradigm, accuracy was similar between trials (main effect of trial, $p = 0.850$) and did not change across the morning (main effect of time, $p = 0.987$). Additionally, when comparing high and low-fit adolescents, accuracy was not different (main effect of fitness, $p = 0.767$), nor was it different when comparing adolescents with high and low MVPA during the PE lesson (main effect of MVPA, $p = 0.344$). The pattern of change for accuracy was similar between trials (trial * time, $p = 0.633$) and the pattern of change was not affected by fitness (time * trial * fitness, $p = 0.807$) or MVPA time during the PE lesson (time * trial * MVPA, $p = 0.206$).

For the five item level of the Sternberg paradigm, accuracy was similar across trials (main effect of trial, $p = 0.669$), but accuracy was reduced across the morning (main effect of time, $F_{(2,148)} = 9.99$, $p < 0.001$, partial $\eta^2 = 0.117$). Accuracy on the five item level of the Sternberg paradigm was not affected by fitness (main effect of fitness, $p = 0.175$) or by MVPA (main effect of MVPA, $p = 0.407$). Whilst the pattern of change for accuracy was similar between trials (trial * time, $p = 0.128$), and it was not affected by fitness (trial * time * fitness, $p = 0.805$); it was affected by MVPA during the PE lesson (trial * time * MVPA, $F_{(2,138)} = 3.41$, $p = 0.036$, partial $\eta^2 = 0.047$; Figure 5). Upon further inspection, accuracy improved immediately following the PE lesson in those who completed more MVPA during the PE lesson when compared to the academic lesson (trial * time, $F_{(2,68)} = 4.30$, $p = 0.023$, partial $\eta^2 = 0.119$; Figure 5A). However, there was no different in

accuracy between the PE and academic trials in those who completed less MVPA during the PE lesson (trial * time, $p = 0.946$; Figure 5B).

Visual search

Response times

Overall, response times on the simple level of visual search were similar for the academic lesson and PE lesson trials (main effect of trial, $p = 0.534$) and did not improve across the morning (main effect of time, $p = 0.822$). Response times on the simple level of the visual search were quicker overall in high-fit adolescents when compared to low-fit adolescents (main effect of fitness, $F_{(1,74)} = 34.74$, $p < 0.001$, partial $\eta^2 = 0.043$); and quicker in those who spent more time during the PE lesson in MVPA compared to those who spent less time in MVPA (main effect of MVPA, $F_{(1,69)} = 16.69$, $p < 0.001$, partial $\eta^2 = 0.022$). Whilst the pattern of change in response times was similar between the academic lesson and PE lesson trials (trial * time, $p = 0.305$), the pattern of change in response times was affected by fitness (trial * time * fitness, $F_{(2,148)} = 4.02$, $p = 0.018$, partial $\eta^2 = 0.021$; Figure 6). Upon further inspection, in high fit adolescents response times were slower immediately following the PE lesson and 45 min following the academic lesson (trial * time, $F_{(2,72)} = 3.34$, $p = 0.036$, partial $\eta^2 = 0.049$; Figure 6A); whilst the pattern of change in response times was similar following the PE and academic lesson in low fit adolescents (trial * time, $p = 0.130$; Figure 6B).

Additionally, response times on the simple level were also affected by the amount of MVPA completed during the PE lesson (trial * time * MVPA, $F_{(2,138)} = 10.18$, $p < 0.001$, partial $\eta^2 = 0.071$; Figure 7). Upon further inspection, in those who completed more MVPA response times were slower immediately following the PE lesson and 45 min following the academic lesson (trial * time, $F_{(2, 68)} = 7.53$, $p < 0.001$, partial $\eta^2 = 0.117$; Figure 7A); whilst in those who completed less MVPA, response times were maintained across the morning on the

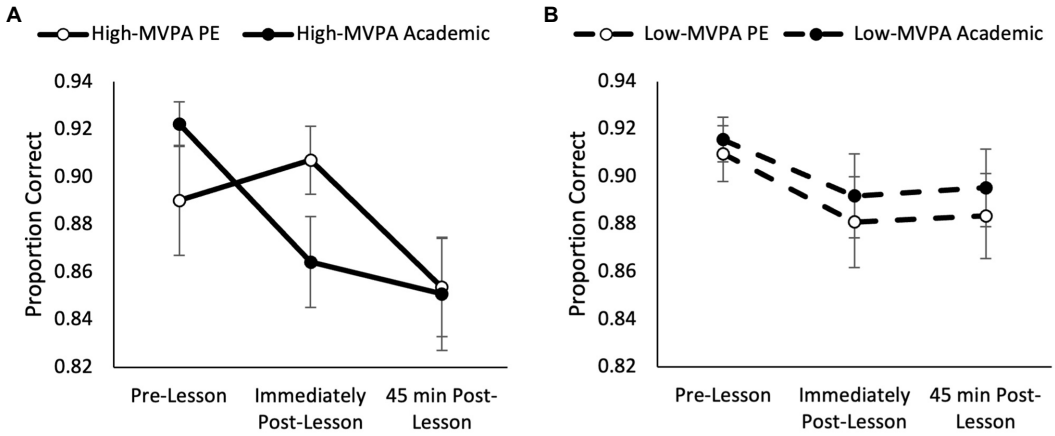


FIGURE 5
Accuracy presented as the proportion of correct responses across the morning on the five item level of the Sternberg paradigm for the high MVPA (trial * time, $p = 0.023$; **A**) and low MVPA (trial * time, $p = 0.946$; **B**) groups (trial * time * MVPA, $p = 0.036$).

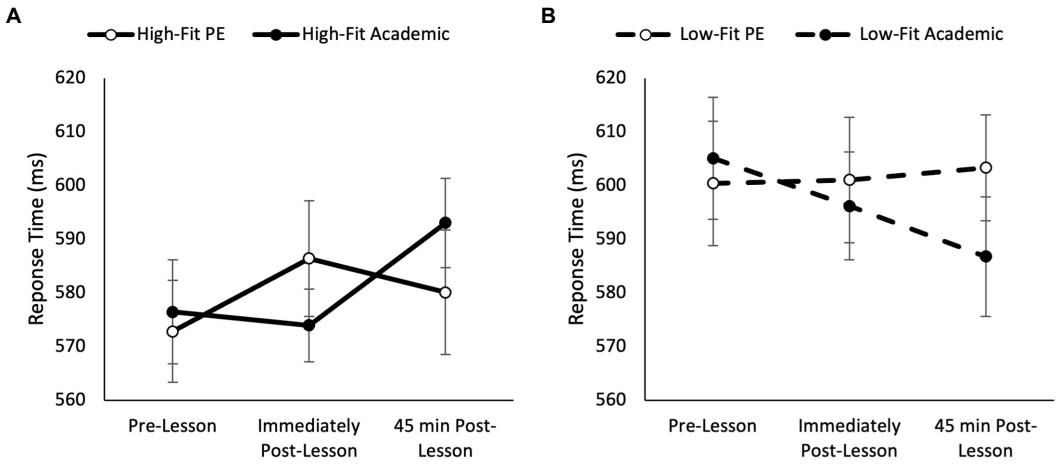


FIGURE 6
Response times across the morning on the simple level of the visual search on the PE and academic lesson trials for the high-fit (trial * time, $p = 0.036$; **A**) and low-fit (trial * time, $p = 0.130$; **B**) groups (trial * time * fitness, $p = 0.018$).

PE trial, and improved 45 min following the academic lesson (trial * time, $F_{(2,72)} = 3.64$, $p = 0.026$, partial $\eta^2 = 0.046$; Figure 7B).

Overall, response times on the complex level of the visual search test were quicker on the academic lesson trial than in the PE lesson trial (main effect of trial, $F_{(1,69)} = 7.97$, $p = 0.005$, partial $\eta^2 = 0.024$) and improved across the morning (main effect of time, $F_{(2,138)} = 16.39$, $p < 0.001$, partial $\eta^2 = 0.115$). Response times on the complex level of the visual search test were not affected by fitness (main effect of fitness, $p = 0.147$) or MVPA time during the PE lesson (main effect of MVPA, $p = 0.616$). Whilst the pattern of change in response times was similar between the academic lesson and PE lesson trials (trial * time, $p = 0.062$), and was not affected by fitness (trial * time * fitness, $p = 0.334$); the pattern of change was affected by MVPA (trial * time * MVPA, $F_{(2,138)} = 3.31$, $p = 0.037$, partial $\eta^2 = 0.030$; Figure 8). Specifically, the pattern of change in response times was similar across the PE and academic trials in adolescents who completed more MVPA during the PE lesson (trial * time, $p = 0.265$; Figure 8A). However, in those adolescents who completed less MVPA, response times improved immediately following the PE lesson (trial * time, $F_{(2,72)} = 5.72$, $p = 0.003$, partial $\eta^2 = 0.093$; Figure 8B).

Accuracy

Accuracy on the simple level of the visual search was similar between the PE and academic lesson trials (main effect of trial, $p = 0.212$), and did not change across the morning (main effect of time, $p = 0.525$). Additionally, when comparing high-fit to low-fit adolescents, accuracy was not affected by fitness (main effect of fitness, $p = 0.681$). Likewise, when comparing those adolescents with high MVPA during the PE lesson against those with low MVPA, accuracy was similar (main effect of MVPA, $p = 0.812$). The pattern of change was similar between trials (time * trial, $p = 0.701$) and the pattern of change between trials was not affected by fitness (time * trial * fitness,

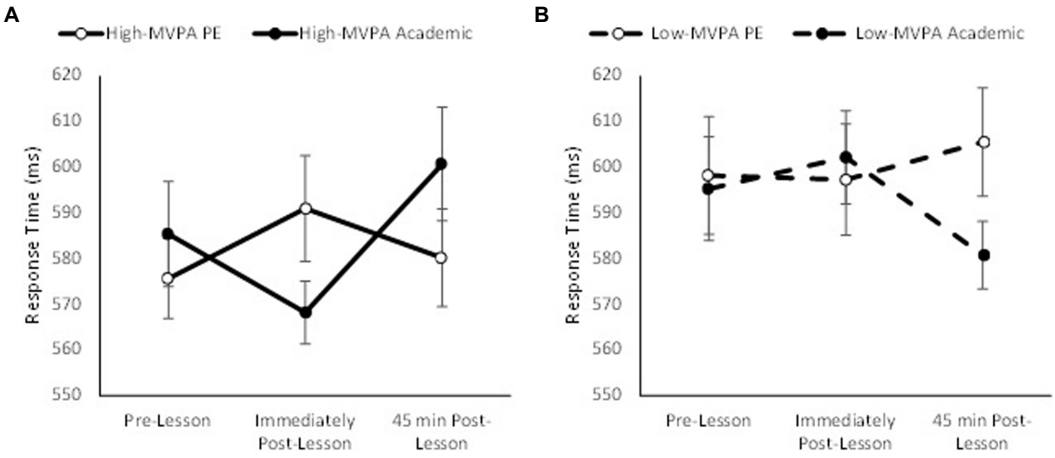


FIGURE 7
Response times across the morning on the simple level of the visual search on the PE and academic lesson trials for the high MVPA (trial * time, $p < 0.001$; **A**) and low MVPA (trial * time, $p = 0.026$; **B**) groups (trial * time * MVPA, $p < 0.001$).

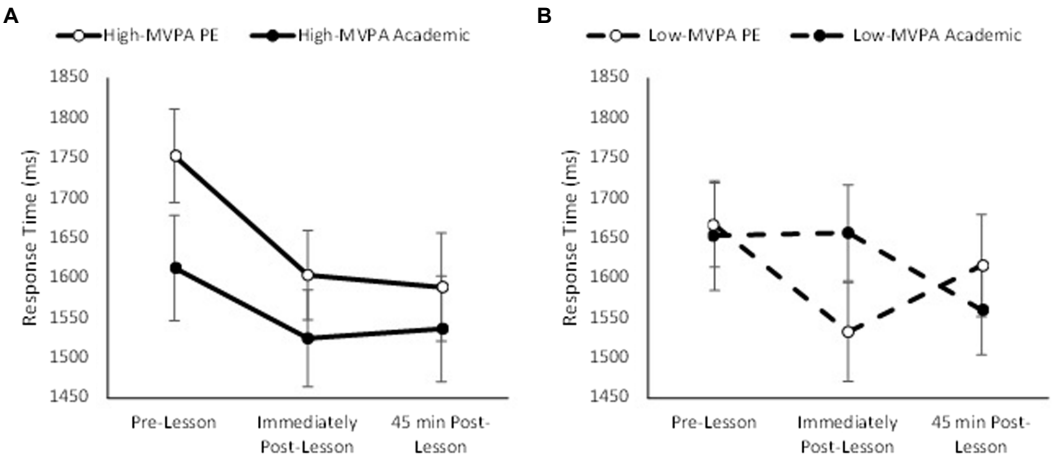


FIGURE 8
Response times across the morning on the complex level of the visual search on the PE and academic lesson trials for the high MVPA (trial * time, $p = 0.265$; **A**) and low MVPA (trial * time, $p = 0.003$; **B**) groups (trial * time * MVPA, $p = 0.037$).

$p = 0.405$) or by MPVA during the PE lesson (time * trial * MVPA, $p = 0.415$).

Overall, accuracy on the complex level of the visual search was similar between the PE and academic lesson trials (main effect of trial, $p = 0.665$), and did not change across the morning (main effect of time, $p = 0.475$). Furthermore, when comparing high-fit to low-fit adolescents, accuracy was not affected (main effect of fitness, $p = 0.358$). However, adolescents who completed more MVPA in the PE lesson had greater overall accuracy than those who completed less MVPA (main effect of MVPA, $F_{(1,69)} = 3.96$, $p = 0.050$, partial $\eta^2 = 0.054$). The pattern of change was similar between trials (time * trial, $p = 0.355$) and the pattern of change between trials was not affected by fitness (time * trial * fitness, $p = 0.358$) or by MPVA during the PE lesson (time * trial * fitness, $p = 0.227$).

Discussion

The main findings of the present study are that a 60 min games-based PE lesson had no effect on perception, working memory, attention, or executive function in adolescents, when compared to a standard academic lesson. However, adolescents who spent a higher percentage of their PE lesson undertaking MVPA experienced some cognitive benefits, as evidenced by improvements in the speed (three item level) and accuracy (five item level) of working memory (as assessed by the Sternberg paradigm). Additionally, the cognitive response to the PE lesson was influenced by fitness as high-fit adolescents demonstrated improvements in speed of working memory, as evidenced by improved response times on the five-item level of the Sternberg paradigm. Furthermore, the present study also shows that high fit adolescents display superior cognition when compared to their lower fit counterparts, across all domains of cognitive function. Finally, MVPA time in the single-gender games-based PE lessons observed in this study was greater than that previously reported for adolescents. On average, adolescents spent 67% of the lesson time undertaking MVPA; although considerable inter-individual variation was evident as time spent in MVPA ranged from 23% in the least active, to 90% in the most active, adolescents.

The present study is the first to examine the acute cognitive response to a games-based PE lesson in adolescents. Overall, perception, working memory, and attention were unchanged following a games-based PE lesson. These results are consistent with those previously reported by Williams et al. (2020), whereby, overall, cognitive function remained unchanged in adolescents following a 60 min football session. The unaffected cognitive response to the 60 min games-based activity reported in this study, and by Williams et al. (2020), could be attributed to the duration of the exercise protocol. Haverkamp et al. (2020) recently reported a larger effect on cognitive function when the acute exercise interventions are of a shorter duration. However, Cooper et al. (2018) previously reported enhanced working memory and executive function in adolescents following a 60 min games-based activity (basketball). The inconsistent findings could be attributed to the activity patters of the respective exercise protocols, as Cooper et al. (2018) reported higher average heart rate than that reported by Williams et al. (2020) and the current study. The pedagogical requirement of a PE lesson could have attributed to a less intense exercise protocol, and resultantly, a lower average heart rate in the current study. Future work should investigate the acute cognitive response to games-based activity of varying intensity and duration.

The present study also demonstrated that high fit adolescents displayed superior cognition compared to their lower fit counterparts, with high fit adolescents exhibiting quicker response times for all domains of cognitive function assessed. The effect of fitness on perception (visual search test) is consistent with the findings of Williams et al. (2022), whereby, the beneficial effect of fitness on visual processing speed was first demonstrated. High fit adolescents also demonstrated quicker response times for attention and working memory, which is consistent with recent evidence of the enhancing effect of fitness on these domains of cognitive function (Cooper et al., 2016; Aadland et al., 2017; Haverkamp et al., 2020; Williams et al., 2020). It has previously been stated that participation in exercise modifies the capacity of the nervous system to adapt its organisation to altered demands and environment, termed neuroplasticity (Hötting and Röder, 2013). Engaging in repetitive aerobic physical activity induces increases in angiogenesis (Best, 2010) and the availability of certain neurotrophins, especially brain-derived neurotrophic factor (BDNF; Cho et al., 2012), which are prerequisites for neuroplasticity (Hötting and Röder, 2013). Consequently, increased angiogenesis and BDNF have been suggested as an explanation for the beneficial effect of fitness on cognitive function (Haverkamp et al., 2020). However, it has recently been demonstrated that there is no association between fitness and BDNF concentration in young people (Williams et al., 2022). Therefore, whilst the current study supports the beneficial effect of fitness on cognitive function, future work should seek to explore the potential mechanisms for this association.

The acute cognitive response to exercise was influenced by the participant's fitness in the present study, with high-fit adolescents demonstrating greater improvements in working memory following the PE lesson. This finding is consistent with the previous evidence that cognitive function is enhanced to a greater extent in high-fit adolescents following an acute bout of games-based activity, when compared to low-fit adolescents (Cooper et al., 2018; Williams et al., 2020). However, in the present study, high-fit adolescents only demonstrated improved working memory following their PE lesson, whereas Cooper et al. (2018) were also able to evidence improved attention and executive function in high-fit adolescents following an acute bout of games-based activity. As the acute exercise-cognition relationship is influenced by moderating factors (e.g., age, physical fitness) and exercise characteristics (e.g., duration, intensity) (Williams et al., 2019), a potential explanation for the discrepant findings could be the higher exercise intensity reported by Cooper et al. (2018) than in the present study. Furthermore, the enhanced cognitive function reported by Williams et al. (2020) in low-fit adolescents when not undertaking exercise, was not reflected in the current study. A potential explanation for not replicating these findings could be that on average, overall fitness was higher for adolescents in the present study when compared with the overall average fitness reported by Williams et al. (2020); and, the difference between fitness for the low and high fit groups was smaller for the present study than previously reported (Williams et al., 2020). The current study presents the novel finding that games-based PE lessons improve cognitive function in high-fit adolescent. Also highlighting that the exercise protocol and individual participant characteristics influence the cognitive response and should be considered in future research.

Supporting the concept that the intensity of physical activity is important for the subsequent cognitive effects, a novel finding of the present study is that the acute cognitive response to a games-based PE lesson is enhanced for those adolescents who spent more time

undertaking MVPA during their PE lesson. Specifically, adolescents with high MVPA during the PE lesson demonstrated improved working memory immediately post-PE lesson; working memory was also enhanced 45-min post-PE lesson. The absence of collinearity between fitness and MVPA amongst participants in the present study, when combined with the positive effect of MVPA on working memory, suggests MVPA enhances acute cognitive function, independent of fitness. An explanation for these findings could be the potential influence of physical activity intensity on functional connectivity across brain regions, primarily those involved in memory and executive function (Moore et al., 2021); resultantly, the efficiency of evaluating the stimulus is increased (Chang et al., 2013). The findings from previous studies investigating the role of physical activity intensity on cognitive function are equivocal, with positive (Syväoja et al., 2013; Lee et al., 2014), inconsistent (Aadland et al., 2017), and negative (Cadenas-Sanchez et al., 2020; Ludyga et al., 2020; Williams et al., 2022) results. The discrepancy between our findings and those previously reported could be attributed to methodological differences, such as utilising self-report measures of physical activity (Syväoja et al., 2013; Aadland et al., 2017); or, the assessment of habitual physical activity intensity (Lee et al., 2014; Cadenas-Sanchez et al., 2020; Williams et al., 2022). Whereas, due to the dynamic relationship between exercise and circulating neurotrophic factors that enhance cognitive function (Cho et al., 2012), the present study investigated the impact of physical activity intensity on cognitive function immediately following a bout of physical activity. Therefore, to the authors' knowledge, our study is the first to examine the effect of device-measured intensity during a single bout of physical activity on acute cognitive function in adolescents, demonstrating that physical activity behaviour impacts working memory in adolescents.

The present study provides valuable insight into the activity patterns during 60 min single-gender, games-based PE lessons. Overall, across the four lessons observed, MVPA was undertaken for 67 ± 14% (40 ± 8 min) of the timetabled lesson time (60 min). Therefore, the recommended minimum 50% of PE lesson time spent in MVPA was exceeded (Association for Physical Education, 2020). Interestingly, MVPA time did not differ between high and low fit adolescents, suggesting that MVPA time during a PE lesson is independent of fitness. Whilst average MVPA time exceeded 50%, time spent in MVPA ranged from 23% in the least active to 90% in the most active adolescents. Consequently, the opportunity for PE to allow all students meet the 60 min of MVPA per day recommendation was not maximised and future work should explore how PE can be modified to increase the amount of MVPA time for the least active students. The MVPA time reported in the present study is higher than the 48.6% (41.3–55.9%) of lesson time previously reported for adolescent PE lessons by Hollis et al. (2017) in their systematic review and meta-analysis. It has previously been stated that MVPA time varies according to the type of activity students engaged in, with team invasion game lessons (e.g., basketball and football) eliciting higher MVPA time than dance, gymnastics, or individual direct competition lessons (Fairclough and Stratton, 2005). However, the MVPA time in the present study is higher than that reported by Fairclough and Stratton (2005) for team invasion game lessons (46%). The higher MVPA reported in the present study could be a result of changes in PE over time and/or the recommendation by the Association for Physical Education (2020) to increase MVPA time in lesson; or, methodological inconsistencies, including the use of observational methods to monitor MVPA time in previous work (Fairclough and Stratton, 2005). Whilst the present study provides a novel contribution to the understanding of MVPA during PE lessons using device-based measures of activity, future studies should examine device measured MVPA in PE lessons across all domains of the national curriculum.

Whilst the present study provides novel insight regarding the effects of curriculum PE lessons on subsequent cognitive function in adolescents, it is not without limitations. Firstly, the present study only recruited participants from a single school year (UK year 8), and given the changes in physical activity and fitness that occur across adolescence, the influence of the PE lesson on cognitive function might be different across stages of adolescence. Additionally, as the present study observed football PE lessons at a single school, the generalisability is limited. Future work should observe PE lessons across several secondary schools to better reflect PE nationally. Moreover, future work across multiple secondary schools would permit further exploration of fitness and MVPA as continuous variables, rather than categorical variables as used in the present study. Furthermore, whilst a games-based PE lesson is a domain of the national curriculum for PE in the United Kingdom (team direct competition), the cognitive response to a PE lesson was not assessed across the remaining domains of the national curriculum; and it cannot be assumed that the responses to all types of PE would be the same. Therefore, future work should explore the influence of all domains of the national curriculum for PE on cognitive function, across all stages of adolescence. Likewise, the examination of MVPA time and exercise intensity was limited to a games-based activity lesson; MVPA and the intensity for all domains of PE lessons should be established in future works.

Conclusion

In summary, the present study highlights that the acute cognitive responses to a games based-PE lesson are moderated by physical activity intensity, whereby adolescents who completed more MVPA during the PE lesson experienced greater cognitive benefits. The findings of the present study would suggest that, if physical activity intensity during PE lessons is high, those lessons will enhance subsequent cognition and ultimately contribute to enhancing academic achievement. Furthermore, the acute cognitive response to a games based-PE lesson is moderated by fitness, whereby high-fit adolescents experienced improved cognitive function compared to their lower-fit peers. Finally, the present study contributes to the growing body of evidence that high fit adolescents demonstrate superior cognition than their lower fit counterparts; highlighting the importance of interventions aimed at improving fitness in this population.

Data availability statement

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

Ethics statement

This study was approved by Nottingham Trent University School of Science and Technology Human Invasive Ethics Committee.

Author contributions

LG, KD, RW, and SC contributed to the conception and design of the study. LG, KD, RW, RB, CS, JM, and SC contributed to data collection. LG and SC performed the statistical analysis. LG wrote the first draft of the manuscript. All authors contributed to the manuscript revision, read, and approved the submitted version.

Acknowledgments

The authors would like to thank the participants and teachers at the secondary school involved for their time and effort 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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aadland, K. N., Moe, V. F., Aadland, E., Anderssen, S. A., Resaland, G. K., and Ommundsen, Y. (2017). Relationship between physical activity, sedentary time, aerobic fitness, motor skills and executive function and academic performance in children. *Mental Health and Physical Activity* 12, 10–18. doi: 10.1016/j.mhpa.2017.01.001

American College of Sports Medicine. (2017). *ACSM's guidelines for exercise testing and prescription* (*11th ed.*). Philadelphia: Lippincott Williams & Wilkins.

Association for Physical Education. (2020). Health position paper. Available at: https://www.afpe.org.uk/physical-education/afpe-2020-health-position-paper/

Bailey, R. C., Olson, J. O. D. I., Pepper, S. L., Porszasz, J. A. N. O. S., Barstow, T. J., and Cooper, D. M. (1995). The level and tempo of children's physical activities: an observational study. *Med. Sci. Sports Exerc.* 27, 1033–1041. doi: 10.1249/00005768-199507000-00012

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Dev. Rev.* 30, 331–351. doi: 10.1016/j.dr.2010.08.001

Budde, H., Voelcker-Rehage, C., Pietrassyk-Kendziorra, S., Machado, S., Ribeiro, P., and Arafat, A. M. (2010). Steroid hormones in the saliva of adolescents after different exercise intensities and their influence on working memory in a school setting. *Psychoneuroendocrinology* 35, 382–391. doi: 10.1016/j.psyneuen.2009.07.015

Cadenas-Sanchez, C., Migueles, J. H., Esteban-Cornejo, I., Mora-Gonzalez, J., Henriksson, P., Rodriquez-Ayllon, M., et al. (2020). Fitness, physical activity, and academic achievement in overweight/obese children. *J. Sports Sci.* 38, 731–740. doi: 10.1080/02640414.2020.1729516

Chang, Y.-K., Huang, C.-J., Chen, K.-F., and Hung, T.-M. (2013). Physical activity and working memory in healthy older adults: an ERP study. *Psychophysiology* 50, 1174–1182. doi: 10.1111/psyp.12089

Cheung, P. (2019). School-based physical activity opportunities in PE lessons and after-school hours: are they associated with children's daily physical activity? *Eur. Phys. Educ. Rev.* 25, 65–75. doi: 10.1177/1356336X17705274

Cho, H-C., Kim, J., Kim, S., Son, Y. H., Lee, N., and Jong, S. H. (2012). The concentrations of serum, plasma, and platelet BDNF are increased by treadmill VO2max performance in healthy college men. *Neurosci. Lett.*, 519, 78–83. doi:10.1016/j.neulet.2012.05.025

Cole, T. J., Bellizzi, M. C., Flegal, K. M., and Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *Br. Med. J.* 320, 1240–1243. doi: 10.1136/bmj.320.7244.1240

Cooper, S. B., Bandelow, S., Nute, M. L., Dring, K. J., Stannard, R. L., Morris, J. G., et al. (2016). Sprint-based exercise and cognitive function in adolescents. *Prev. Med. Rep.* 4, 155–161. doi: 10.1016/j.pmedr.2016.06.004

Cooper, S. B., Bandelow, S., Nute, M. L., Morris, J. G., and Nevill, M. E. (2012). The effects of a mid-morning bout of exercise on adolescents' cognitive function. *Ment. Health Phys. Act.* 5, 183–190. doi: 10.1016/j.mhpa.2012.10.002

Cooper, S. B., Bandelow, S., Nute, M. L., Morris, J. G., and Nevill, M. E. (2015). Breakfast glycaemic index and exercise: combined effects on adolescents' cognition. *Physiol. Behav.* 139, 104–111. doi: 10.1016/j.physbeh.2014.11.024

Cooper, S. B., Dring, K. J., Morris, J. G., Sunderland, C., Bandelow, S., and Nevill, M. E. (2018). High intensity intermittent games-based activity and adolescents' cognition: moderating effect of physical fitness. *BMC Public Health* 18, 603–616. doi: 10.1186/s12889-018-5514-6

Crova, C., Struzzolino, I., Marchetti, R., Masci, I., Vannozzi, G., Forte, R., et al. (2014). Cognitively challenging physical activity benefits executive function in overweight children. *J. Sports Sci.* 32, 201–211. doi: 10.1080/02640414.2013.828849

Department for Education. (2013). Physical education programmes of study: key stages 3 and 4. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/239086/SECONDARY_national_curriculum_-_Physical_education.pdf

Dring, K. J., Cooper, S. B., Morris, J. G., Sunderland, C., Foulds, G. A., Pockley, A. G., et al. (2018). Cytokine, glycemic, and insulinemic responses to an acute bout of games-based activity in adolescents. *Scand. J. Med. Sci. Sports* 29, 597–605. doi: 10.1111/sms.13378

Esteban-Cornejo, I., Tejero-Gonzalez, C. M., Sallis, J. F., and Veiga, O. L. (2015). Physical activity and cognition in adolescents: a systematic review. *J. Sci. Med. Sport* 18, 534–539. doi: 10.1016/j.jsams.2014.07.007

Fairclough, S., and Stratton, G. (2005). Physical activity levels in middle and high school physical education: a review. *Pediatr. Exerc. Sci.* 17, 217–236. doi: 10.1016/j.jsams.2014.07.007

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Garcia-Hermoso, A., Ramírez-Vélez, R., Lubans, D. R., and Izquierdo, M. (2021). Effects of physical education interventions on cognition and academic performance outcomes in children and adolescents: a systematic review and meta-analysis. *Br. J. Sports Med.* 55, 1224–1232. doi: 10.1136/bjsports-2021-104112

Hatch, L. M., Williams, R. A., Dring, K. J., Sunderland, C., Nevill, M. E., Sarkar, M., et al. (2021). The daily mile: acute effects on children's cognitive function and factors affecting their enjoyment. *Psychol. Sport Exerc.* 57:102047. doi: 10.1016/j.psychsport.2021.102047

Haverkamp, B. F., Wiersma, R., Vertessen, K., van Ewijk, H., Oosterlaan, J., and Hartman, E. (2020). Effects of physical activity interventions on cognitive outcomes and academic performance in adolescents and young adults: A meta-analysis. *J. Sports Sci.* 38, 2637–2660. doi: 10.1080/02640414.2020.1794763

Hills, A. P., Dengel, D. R., and Lubans, D. R. (2015). Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog. Cardiovasc. Dis.* 57, 368–374. doi: 10.1016/j.pcad.2014.09.010

Hollis, J. L., Sutherland, R., Williams, A. J., Campbell, E., Nathan, N., Wolfenden, L., et al. (2017). A systematic review and meta-analysis of moderate-to-vigorous physical activity levels in secondary school physical education lessons. *International Journal of Behavioural Nutrition* 14, 52–77. doi: 10.1186/s12966-017-0504-0

Howe, C. A., Freedson, P. S., Feldman, H. A., and Osganian, S. K. (2010). Energy expenditure and enjoyment of common children's games in a simulated free-play environment. *J. Pediatr.* 157, 936–942.e2. doi: 10.1016/j.jpeds.2010.06.041

Lee, T. M. C., Wong, M. L., Lau, B. W.-M., Lee, J. C.-D., Yau, S.-Y., and So, K.-F. (2014). Aerobic exercise interacts with neurotrophic factors to predict cognitive functioning in adolescents. *Psychoneuroendocrinology* 39, 214–224. doi: 10.1016/j.psyneuen.2013.09.019

Ludyga, S., Gerber, M., Pühse, U., Looser, V. N., and Kamijo, K. (2020). Systematic review and meta-analysis investigating moderators of long-term effects of exercise on cognition in healthy individuals. *Nat. Hum. Behav.* 4, 603–612. doi: 10.1038/s41562-020-0851-8

Lyyra, N., Heikinaro-Johansson, P., and Lyyra, M. (2017). Exploring in-class physical activity levels during physical education lessons in Finland. *Journal of Physical Education and Sport* 17, 815–820. doi: 10.7752/jpes.2017.02124

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., and Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cogn. Psychol.* 41, 49–100. doi: 10.1006/cogp.1999.0734

Moore, D., Jung, M., Hillman, C. H., Kang, M., and Loprinzi, P. D. (2021). Interrelationship between exercise, functional connectivity, and cognition among healthy adults: a systematic review. *Psychophysiology* 59:e14014. doi: 10.1111/psyp.14014

Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D. G., Cameron, N., et al. (2015). Enhancing a somatic maturity prediction model. *Med. Sci. Sports Exerc.* 47, 1755–1764. doi: 10.1249/mss.0000000000000588

Mooses, K., and Pihu, M., Riso, E-M., Hannus, A., Kaasik, P., and Kull, M. (2017). Physical education increases daily moderate to vigorous physical activity and reduces sedentary time. *J. Sch. Health*, 87, 602–607. doi:10.1111/josh.12530

National Statistics. (2021). School workforce in England. Available at: https://www.gov.uk/government/collections/statistics-school-workforce

Pirrie, A. M., and Lodewyk, K. R. (2012). Investigating links between moderate-to-vigorous physical activity and cognitive performance in elementary school students. *Ment. Health Phys. Act.* 5, 93–98. doi: 10.1016/j.mhpa.2012.04.001

Ramsbottom, R., Brewer, J., and Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *Br. J. Sports Med.* 22, 141–144. doi: 10.1136/bjsm.22.4.141

Randers, M. B., Nielsen, J. J., Bangsbo, J., and Krustrup, P. (2014). Physiological response and activity profile in recreational small-sided football: no effect of the number of players. *Scandinavian Journal of Medicine and Science in Sports* 24, 130–137. doi: 10.1111/sms.12232

Rasberry, C. N., Lee, S. M., Robin, L., Laris, B. A., Russell, L. A., Coyle, K. K., et al. (2011). The association between school-based physical activity, including physical education, and academic performance: a systematic review of the literature. *Prev. Med.* 52, S10–S20. doi: 10.1016/j.ypmed.2011.01.027

Romeo, R. D., and McEwen, B. S. (2006). Stress and the adolescent brain. *Ann. N. Y. Acad. Sci.* 1094, 202–214. doi: 10.1196/annals.1376.022

Rowlands, A. V., Pilgrim, E. L., and Eston, R. G. (2008). Patterns of habitual activity across weekdays and weekend days in 9–11-year-old children. *Prev. Med.* 46, 317–324. doi: 10.1016/j.ypmed.2007.11.004

Schmitt, J. A. J., Benton, D., and Kallus, K. W. (2005). General methodological considerations for the assessment of nutritional influences on human cognitive functions. *Eur. J. Nutr.* 44, 459–464. doi: 10.1007/s00394-005-0585-4

Slingerland, M., Oomen, J., and Borghouts, L. (2011). Physical activity levels during Dutch primary and secondary school physical education. *Eur. J. Sport Sci.* 11, 249–257. doi: 10.1080/17461391.2010.506661

Slingerland, M., Borghouts, L. B., and Hesselink, M. K. C. (2012). Physical activity energy expenditure in Dutch adolescents: contribution of active transport to school, physical education, and leisure time activities. *J. Sch. Health* 82, 225–232. doi: 10.1111/j.1746-1561.2012.00691.x

Sneck, S., Viholainen, H., Syväoja, H., Kankaapää, A., and Hakonen, H., Poikkeus, A-M., Poikkeus, A.M., and Tammelin, T. (2019). Effects of school-based physical activity on mathematics performance in children: a systematic review. *International Journal of Behavioural Nutrition and Physical Activity*, 16, 109–123. doi:10.1186/s12966-019-0866-6

Sport England. (2021). Active lives children and young people report. Available at: https://www.sportengland.org/know-your-audience/data/active-lives

Sternberg, S. (1969). Memory-scanning: mental processes revealed by reaction-time experiments. *Am. Sci.* 57, 421–457. http://www.jstor.org/stable/27828738.

Syväoja, H., Kantomaa, M., Ahonen, T., Hakonen, H., Kankaanpää, A., and Tammelin, T. (2013). Physical activity, sedentary behaviour, and academic performance in Finnish children. *Med. Sci. Sports Exerc.* 45, 2098–2104. doi: 10.1249/MSS.0b013e318296d7b8

UK Chief Medical Officers. (2019). UK chief medical officers' physical activity guidelines. (2019). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/832868/uk-chief-medical-officers-physical-activity-guidelines.pdf

van den Berg, V., Saliasi, E., de Goot, R. H. M., Jolles, J., Chinapaw, M. J. M., and Singh, A. S. (2016). Physical activity in the school setting: cognitive performance is not affected by three different types of acute exercise. *Front. Psychol.* 7, 723–731. doi: 10.3389/fpsyg.2016.00723

van Slujis, E. M. F., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., et al. (2021). Physical activity behaviours in adolescence: current evidence and opportunities for intervention. *Lancet* 398, 429–442. doi: 10.1016/S0140-6736(21)01259-9

Wallace, L., Buchan, D., and Sculthorpe, N. (2020). A comparison of activity levels of girls in single-gender and mixed-gender physical education. *Eur. Phys. Educ. Rev.* 26, 231–240. doi: 10.1177/1356336X19849456

Westerstahl, M., Barnekow-Bergkvist, M., and Jansson, E. (2005). Low physical activity among adolescents in practical education. *Scandinavian Journal of Medicine and Science in Sport* 15, 287–297. doi: 10.1111/j.1600-0838.2004.00420.x

Williams, R. A., Cooper, S. B., Dring, K. J., Hatch, L., Morris, J. G., Sun, F.-H., et al. (2022). Physical fitness, physical activity and adiposity: associations with risk factors for cardiometabolic disease and cognitive function across adolescence. *BMC Pediatrics* 22:75. doi: 10.1186/s12887-022-03118-3

Williams, R. A., Cooper, S. B., Dring, K. J., Hatch, L., Morris, J. G., Sunderland, C., et al. (2020). Effect of football activity and physical fitness on information processing, inhibitory control and working memory in adolescents. *BMC Public Health* 20, 1398–1314. doi: 10.1186/s12889-020-09484-w

Williams, R. A., Hatch, L., and Cooper, S. B. (2019). A review of factors affecting the acute exercise-cognition relationship in children and adolescents. *OBM Integrative and Complementary Medicine* 4:1. doi: 10.21926/obm.icm.1903049

Zhou, Y., and Wang, L. (2019). Correlates of physical activity of students in secondary school physical education: a systematic review of literature. *Bio Med Research International* 2019. doi: 10.1155/2019/4563484

frontiers | Frontiers in Psychology

TYPE Systematic Review
PUBLISHED 30 March 2023
DOI 10.3389/fpsyg.2023.1136900

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University, Japan

REVIEWED BY
Laisa Liane Paineiras-Domingos,
Federal University of Bahia (UFBA), Brazil
Majed M. Alhumaid,
King Faisal University, Saudi Arabia

*CORRESPONDENCE
Yanru Lin
✉ 46145428@qq.com
Wei Gao
✉ 2499952260@qq.com

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

RECEIVED 03 January 2023
ACCEPTED 07 March 2023
PUBLISHED 30 March 2023

CITATION
Lin Y and Gao W (2023) The effects of physical exercise on anxiety symptoms of college students: A meta-analysis.
Front. Psychol. 14:1136900.
doi: 10.3389/fpsyg.2023.1136900

The effects of physical exercise on anxiety symptoms of college students: A meta-analysis

Yanru Lin* and Wei Gao*

School of Physical Education and Sport Science, Fujian Normal University, Fuzhou, China

Objective: This study aimed to evaluate the effect of an exercise intervention on improving and alleviating anxiety symptoms in college students with a meta-analytical approach.

Methods: Several databases (e.g., PubMed, Embase, and the Cochrane Library) were used to search for randomized controlled trials (in short, RCTs) on interventions for physical exercise or aerobic exercise in college students with anxiety symptoms. Stata software, version 16.0, was applied sequentially for traditional meta-analysis, subgroup analysis, and publication bias analysis.

Results: A total of nine papers were included. The total literature effect [SMD = −0.55, 95% CI = −0.76 to −0.35, Z = 5.38 (P < 0.001)] indicated that physical activity had a significant effect on alleviating anxiety. Subgroup analysis also showed that exercise interventions using aerobic exercise or yoga were effective in relieving anxiety (SMD = −0.39, 95% CI = −0.74 to −0.04; SMD = −0.76, 95% CI = −1.14 to −0.39).

Conclusion: Physical activity interventions were shown to have a positive effect on alleviating anxiety in college students. Aerobic exercise was found to be the optimal mode.

KEYWORDS

aerobic exercise, type of exercise, exercise intensity, psychology, exercise time

1. Introduction

Anxiety is composed of complex emotional states, such as tension, worry, and uneasiness, that arise from upcoming situations that could pose a danger or threat (Shihua et al., 2016). If anxiety states become severe, they have the potential to develop into undesirable symptoms and eventually become anxiety disorders (Menghuan and Qingqi, 2021). An anxiety disorder is mainly characterized by anxious emotional experiences, which are manifested as fear, restlessness, etc., that can damage the original healthy life and greatly reduce the effect of disease treatment.

Anxiety is becoming a pervasive public health problem that has been associated with unhealthy behaviors, such as lack of physical activity, smoking, and poor diet, subsequently leading to an increased risk of health problems, even among healthy individuals (Bonnet et al., 2005). College students are among the most affected groups of people due to their potentially having to manage their stress, anger, or frustration on their own for the first

time (Liu et al., 2022). They must not only face various problems in their studies, work, and feelings but also solve problems of interpersonal communication. Without guidance and support, college students could feel anxious and pressured (Guo et al., 2018). A substantial proportion of anxious college students have sub-health problems due to unhealthy living habits, such as drinking, smoking, staying up late and eating irregularly. During the outbreak of the novel coronavirus, the mental health problems of college students have been reported as becoming more serious, and the physical inactivity caused by the lockdown has caused student's mental status to become even worse (Rogowska et al., 2020; Xiang et al., 2020).

When college students encounter mental health problems, they tend to solve them on their own, and professional psychological counseling treatment or medication is their last option (Fortney et al., 2016). According to previous studies, current treatments for anxiety disorders include pharmacotherapy with serotonin reuptake inhibitors and cognitive behavioral therapy (CBT) (Taylor et al., 2012), with medication being the most common treatment for anxiety (Barlow, 2004). The effectiveness of medication has been confirmed in treating anxiety disorders, but medication's side effects are significant. Treatment with medication also has the possibility of relapse after stopping the medication, so it might not be a long-term solution for some patients (Broocks et al., 1998). At the same time, some scholars have demonstrated that exercise can bring many physiological changes that could improve emotional status and reduce stress and anxiety levels (Warburton et al., 2006; Wipfli et al., 2008; Carter et al., 2021). Exercise interventions have become a complementary and alternative method for relieving anxiety. Mind-body exercises are increasingly used as adjunctive and alternative therapies to manage psychological stress. Some studies have also suggested exercise as a possible option for treating anxiety symptoms and anxiety disorders, playing a dual role in adjunctive therapy (pharmacotherapy or psychotherapy) and exercise (Paluska and Schwenk, 2000; Hovland et al., 2013; Mohamed and Alawna, 2020; Wang et al., 2020). However, exercise interventions can only be used as an auxiliary means (in conjunction with other treatments) and cannot be used as the only means to treat psychological disorders.

Exercise interventions are planned and organized with the goal of improving physical fitness and enhancing positive mood. For studies aimed at determining the effects of exercise on mental health, most have preferred a form of exercise that can benefit cardiopulmonary regulation, such as aerobic exercise (Broman-Fulks et al., 2004; Abd El-Kade and Al-Jiffri, 2016). Other forms of exercise, such as yoga and tai chi, have also been found to be effective in improving anxiety (Berger and Owen, 1992; Huston and McFarlane, 2016).

For people with anxiety disorders, exercise can be a treatment option that is promising, affordable and accessible. Numerous observational studies have demonstrated that exercise, especially aerobic exercise, is inversely associated with anxiety symptoms (Larun et al., 2006; Wegner et al., 2014; LeBouthillier and Asmundson, 2015; Stonerock et al., 2015). Both qualitative and quantitative studies have illustrated the effects of aerobic exercise on anxiety symptoms. For example, people who perform physical activity regularly can have higher self-confidence and less anxiety and depression. There have also been studies linking aerobic exercise to cognitive abilities that have confirmed that aerobic exercise can improve cognitive performance (Masley et al., 2009; Stern et al., 2019). Aerobic exercise is effective for people's cognitive behavior, subjective wellbeing and mental health, and people's cognitive control and attention are also enhanced after aerobic exercise (White et al., 2017; Pontifex et al., 2019). However, excessive, inappropriate movement can still cause some damage to the body and increase the risk of anxiety. At the same time, few studies have compared the effectiveness of aerobic exercise with that of other exercises in improving anxiety symptoms. Therefore, the main purpose of this study was to explore the efficacy of different modes of exercise as a treatment regimen for anxiety disorders in college students. Additionally, the relationships of different exercise intensities, exercise times and exercise types with anxiety in college students were also determined.

2. Materials and methods

2.1. Literature search strategies

The literature search used the Boolean logic algorithm to obtain subject words and free words, covering databases including China national knowledge infrastructure (CNKI), Wanfang, Weipu, PubMed, Embase, Cochrane Library, and Web of Science for articles published up to January 19, 2022. The search strategy was generated as follows: [(Anxiety OR Angst OR social anxiety OR Anxieties OR anxiety social OR Hypervigilance OR Nervousness OR Anxiousness) AND (Exercise OR physical activity OR Exercises OR activities physical OR activity physical OR physical activities) AND (randomized controlled trial OR randomized OR placebo)].

2.2. Inclusion and exclusion criteria of literature

The literature screening applied population, intervention, comparison, outcome and study design (PICOS) strategies, which have been widely used in evidence-based medicine or practice. It is necessary to specifically identify the acronyms for all or some of the elements in clinical trials (Akobeng, 2005). Specifically, P refers to the research object (participants), I the intervention method (intervention), C the control group (comparison), O the outcome index (out-come), and S the study design. In the current study, the literature inclusion criteria were: (1) the research target was college students; (2) the intervention methods were aerobic exercise, yoga, etc.; and (3) the studies were randomized, controlled experiments. The exclusion criteria were gray literature and review literature.

2.3. Literature quality evaluation

This study used the he Physiotherapy Evidence Database (or "PEDro" for short) scale to evaluate the quality of RCTs (Verhagen et al., 1998). Literature quality scoring was conducted independently by two authors. If there was any disagreement, a third author was consulted until a unanimous decision was made.

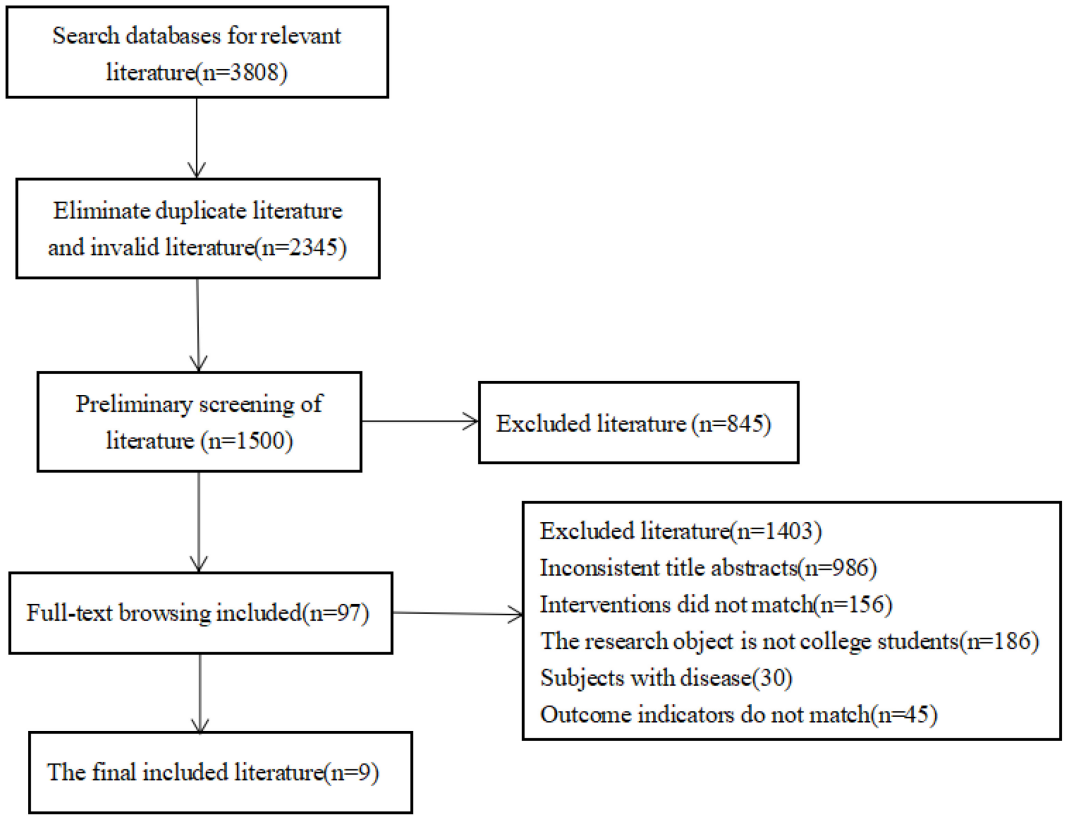


FIGURE 1
Literature screening flowchart.

2.4. Statistical methods

The included literature was analyzed using Stata software, version 16.0. The outcome measures in the included literature were continuous variables, which were combined with the effect amounts. The effect indicators were calculated using the standard mean difference (SMD) and 95% CI calculation method. The heterogeneity between the studies was statistically analyzed by I^2. If $I^2 > 50\%$, the heterogeneity was analyzed by a random effects model. Otherwise ($I^2 < 50\%$), a fixed-effects model was applied. Stata software, version 16.0, was used for bias analysis and subgroup analysis.

3. Results

3.1. Included meta-analyses

The PRISMA flowchart in Figure 1 depicts the specific literature search process. A total of 3,808 relevant documents were obtained through computer searches, and 2,345 were retained after removing duplications. During the screening process, 854 articles were excluded after reading the titles and abstracts. Nine documents were finally included after eliminating interventions that did not include exercises or physical activity, targeted non-university students, or had inconsistent outcome indicators (n = 1,491 removed).

3.2. Basic features of the included literature

Nine studies and 483 participants were included in the current study, including four aerobic exercise interventions, two yoga interventions, one intervention applying aerobic exercise combined with resistance training, and two other forms. All of the studies included were written in English. Table 1 demonstrates the basic features of these studies, including the intensity and frequency of exercise and the outcome indicators. Specifically, three studies used social anxiety as the outcome indicator, and one used heart rate.

3.3. Inclusion in literature quality evaluation

For the literature quality evaluation, all of the included literature achieved the criteria of "random allocation," "intention-to-treat analysis (ITT) intentional treatment analysis," "statistical analysis between groups," and "point measurement and variation value measurement." For the PEDro scoring, 1 article received 5 points, 7 received 6 points, and 1 received 8 points. The average PEDro score of the included literature was approximately 6 points. The overall methodological quality was adequate (Table 2).

TABLE 1 Basic features of the included literature.

Study	Experimental interventions	Sample size	Exercise intensity	Duration	Frequency	Time	Outcomes
Anshel, 1996	Aerobics exercise	60	High	10 weeks	1 time/week	30 min	Heart rate
Albracht-Schulte and Robert-McComb, 2018	Yoga	40	Medium	4 weeks	2 times/week	30 min	STAI rating
Jazaieri et al., 2012	Mindfulness intervention	56	Low	12 weeks	3 times/week	70 min	SIAS rating
Broman-Fulks and Storey, 2008	Aerobics exercise	24	Medium	2 weeks	3 times/week	20 min	ASI-R score
Blough and Loprinzi, 2018	Aerobics exercise	57	High	24 weeks	3 times/week	50 min	PHQ-9
Herring et al., 2012	Aerobic exercise, resistance	30	High	6 weeks	2 times/week	40 min	PSWQ score
Smits et al., 2008	Aerobic exercise	60	High	3 weeks	2 times/week	20 min	ASI, BAI
Tekur et al., 2012	Yoga	80	Medium	1 week	5 times/week	60 min	STAI rating
Tsai et al., 2003	Tai Chi	76	High	12 weeks	3 times/week	50 min	STAI rating

STAI score, Status-Trait Anxiety Scale; SIAS score, Social Anxiety Scale; ASI-R score, anxiety sensitivity index revision; PHQ-9 score, depression screening scale; NIMH-SR, The National Institute of Mental Health Self-Rating Scale; ASI, anxiety sensitivity index; BAI, beck anxiety inventory.

TABLE 2 Methodological quality assessment of the included literature using the tool PEDro scale.

Study	Random allocation	Distribute hide	Baseline similar	Subjects were blinded	Baseline similar	Result blind	With-drawal rate < 15%	ITT intentional treatment analysis	Statistical analysis between groups	Point measurements and variance magnitudes	Total
Anshel, 1996	1	0	1	0	0	0	1	1	1	1	6
Albracht-Schulte and Robert-McComb, 2018	1	0	1	0	0	0	0	1	1	1	5
Jazaieri et al., 2012	1	0	1	0	0	0	1	1	1	1	6
Broman-Fulks and Storey, 2008	1	0	1	0	0	0	1	1	1	1	6
Blough and Loprinzi, 2018	1	0	1	0	0	0	1	1	1	1	6
Herring et al., 2012	1	0	1	0	0	0	1	1	1	1	6
Smits et al., 2008	1	0	1	0	0	0	1	1	1	1	6
Tekur et al., 2012	1	1	1	0	0	1	1	1	1	1	8
Tsai et al., 2003	1	1	1	0	0	0	1	1	1	1	6

3.4. Meta-analysis results

Forest maps were used for heterogeneity testing. The results showed that there was heterogeneity between the studies ($I^2 = 63.5\%$, $P < 0.05$); thus, a random effects model was adopted for the combined effect size of SMD. The combined effect size test was statistically significant ($Z = 5.38$ $p < 0.001$). The total SMD = −0.55, and the 95% CI = −0.76 to −0.35, as shown in Figure 2.

3.5. Publication bias

Egger regression analysis was used to test for the publication bias of the nine included articles. The results of Egger's test–$t = 0.67$, 95% CI = −4.69 to 8.34, $P = 0.52$–demonstrated that there was no publication bias in the included literature (Figure 3).

3.6. Subgroup analysis

Subgroup analysis was conducted according to exercise type, exercise frequency, exercise duration, and exercise intensity. In terms of the exercise type, studies were divided into four different groups for analysis: aerobic exercise (included four articles), resistance exercise (2), yoga (1) and other exercises (2). Aerobic exercise, yoga, and other types of interventions were statistically significant ($P < 0.05$) for improving anxiety symptoms, while resistance exercise was not statistically significant

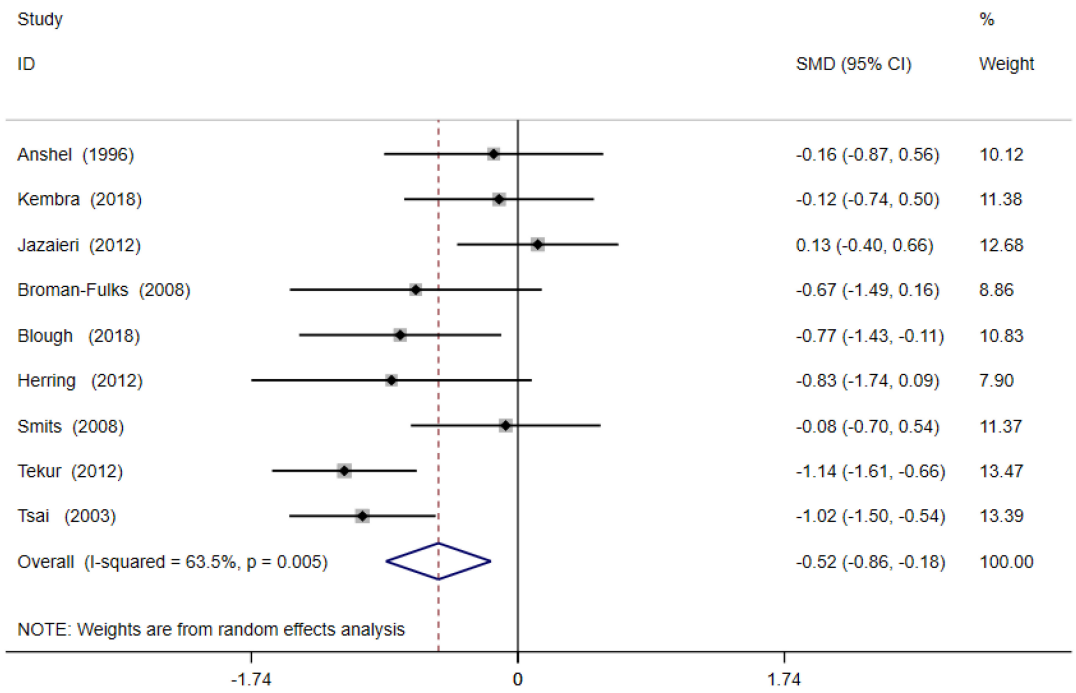


FIGURE 2
Forest diagram of physical activity and anxiety symptoms.

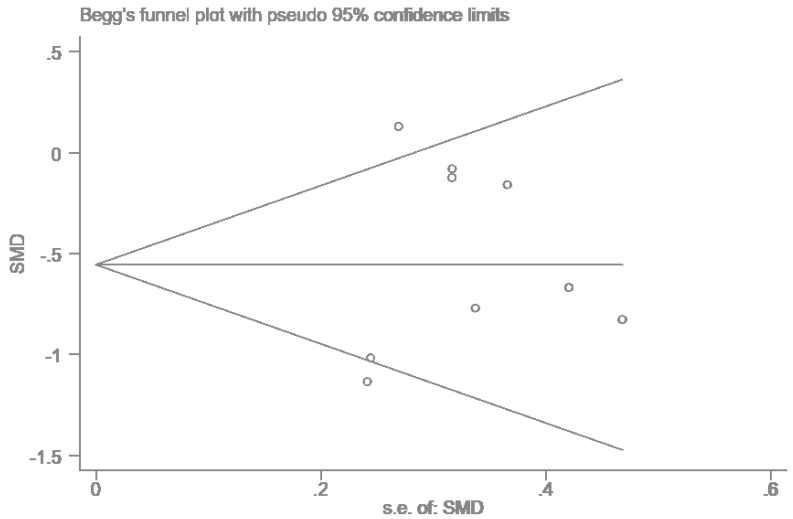


FIGURE 3
Publication bias graph.

($P > 0.05$). In terms of exercise frequency, the included studies were divided into three groups: high frequency (≥5 times/week) (included one article), moderate frequency (3–4 times/week) (4) and low frequency (1–2 times/week) (4). Both high frequency (SMD = −1.14, 95% CI = −1.61 to −0.66) and moderate frequency (SMD = −0.57, 95% CI = −0.87 to −0.28) were found to be statistically significant for improving anxiety symptoms. Compared with the control group, the effects of the interventions with high and moderate exercise frequencies were statistically significant ($P < 0.001$), but the low exercise frequency was not ($P > 0.05$). The specific results are shown in Table 3.

In terms of duration, the included studies were divided into three groups: short duration (≤8 weeks; 5 articles included), medium duration (8–14 weeks; three articles included) and long duration (>14 weeks; one article included). Compared with the control group, the medium and long durations were found to be statistically significant for anxiety ($P < 0.001$), while the short duration was not ($P > 0.05$). In terms of exercise intensity, the included studies were divided into three groups: high intensity

TABLE 3 Summary of meta-analysis results.

Moderator	Subgroup	SMD	95% CI	Subgroup compared with control group		Subgroup comparison	
				Z	*P*	I^2	*P*
Type of exercise	Aerobics exercise	−0.39	−0.74 to −0.04	2.22	0.027	2.1%	0.382
	Resistance exercise	−0.83	−1.74 to 0.09	1.77	0.077	–	–
	yoga	−0.76	−1.14 to −0.39	3.98	0.000	84.5%	0.011
	Other	−0.50	−0.85 to −0.14	2.76	0.006	90%	0.002
Exercise frequency	High (≥5 times/week)	−1.14	−1.61 to −0.66	4.70	0.000	–	–
	Medium (3–4 times/week)	−0.57	−0.87 to −0.28	3.84	0.000	71%	0.015
	Low	−0.22	−0.57 to 0.13	1.23	0.217	0.00%	0.573
Exercise duration	Short (≤8 weeks)	−0.29	−0.61 to 0.03	1.75	0.080	0.00%	0.563
	Medium (8–14 weeks)	−0.93	−1.32 to −0.54	4.71	0.000	50.0%	0.553
	Long (>14 weeks)	−0.57	−0.92 to −0.22	3.18	0.001	91.8%	0.000
Exercise intensity	High	−0.41	−0.76 to −0.05	2.26	0.024	14.1%	0.322
	Medium	−0.84	−1.12 to −0.57	5.90	0.000	59.0%	0.063
	Low	0.13	−0.40 to 0.66	0.48	0.629	–	–

(included four articles), moderate intensity (4) and low intensity (1). High-intensity exercise (SMD = −0.41, 95% CI = −0.76 to −0.05) and moderate exercise intensity (SMD = −0.84, 95% CI = −1.12 to −0.57) were found to be statistically significant for anxiety, but low exercise intensity was not (SMD = 0.13, 95% CI = −0.40 to 0.66). Compared with the control group, the effects of the interventions with high and moderate exercise intensity were statistically significant ($P < 0.05$), while low exercise intensity was not ($P > 0.05$). The findings revealed that exercise interventions with higher intensity or longer durations could be more effective for relieving anxiety symptoms.

4. Discussion

In this section, firstly we study the intervention effects of physical activity on anxiety. Then, the effect of different exercise intensities on anxiety will be discussed briefly.

4.1. Intervention effects of physical activity on anxiety

The results of this study showed that exercise interventions play a certain role in reducing the symptoms of psychological anxiety in college students. Exercise type, time, and frequency have differing effects on reducing the symptoms of anxiety. In the literature included within this study, most of the interventions consisted of aerobic exercise (Kramer et al., 2005; Marcos de Souza Moura et al., 2015; Yin et al., 2021; Brinsley et al., 2022). Aerobic exercise can be used as an adjunctive therapy to improve the physical health of people with anxiety disorders and has benefits in reducing anxiety symptoms (Bartley et al., 2013). It also helps to prevent heart disease and obesity (Bauman, 2004). With the continuous development of society and the variety of forms of exercise, intervention methods have also diversified, such as resistance training and yoga. The results demonstrated in Table 3 confirmed that, in the subgroup analysis of exercise type, in addition to resistance exercise, aerobic exercise, yoga and other exercise intervention types were statistically significant. Earlier studies have found that low or moderate resistance training might not have an effect on anxiety (Garwin et al., 1997; Focht and Koltyn, 1999). Conversely, high-intensity resistance training might be associated with an increase in state anxiety (Arent et al., 2005). The decrease in anxiety was not significant under resistance exercise (Hill et al., 2019), and resistance exercise was not statistically significant in relieving anxiety symptoms in this study. Aerobic exercise and other types of exercise have greater effects than yoga, indicating smaller group-to-group differences in the included literature.

Different exercise modes, exercise durations and exercise intensities have different effects on improving physical function and have effects on relieving state anxiety and anxiety (Rýzková et al., 2018; Margulis et al., 2021; Ji et al., 2022). A subgroup analysis of exercise frequency revealed that the frequency of exercise is also necessary for anxiety relief. Therefore, in this study, exercise frequency was divided into three levels for analysis to seek the best exercise effect (Russell, 2002; Broman-Fulks et al., 2018). Both the high-frequency exercise group and the medium-frequency exercise group were statistically significant, but the low-frequency exercise frequency was not statistically significant. A higher frequency of exercise in an anxious state can prompt patients to devote more time and energy to exercise so that some anxiety in life or work can be relieved and released during exercise. For anxious states, the need for more treatment options has been emphasized (Ezekowitz et al., 1995). The choice of non-pharmacological interventions can also promote the reduction of anxiety symptoms in college students, and exercise can effectively relieve anxiety symptoms (Carek et al., 2011). Currently, due to the increased psychological burden of learning pressure and social interaction, college students must alleviate their anxiety through a series of exercise interventions or auxiliary therapies (Beiter et al., 2015). Aerobic exercise, such as jogging, as the daily exercise of college students, is easy to popularize and apply in colleges and universities and can be used as an effective intervention measure to prevent

college students' anxiety, stress, and depression (Ibrahim et al., 2013; Stubbs et al., 2017). Exercise can reduce negative emotions and promote the transformation of these negative emotions into positive aspects.

4.2. The effect of different exercise intensities on anxiety

Exercise load is a concrete manifestation of exercise time and exercise intensity, and it is a factor that affects the outcome of an exercise. The results of the subgroup analysis showed that medium- and long-term exercise had certain regulatory effects on the intervention effect, and the 95% CI did not contain 0, confirming the significance. Short-term exercise did not have a good effect on awakening body function, and there was no significant difference between the groups. Short-term aerobic exercise has little effect on improving mood and anxiety. This subgroup analysis primarily reported the effect of moderate- or vigorous-intensity physical activity on anxiety, reflecting that a subjective, transient emotional state was also associated with a larger effect size of exercise. A study comparing the effects of swimming, fencing, body conditioning, and yoga classes found that only the yoga treatment group showed that short-term and long-term yoga exercise significantly reduced state anxiety (Berger and Owen, 1988). We also found large differences in exercise interventions due to the studies involving different exercise patterns, times, frequencies, and intensities. The differences in each subgroup were large in the analysis. From the overall subgroup analysis, the effects of lower intensity exercise, lower exercise frequency, and short exercise intervention cycles on anxiety were not statistically significant, and the 95% CI contained 0. The duration, frequency, and intensity of exercise had effects on the experimental intervention. In the process of relieving anxiety, it is not possible to rely solely on physical activity, and it should be used in conjunction with medication, psychological counseling, and psychotherapy to establish a good psychological state.

4.3. Limitations

This study had some limitations. First, the included study subjects were university students. Therefore, applying these findings to others in the same age group might be restricted, such as in young people who are already working or young women of childbearing age. Second, the limited number of included studies might have led to some degree of selection bias. Finally, this study included diverse indicators of outcome evaluation, and the heterogeneity test results were relatively large. Therefore, quality control standards for future clinical trials should be based on evidence-based medical standards.

5. Conclusion

In summary, aerobic exercise and yoga, as well as other types of exercise, can relieve anxious states. Moderate to high intensity, longer duration periods, aerobic exercise with a higher exercise frequency, and other types of exercise have significant effects on anxiety relief. The current study suggested incorporating appropriate exercise into the lives of people with anxiety symptoms for the significant benefits of alleviating anxiety and developing physical and mental health.

Data availability statement

The original contributions presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding authors.

Author contributions

YL was responsible for writing the manuscript. WG was responsible for data collection and analysis. Both authors contributed to the article and approved the submitted version.

Funding

This work was supported by the Fujian Social Science Planning Project in China (grant number: FJ2020B080).

Acknowledgments

We thank all authors for their encouragement and guidance throughout this project.

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

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1136900/full#supplementary-material

References

Abd El-Kade, S. M., and Al-Jiffri, O. H. (2016). Exercise alleviates depression related systemic inflammation in chronic obstructive pulmonary disease patients. *Afr. Health Sci.* 16, 1078–1088. doi: 10.4314/ahs.v16i4.25

Akobeng, A. K. (2005). Principles of evidence based medicine. *Arch. Dis. Child.* 90, 837–840. doi: 10.1136/adc.2005.071761

Albracht-Schulte, K., and Robert-McComb, J. (2018). The effects of yoga and quiet rest on subjective levels of anxiety and physiological correlates: A 2-way crossover randomized trial. *BMC Complement. Altern. Med.* 18:280. doi: 10.1186/s12906-018-2343-1

Anshel, M. H. (1996). Effect of chronic aerobic exercise and progressive relaxation on motor performance and affect following acute stress. *Behav. Med.* 21, 186–196. doi: 10.1080/08964289.1996.9933757

Arent, S. M., Landers, D. M., Matt, K. S., and Etnier, J. L. (2005). Dose-response and mechanistic issues in the resistance training and affect relationship. *J. Sport Exerc. Psychol.* 27, 92–110. doi: 10.1123/jsep.27.1.92

Barlow, D. H. (2004). *Anxiety and its disorders: The nature and treatment of anxiety and panic*. New York: Guilford press.

Bartley, C. A., Hay, M., and Bloch, M. H. (2013). Meta-analysis: Aerobic exercise for the treatment of anxiety disorders. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 45, 34–39. doi: 10.1016/j.pnpbp.2013.04.016

Bauman, A. E. (2004). Updating the evidence that physical activity is good for health: An epidemiological review 2000–2003. *J. Sci. Med. Sport* 7, 6–19. doi: 10.1016/S1440-2440(04)80273-1

Beiter, R., Nash, R., McCrady, M., Rhoades, D., Linscomb, M., Clarahan, M., et al. (2015). The prevalence and correlates of depression, anxiety, and stress in a sample of college students. *J. Affect. Disord.* 173, 90–96. doi: 10.1016/j.jad.2014.10.054

Berger, B. G., and Owen, D. R. (1988). Stress reduction and mood enhancement in four exercise modes: Swimming, body conditioning, hatha yoga, and fencing. *Res. Q. Exerc. Sport* 59, 148–159. doi: 10.1080/02701367.1988.10605493

Berger, B. G., and Owen, D. R. (1992). Mood alteration with yoga and swimming: Aerobic exercise may not be necessary. *Percept. Mot. Skills* 75(Suppl. 3), 1331–1343. doi: 10.2466/pms.1992.75.3f.1331

Blough, J., and Loprinzi, P. D. (2018). Experimentally investigating the joint effects of physical activity and sedentary behavior on depression and anxiety: A randomized controlled trial. *J. Affect. Disord.* 239, 258–268. doi: 10.1016/j.jad.2018.07.019

Bonnet, F., Irving, K., Terra, J. L., Nony, P., Berthezène, F., and Moulin, P. (2005). Anxiety and depression are associated with unhealthy lifestyle in patients at risk of cardiovascular disease. *Atherosclerosis* 178, 339–344. doi: 10.1016/j.atherosclerosis.2004.08.035

Brinsley, J., Smout, M., Girard, D., and Davison, K. (2022). Acute mood and cardiovascular responses to moderate intensity vinyasa yoga, static yin yoga and aerobic exercise in people with depression and/or anxiety disorders: A 5-arm randomised controlled trial. *Ment. Health Phys. Act.* 22:100450. doi: 10.1016/j.mhpa.2022.100450

Broman-Fulks, J. J., Abraham, C. M., Thomas, K., Canu, W. H., and Nieman, D. C. (2018). Anxiety sensitivity mediates the relationship between exercise frequency and anxiety and depression symptomology. *Stress Health* 34, 500–508. doi: 10.1002/smi.2810

Broman-Fulks, J. J., and Storey, K. M. (2008). Evaluation of a brief aerobic exercise intervention for high anxiety sensitivity. *Anxiety Stress Coping* 21, 117–128. doi: 10.1080/10615800701762675

Broman-Fulks, J. J., Berman, M. E., Rabian, B. A., and Webster, M. J. (2004). Effects of aerobic exercise on anxiety sensitivity. *Behav. Res. Ther.* 42, 125–136. doi: 10.1016/S0005-7967(03)00103-7

Broocks, A., Bandelow, B., Pekrun, G., George, A., Meyer, T., Bartmann, U., et al. (1998). Comparison of aerobic exercise, clomipramine, and placebo in the treatment of panic disorder. *Am. J. Psychiatry* 155, 603–609. doi: 10.1176/ajp.155.5.603

Carek, P. J., Laibstain, S. E., and Carek, S. M. (2011). Exercise for the treatment of depression and anxiety. *Int. J. Psychiatry Med.* 41, 15–28. doi: 10.2190/PM.41.1.c

Carter, T., Pascoe, M., Bastounis, A., Morres, I. D., Callaghan, P., and Parker, A. G. (2021). The effect of physical activity on anxiety in children and young people: A systematic review and meta-analysis. *J. Affect. Disord.* 285, 10–21. doi: 10.1016/j.jad.2021.02.026

Ezekowitz, M. D., James, K. E., Nazarian, S. M., Davenport, J., Broderick, J. P., Gupta, S. R., et al. (1995). Silent cerebral infarction in patients with nonrheumatic atrial fibrillation. *Circulation* 92, 2178–2182. doi: 10.1161/01

Focht, B. C., and Koltyn, K. F. (1999). Influences of resistance exercise of different intensities on state anxiety and blood pressure. *Med. Sci. Sports Exerc.* 31, 456–463. doi: 10.1097/00005768-199903000-00016

Fortney, J. C., Curran, G. M., Hunt, J. B., Cheney, A. M., Lu, L., Valenstein, M., et al. (2016). Prevalence of probable mental disorders and help-seeking behaviors among veteran and non-veteran community college students. *Gen. Hosp. Psychiatry* 38, 99–104. doi: 10.1016/j.genhosppsych.2015.09.007

Garwin, A. W., Koltyn, K. F., and Morgan, W. P. (1997). Influence of acute physical activity and relaxation on state anxiety and blood lactate in untrained college males. *Int. J. Sports Med.* 28, 470–476. doi: 10.1055/s-2007-972666

Guo, Y. U., Xu, M., Ji, M., Wei, Z., Zhang, J., Hu, Q., et al. (2018). The effect of Imaginary Working Qigong on the psychological well-being of college students: Study protocol for a randomized controlled trial. *Medicine* 97:e13043. doi: 10.1097/MD.0000000000013043

Herring, M. P., Jacob, M. L., Suveg, C., Dishman, R. K., and O'Connor, P. J. (2012). Feasibility of exercise training for the short-term treatment of generalized anxiety disorder: A randomized controlled trial. *Psychother. Psychosom.* 81, 21–28. doi: 10.1159/000327898

Hill, M. D., Gibson, A. M., Wagerman, S. A., Flores, E. D., and Kelly, L. A. (2019). The effects of aerobic and resistance exercise on state anxiety and cognitive function. *Sci. Sports* 34, 216–221. doi: 10.1016/j.scispo.2018.09.004

Hovland, A., Nordhus, I. H., Sjøbø, T., Gjestad, B. A., Birknes, B., Martinsen, E. W., et al. (2013). Comparing physical exercise in groups to group cognitive behaviour therapy for the treatment of panic disorder in a randomized controlled trial. *Behav. Cogn. Psychother.* 41, 408–432. doi: 10.1017/S1352465812000446

Huston, P., and McFarlane, B. (2016). Health benefits of tai chi: What is the evidence? *Can. Fam. Physician* 62, 881–890.

Ibrahim, A. K., Kelly, S. J., Adams, C. E., and Glazebrook, C. (2013). A systematic review of studies of depression prevalence in university students. *J. Psychiatr. Res.* 47, 391–400. doi: 10.1016/j.jpsychires.2012.11.015

Jazaieri, H., Goldin, P. R., Werner, K., Ziv, M., and Gross, J. J. (2012). A randomized trial of MBSR versus aerobic exercise for social anxiety disorder. *J. Clin. Psychol.* 68, 715–731. doi: 10.1002/jclp.21863

Ji, C., Yang, J., Lin, L., and Chen, S. (2022). Physical exercise ameliorates anxiety, depression and sleep quality in college students: Experimental evidence from exercise intensity and frequency. *Behav. Sci.* 12:61. doi: 10.3390/bs12030061

Kramer, A. F., Colcombe, S. J., McAuley, E., Scalf, P. E., and Erickson, K. I. (2005). Fitness, aging and neurocognitive function. *Neurobiol. Aging* 26, 124–127. doi: 10.1016/j.neurobiolaging.2005.09.009

Larun, L., Nordheim, L. V., Ekeland, E., Hagen, K. B., and Heian, F. (2006). Exercise in prevention and treatment of anxiety and depression among children and young people. *Cochrane Database Syst. Rev.* CD004691. doi: 10.1002/14651858.CD004691.pub2

LeBouthillier, D. M., and Asmundson, G. J. (2015). A single bout of aerobic exercise reduces anxiety sensitivity but not intolerance of uncertainty or distress tolerance: A randomized controlled trial. *Cogn. Behav. Ther.* 44, 252–263. doi: 10.1080/16506073.2015.1028094

Liu, H. X., Chow, B. C., Hu, C., Hassel, H., and Huang, W. Y. (2022). eHealth usage among Chinese college students: Qualitative findings. *BMC Public Health* 22:1088. doi: 10.1186/s12889-022-13521-1

Marcos de Souza Moura, A., Khede Lamego, M., Paes, F., Ferreira Rocha, N. B., Simoes-Silva, V., Almeida Rocha, S., et al. (2015).). Effects of aerobic exercise on anxiety disorders: A systematic review. *CNS Neurol. Disord. Drug Targets* 14, 1184–1193. doi: 10.2174/1871527315666151111121259

Margulis, A., Andrews, K., He, Z., and Chen, W. (2021). The effects of different types of physical activities on stress and anxiety in college students. *Curr. Psychol.* 1–7. doi: 10.1007/s12144-021-01881-7

Masley, S., Roetzheim, R., and Gualtieri, T. (2009). Aerobic exercise enhances cognitive flexibility. *J. Clin. Psychol. Med. Settings* 16, 186–193. doi: 10.1007/s10880-009-9159-6

Menghuan, X., and Qingqi, W. (2021). Try the anxious constitution. *Chin. J. Tradit. Chin. Med.* 36, 3101–3103.

Mohamed, A. A., and Alawna, M. (2020). Role of increasing the aerobic capacity on improving the function of immune and respiratory systems in patients with coronavirus (COVID-19): A review. *Diabetes Metab. Syndr.* 14, 489–496. doi: 10.1016/j.dsx.2020.04.038

Paluska, S. A., and Schwenk, T. L. (2000). Physical activity and mental health. *Sports Med.* 29, 167–180. doi: 10.1016/S2215-0366(18)30354-7

Pontifex, M. B., McGowan, A. L., Chandler, M. C., Gwizdala, K. L., Parks, A. C., Fenn, K., et al. (2019). A primer on investigating the after effects of acute bouts of physical activity on cognition. *Psychol. Sport Exerc.* 40, 1–22. doi: 10.1016/j.psychsport.2018.08.015

Rogowska, A. M., Pavlova, I., Kuśnierz, C., Ochnik, D., Bodnar, I., and Petrytsa, P. (2020). Does physical activity matter for the mental health of university students during the COVID-19 pandemic? *J. Clin. Med.* 9:3494. doi: 10.3390/jcm9113494

Russell, W. D. (2002). Comparison of self-esteem, body satisfaction, and social physique anxiety across males of different exercise frequency and racial background. *J. Sport Behav.* 25, 74–90.

Rýzková, E., Labudova, J., Grznár, L. U., and Šmída, M. (2018). Effects of aquafitness with high intensity interval training on physical fitness. *J. Phys. Educ. Sport* 18, 373–381. doi: 10.7752/jpes.2018.s151

Shihua, Z., Qiaoyun, T., and Aijun, Z. (2016). Investigation of depression and anxiety in college students and analysis of related factors. *Chongqing Med.* 45, 2835–2837. doi: 10.3969/j.issn.1671-8348.2016.20.032

Smits, J. A., Berry, A. C., Rosenfield, D., Powers, M. B., Behar, E., and Otto, M. W. (2008). Reducing anxiety sensitivity with exercise. *Depress. Anxiety* 25, 689–699. doi: 10.1002/da.20411

Stern, Y., MacKay-Brandt, A., Lee, S., McKinley, P., McIntyre, K., Razlighi, Q., et al. (2019). Effect of aerobic exercise on cognition in younger adults: A randomized clinical trial. *Neurology* 92, e905–e916. doi: 10.1212/WNL.0000000000007003

Stonerock, G. L., Hoffman, B. M., Smith, P. J., and Blumenthal, J. A. (2015). Exercise as treatment for anxiety: Systematic review and analysis. *Ann. Behav. Med.* 49, 542–556. doi: 10.1007/s12160-014-9685-9

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., et al. (2017). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Res.* 249, 102–108. doi: 10.1016/j.psychres.2016.12.020

Taylor, S., Abramowitz, J. S., and McKay, D. (2012). Non-adherence and non-response in the treatment of anxiety disorders. *J. Anxiety Disord.* 26, 583–589. doi: 10.1016/j.janxdis.2012.02.010

Tekur, P., Nagarathna, R., Chametcha, S., Hankey, A., and Nagendra, H. R. (2012). A comprehensive yoga programs improves pain, anxiety and depression in chronic low back pain patients more than exercise: An RCT. *Complement. Ther. Med.* 20, 107–118. doi: 10.1016/j.ctim.2011.12.009

Tsai, J. C., Wang, W. H., Chan, P., Lin, L. J., Wang, C. H., Tomlinson, B., et al. (2003). The beneficial effects of Tai Chi Chuan on blood pressure and lipid profile and anxiety status in a randomized controlled trial. *J. Altern. Complement. Med.* 9, 747–754. doi: 10.1089/107555303322524599

Verhagen, A. P., De Vet, H. C., De Bie, R. A., Kessels, A. G., Boers, M., Bouter, L. M., et al. (1998). The Delphi list: A criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *J. Clin. Epidemiol.* 51, 1235–1241. doi: 10.1016/S0895-4356(98)00131-0

Wang, X., Lei, S. M., Le, S., Yang, Y., Zhang, B., Yao, W., et al. (2020). Bidirectional influence of the COVID-19 pandemic lockdowns on health behaviors and quality of life among Chinese adults. *Int. J. Environ. Res. Public Health* 17:5575. doi: 10.3390/ijerph17155575

Warburton, D. E., Nicol, C. W., and Bredin, S. S. (2006). Health benefits of physical activity: The evidence. *CMAJ* 174, 801–809. doi: 10.1503/cmaj.051351

Wegner, M., Helmich, I., Machado, S., Nardi, A., Arias-Carrion, O., and Budde, H. (2014). Effects of exercise on anxiety and depression disorders: Review of meta-analyses and neurobiological mechanisms. *CNS Neurol. Disord. Drug Targets* 13, 1002–1014. doi: 10.2174/1871527313666140612102841

White, R. L., Babic, M. J., Parker, P. D., Lubans, D. R., Astell-Burt, T., and Lonsdale, C. (2017). Domain-specific physical activity and mental health: A meta-analysis. *Am. J. Prev. Med.* 52, 653–666. doi: 10.1016/j.amepre.2016.12.008

Wipfli, B. M., Rethorst, C. D., and Landers, D. M. (2008). The anxiolytic effects of exercise: A meta-analysis of randomized trials and dose–response analysis. *J. Sport Exerc. Psychol.* 30, 392–410. doi: 10.1123/jsep.30.4.392

Xiang, M. Q., Tan, X. M., Sun, J., Yang, H. Y., Zhao, X. P., Liu, L., et al. (2020). Relationship of physical activity with anxiety and depression symptoms in Chinese college students during the COVID-19 outbreak. *Front. Psychol.* 11:582436. doi: 10.3389/fpsyg.2020.582436

Yin, J., Tang, L., and Dishman, R. K. (2021). The effects of a single session of mindful exercise on anxiety: A systematic review and meta-analysis. *Ment. Health Phys. Act.* 21:100403. doi: 10.1016/j.mhpa.2021.100403

frontiers | Frontiers in Psychiatry

TYPE Original Research
PUBLISHED 25 April 2023
DOI 10.3389/fpsyt.2023.1179417

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Shou Liu,
Qinghai University Medical College, China
Samuel Forjuoh,
Texas A&M University, United States

*CORRESPONDENCE
Xiu-Jun Liu
✉ xiujunliu7819@163.com

†The authors have contributed equally to this work

RECEIVED 04 March 2023
ACCEPTED 03 April 2023
PUBLISHED 25 April 2023

CITATION
Wu K-G, Chen S-J, Hu Y-N, Mei S-F, Chen W-C, Huang X-E, Xu Z-F, Li M-C, Zhong B-L and Liu X-J (2023) The relationship between physical activity and depression among community-dwelling adults in Wuhan, China.
Front. Psychiatry 14:1179417.
doi: 10.3389/fpsyt.2023.1179417

The relationship between physical activity and depression among community-dwelling adults in Wuhan, China

Kai-Ge Wu[1,2,3,4†], Si-Jing Chen[2,3†], Ya-Ni Hu[2,3], Shu-Fang Mei[2,3], Wen-Cai Chen[2,3], Xian-E Huang[2,3], Zai-Feng Xu[2,3], Ming-Chao Li[2,3], Bao-Liang Zhong[2,3] and Xiu-Jun Liu[1,2,3,4*]

[1]Institute of Education, China University of Geosciences (Wuhan), Wuhan, China, [2]Department of Psychiatry, Wuhan Mental Health Center, Wuhan, China, [3]Department of Psychiatry, Affiliated Wuhan Mental Health Center, Tongji Medical College of Huazhong University of Science and Technology, Wuhan, China, [4]Research Center for Psychological and Health Sciences, China University of Geosciences (Wuhan), Wuhan, China

Background: While the association between physical activity (PA) and depression has been established, there is limited research on the effect of PA on the risk of depression among Chinese individuals. Thus, this study aimed to investigate the relationship between PA and depression among Chinese individuals.

Methods: We used a stratified random sampling approach to recruit participants from five urban districts in Wuhan, China. A total of 5,583 permanent residents aged 18years or older completed questionnaires, which included the International Physical Activity Questionnaire Short Form (IPAQ-SF) to measure PA, and the 9-item Patient Health Questionnaire (PHQ-9) to evaluate depressive symptoms. To control for potential confounders, multiple logistic regression was employed to assess the association of PA with depression.

Results: The depression group had significantly lower weekly PA levels, measured in metabolic equivalent of task-minutes per week (MET-min/w), compared to the non-depression group [1,770 (693–4,200) MET-min/w vs. 2,772 (1,324–4,893) MET-min/w, $p<0.001$]. In the fully adjusted model, the moderate and high PA level groups had lower odds ratios (ORs) for depressive symptoms compared to the low PA level group [OR (95% confidence interval (CI))=0.670 (0.523–0.858), 0.618 (0.484–0.790), respectively]. Among males, moderate and high levels of PA were associated with lower risk of depression compared to low PA levels [OR (95% CI)=0.417 (0.268–0.649), 0.381 (0.244–0.593), respectively]. However, this association was not observed in females [OR (95% CI)=0.827 (0.610–1.121), 0.782 (0.579–1.056), respectively]. The study found a significant interaction between PA levels and gender in relation to depression (*P* for interaction=0.019).

Conclusion: The findings suggest a negative association between PA and risk of depressive symptoms, indicating that moderate to high levels of PA may serve as a protective factor against depressive symptoms.

KEYWORDS

depression, physical activity, mental health, China, female

1. Introduction

Depression is a leading cause of disability worldwide and has a profound impact on the mental health of the general population (1–4). In recent years, several studies have indicated a significant rise in the prevalence of depression (5–7). A 2020 meta-analysis, which included 12 studies, reported a pooled prevalence of 25% for depressive symptoms (8). To develop effective treatments and preventive measures for depression, it is crucial to investigate the patterns of depression and their associated factors.

Research findings indicate that there is a connection between physical activity (PA) and depression, and that PA may serve as a protective factor against depression (9, 10). These effects are thought to be mediated by several mechanisms, including changes in brain structure and function, social interaction and self-efficacy, and improvements in sleep quality (11). Although the most effective level of PA for reducing the risk of depression is still a topic of debate, PA is generally considered beneficial for depression. Some studies suggest that moderate and vigorous PA may both be effective in preventing depression, while other studies raise concerns that high levels of PA may not provide any additional benefits (12–14).

Previous research that examined the link between PA and depression has mostly focused on special subpopulations, such as older adults, teenagers, women, or college students (10, 13–17). However, there is limited evidence from epidemiological studies conducted on large sample populations, particularly among the general adult population in Chinese communities.

The objective of this study was to examine the relationship between PA and depression among a sample of adult residents in China. Considering the differences in prevalence of depression and mediating mechanisms between the genders (18), we aimed to investigate potential gender differences in this association.

2. Materials and methods

2.1. Study population

Between October and December, 2021, we conducted a cross-sectional household survey of permanent residents aged 18 years and older in Wuhan, Hubei Province, China. Wuhan is a large city with a population of 11.21 million, which is fairly representative of the central region of China. By using a stratified random sampling approach, two central districts and three suburban districts in Wuhan were randomly selected in the first stage of the sampling. From each of the selected districts, we chose two streets, and subsequently, we randomly selected three communities or villages from each street. Within each community or village, we randomly selected 180 households. Finally, we randomly selected one adult participant from each selected household, provided that they had resided in the selected community or village for at least six consecutive months.

Sample size was calculated using the formula $N = deff \cdot \mu^2 p\ (1 - p)/d^2$. A 95% confidence level (two-tailed) was used, corresponding to $u = 1.96$. Based on the research of Lu et al., the prevalence of depression among Chinese was 3.4% (19). The design efficiency (*deff*) was set at 2. The relative error (r) was 20%, and d was calculated as 0.68 (20% × 3.4%). Using these values, the sample size was determined to be 5,457.

In order to ensure that residents were aware of the procedure and purpose of the study, informed consent was obtained before the survey. The study was approved by the Ethics Committee of Wuhan Mental Health Centre.

2.2. Measurements

Trained investigators conducted face-to-face interviews with residents and completed questionnaires on-site. The survey utilized a self-developed online platform to collect data. The questionnaires included information on PA, depressive symptoms, and socio-demographic characteristics.

PA was measured using the International Physical Activity Questionnaire Short Form (IPAQ-SF)—Chinese version in the present study (20). The IPAQ-SF was considered a reliable instrument to assess the total amount of PA obtained in common people aged 15–65 years (21). It is a 7-item self-report scale that calculates daily metabolic equivalents (METs) for the past 7 days. The PA level was classified into three groups (high, moderate, and low) based on the IPAQ-SF scoring protocol (22). IPAQ-SF has been used extensively and its reliability is well-documented (Intraclass Correlation Coefficient (ICC) = 0.79) (20).

The presence and severity of depression were estimated by the Chinese version of the 9-item Patient Health Questionnaire (PHQ-9) (23). This questionnaire has 9 items, and each item was scored on 4 point-scale (0 = Not at all to 3 = Nearly every day) and the total score ranged from 0 to 27. The total score of ≥5, ≥10, ≥15, and ≥20 are identified as mild, moderate, moderately severe, and severe depressive symptoms, respectively (23). Thus, this study used a total score of 5 as a cut-off point to generate the binary depression variable. The Cronbach's alpha of PHQ-9 was 0.863 in this study.

Socio-demographic information collected in the study included gender, age, body mass index (BMI), education level, marital status, monthly family income, smoking status, alcohol drinking status, presence of insomnia, and the number of chronic diseases. The Insomnia Severity Index (ISI) was used to evaluate insomnia status (24), with a cutoff value of 7 and a total score range of 0 to 28 points (25). The internal consistency of ISI was 0.929 for the current study. The number of chronic diseases was determined by a multiple-choice question inquiring whether respondents were currently suffering from any of the 12 chronic diseases listed, including hypertension, gastritis, and diabetes, with an additional option for "other."

2.3. Statistical analyses

For descriptive analysis, Student's t-test was used to compare continuous variables, and differences in categorical variables were compared using the chi-square (χ^2) test. When continuous data was not normally distributed, the nonparametric Mann–Whitney U-test was employed. Logistic regression was then used to examine the association between PA and depression, controlling for potential confounding factors in three models. Model 1 adjusted for gender (female or male), age (continuous), and BMI (continuous); model 2 added marital status (unmarried or married), education (primary school and below, middle school, high school or college and above), monthly family income (<3,000 RMB, 3,000–5,999 RMB, 6,000–9,999

RMB or ≥ 10,000 RMB), current smoking status (no or yes), and current alcohol drinking status (no or yes); and model 3 additionally accounted for insomnia (no or yes) and the number of chronic diseases (0, 1 or ≥ 2). Stratified analyses were performed to evaluate the consistency of the association between PA and depression, considering gender (female or male), age (<60 or ≥ 60 years), BMI (<18.5 kg/m^2, 18.5–23.9 kg/m^2, 24.0–27.9 kg/m^2 or ≥ 28.0 kg/m^2), monthly family income (<3,000 RMB, 3,000–5,999 RMB, 6,000–9,999 RMB or ≥ 10,000 RMB), insomnia (no or yes) and the number of chronic diseases (0, 1 or ≥ 2). The odds ratios for depression of PA levels were calculated across different subgroups, adjusted for gender, age, BMI, marital status, education, monthly family income, current smoking status, and current alcohol drinking status, insomnia and the number of chronic diseases. Likelihood ratio tests were conducted to examine interactions. All data were analyzed using SPSS 25.0 (IBM Corp., Armonk, NY, United States), and statistical significance was set at $p < 0.05$.

3. Results

A total of 5,887 residents were enrolled, and 5,583 completed the assessment. In our study, 765 participants (13.7%) exhibited depressive symptoms. The mean value and standard deviation of age and BMI were 55.66 ± 15.11 years and 23.37 ± 3.33 kg/m^2, respectively.

The sociodemographic characteristics were compared between individuals with and without depression (Table 1). Compared with non-depression participants, individuals with depression had higher odds of being younger, female, unmarried, and not currently smoking nor drinking alcohol, while with lower levels of BMI, education, and monthly family income. Moreover, individuals with depression had a higher prevalence of chronic diseases, as well as a greater incidence of insomnia. The group reporting depressive symptoms had a significantly lower median (IQR) of PA at 1,770 (693–4,200) MET-min/w compared to the group without depressive symptoms, which had a median (IQR) of 2,772 (1,324–4,893) MET-min/w ($p < 0.001$).

The relationships were examined between PA levels and depression, as shown in Table 2. In the final model, a significant association between depression and PA was observed after adjusting for gender, age, BMI, marital status, education, monthly family income, current smoking status, current alcohol, insomnia and the number of chronic diseases. Participants with moderate or high level of PA had a significant lower risk of depression than those with low PA level in the fully adjusted model [OR (95% CI) = 0.670 (0.523–0.858), 0.618 (0.484–0.790), respectively].

Table 3 presented the adjusted ORs for depression of PA levels by subgroups. The PA-depression association was not significantly differed by age, BMI, insomnia and the number of chronic diseases. In male group, lower ORs for depression of moderate and high PA levels were observed [OR (95%) = 0.417 (0.268–0.649), 0.381 (0.244–0.593), respectively], whereas similar result was not found in female group [OR (95%) = 0.827 (0.610–1.121), 0.782 (0.579–1.056), respectively]. In households with a monthly income of less than 3,000 RMB, moderate to high levels of PA decreased the ORs for depression [OR (95% CI) = 0.434 (0.267–0.706), 0.462 (0.294–0.727), respectively]. However, in the 3,000–5,999 RMB group, the protect role was only found for high PA level [OR (95% CI) = 0.678 (0.387–1.188)], and in the group of monthly family income higher than 6,000, the protect effect was not observed for both moderate and high PA levels [6,000–9,999 RMB: OR (95% CI) = 0.689 (0.408–1.162), 0.705 (0.417–1.191), respectively; ≥10,000 RMB: OR (95% CI) =0.960 (0.594–1.551), 0.944 (0.570–1.565), respectively]. In addition, moderate to high levels of PA had a protective effect for individuals with a BMI of 18.5–23.9 kg/m^2 [OR (95% CI) = 0.637 (0.460–0.882), 0.579 (0.419–0.799), respectively] and without chronic diseases [OR (95% CI) = 0.620 (0.439–0.877), 0.651 (0.460–0.923), respectively].

4. Discussion

The present study investigated the association between PA and depression among Chinese adults. We observed a significant negative correlation between PA level and odds of depression, although this association was only evident in men but not in women.

Our study found a prevalence rate of 13.7% for depressive symptoms among permanent residents aged 18 years or older in Wuhan, China. Our results are consistent with previous studies, which have also shown that depressive symptoms are more common in females than in males (14.9% vs. 11.3%) (13, 26). This may be attributed to females' high sensitivity to psychological and physical stress, which may increase their susceptibility to depression, particularly during emergencies (18, 27).

Our study revealed that both moderate and high levels of PA were associated with a lower risk of depressive symptoms. These findings are consistent with the results of previous studies by Chi et al. and Mumba et al., which have shown that moderate to high levels of PA are associated with lower levels of depression compared to lower levels of PA (13, 14). In contrast, other studies have shown that vigorous PA does not have additional protection against depression and that it may increase the risk of depression (12, 28). Our results supported the former view, suggesting that both moderate and high levels of PA had a protective effect against depression, and the risk of depression decreased with increasing levels of PA. Many studies have demonstrated the positive effects of PA on mental health through several neurobiological, psychosocial, and behavioral mechanisms. The neurobiological mechanism hypothesis suggests that PA results in changes in the structure and function of the brain, which enhances mental health (11, 29). The psychosocial mechanism hypothesis proposes that PA provides opportunities for social interaction, self-efficacy, and improved body image, leading to better mental health (30, 31). Lastly, the behavioral mechanism hypothesis posits that engaging in vigorous PA may increase the need for sleep, which promotes energy conservation and body restoration, ultimately contributing to better mental health (32, 33).

According to our findings, PA may not have protective effect on women, which differed from previous studies. Meng et al.'s study of 1,892 elderly women (aged 55–70) found that moderate leisure-time physical activity (LTPA) was associated with reduced depression, whereas vigorous LTPA could increase the risk (28). Similarly, Luo et al.'s study on middle-aged women (aged 42–52) found that adequate PA (at least 150–300 min of moderate-intensity aerobic activity per week) was a protective factor against depressive symptoms (17). The protective effect of PA on women in our study was not significant, probably due to the type of PA performed. Several studies have shown that aerobic and strength exercises are the most effective in alleviating depression (34, 35). However, it is possible that some of the individuals in our study may have reported doing household chores as part of

TABLE 1 Demographic characteristics according to depression status.

Parameters	Non-depression (*n*=4,818)	Depression (*n*=765)	χ^2/t/*Z*	*p*-value
Gender, *n*(%)			13.732	<0.001
Female	3,148 (85.1)	552 (14.9)		
Male	1,670 (88.7)	213 (11.3)		
Age (years)	56.1 ± 14.9	53.1 ± 16.4	4.743	<0.001
BMI (kg/m^2)	23.4 ± 3.3	23.0 ± 3.5	2.963	0.003
Education, *n* (%)			84.945	<0.001
Primary school and below	1,439 (84.4)	265 (15.6)		
Middle school	1,480 (90.6)	153 (9.4)		
High school	1,034 (89.4)	122 (10.6)		
College and above	865 (79.4)	225 (20.6)		
Marital status, *n* (%)			30.738	<0.001
Married	4,139 (87.4)	598 (12.6)		
Unmarried and others	679 (80.3)	167 (19.7)		
Monthly family income, n (%)			19.339	<0.001
<3,000 RMB	1,098 (83.6)	216 (16.4)		
3,000–5,999 RMB	1,037 (85.9)	170 (14.1)		
6,000–9,999 RMB	1,446 (89.1)	177 (10.9)		
≥10,000 RMB	1,237 (86.0)	202 (14.0)		
Current smoking status, *n* (%)			10.487	0.001
No	4,023 (85.7)	674 (14.3)		
Yes	795 (89.7)	91 (10.3)		
Current alcohol drinking status, *n* (%)			4.889	0.027
No	4,168 (85.9)	684 (14.1)		
Yes	650 (88.9)	81 (11.1)		
Insomnia, *n* (%)			1172.54	<0.001
No	4,367 (93.2)	319 (6.8)		
Yes	451 (50.3)	446 (19.7)		
Number of chronic diseases, *n* (%)			88.657	<0.001
0	2,693 (89.1)	328 (10.9)		
1	1,260 (87.1)	187 (12.9)		
≥2	622 (76.5)	191 (23.5)		
Physical activity (MET-min/w)	2,772 (1324–4,893)	1770 (693–4,200)	# -6.068	<0.001

#Mann–Whitney *U*-test was conducted.

their PA. Previous studies have suggested that increased workload and lack of skill utilization during household chores may be risk factors for depression in women (36), and that women with high household workload have higher rates of mental disorders than women with low household workload (37). Moreover, the age range of women in this study was wider (18–95 years). The effect of PA may vary among women of different age groups, which calls for further research.

Our study suggested that the protective effect of PA against depression may vary across income groups. PA had no significant protective effect against depression in high-income households, but had a significant protective effect in low-income households. PA may be an inexpensive and feasible way to reduce depression in low-income households. Conversely, high-income households may have more options available to alleviate depression, which could reduce the protective effect of PA. As for the role of BMI and number of chronic diseases in the relationship between PA and depression, further research is needed due to the small sample size in some of the subgroups of these variables.

Several limitations of the present study should be acknowledged. Firstly, the cross-sectional design of our study precluded making causal inferences, even though we controlled for relevant covariates. Future research should consider more comprehensive longitudinal studies to better understand the relationships between the variables. Secondly, PA was collected through self-reported instruments, which may be subject to biases resulting from social expectations and memory errors. Thirdly, it should be noted that the PHQ-9 assessment of depression served as a screening tool and does not provide a clinical diagnosis. As a result, future studies may need to incorporate diagnostic interviews to ensure that results are more precise and reliable. Fourthly, the study only

TABLE 2 Association of physical activity levels with depression.

	Physical activity, OR (95% CI)			*P*-value
	Low	Moderate	High	
Crude	1	0.595 (0.482，0.735)	0.493 (0.400，0.607)	<0.001
Model 1	1	0.610 (0.493，0.754)	0.506 (0.409，0.625)	<0.001
Model 2	1	0.657 (0.529，0.815)	0.550 (0.444，0.682)	<0.001
Model 3	1	0.670 (0.523，0.858)	0.618 (0.484，0.790)	<0.001

Model 1: adjusted for gender, age, BMI. Model 2: additionally adjusted for marital status, education, monthly family income, current smoking status, current alcohol drinking status. Model 3: additionally adjusted for insomnia, number of chronic diseases.

TABLE 3 Odd ratios for depression of physical activity levels by subgroups.

Subgroups	*N*	Physical activity			*P* for interaction
		Low	Moderate	High	
Gender					0.019
Female	3,700	1	0.827 (0.610, 1.121)	0.782 (0.579，1.056)	
Male	1,883	1	0.417 (0.268, 0.649)	0.381 (0.244，0.593)	
Age					0.434
≤60	3,136	1	0.724 (0.531, 0.988)	0.644 (0.470，0.882)	
>60	2,447	1	0.554 (0.365, 0.840)	0.583 (0.390，0.870)	
BMI					0.249
<18.5 kg/m^2	288	1	0.595 (0.233, 1.516)	0.917 (0.369, 2.281)	
18.5–23.9 kg/m^2	3,130	1	0.637 (0.460, 0.882)	0.579 (0.419, 0.799)	
24.0–27.9 kg/m^2	1,692	1	0.842 (0.515, 1.376)	0.624 (0.382, 1.020)	
≥28.0 kg/m^2	473	1	0.362 (0.142, 0.924)	0.740 (0.309, 1.769)	
Monthly family income					0.311
<3,000 RMB	1,314	1	0.434 (0.267, 0.706)	0.462 (0.294, 0.727)	
3,000–5,999 RMB	1,207	1	0.678 (0.387, 1.188)	0.539 (0.313, 0.927)	
6,000–9,999 RMB	1,623	1	0.689 (0.408, 1.162)	0.705 (0.417, 1.191)	
≥10,000 RMB	1,439	1	0.960 (0.594, 1.551)	0.944 (0.570, 1.565)	
Insomnia					0.871
No	4,686	1	0.637 (0.463, 0.877)	0.606 (0.442, 0.831)	
Yes	897	1	0.670 (0.452, 0.995)	0.605 (0.411, 0.890)	
Number of chronic diseases					0.768
0	3,021	1	0.620 (0.439, 0.877)	0.651 (0.460, 0.923)	
1	1,447	1	0.710 (0.421, 1.197)	0.688 (0.415, 1.141)	
≥2	813	1	0.696 (0.419, 1.156)	0.546 (0.333, 0.896)	

All models are adjusted for gender, age, BMI, marital status, education, monthly family income, current smoking status, and current alcohol drinking status, insomnia and the number of chronic diseases.

involved permanent residents in Wuhan, which may limit the generalizability of our findings to residents of other Chinese provinces due to differences in economy and living habits.

5. Conclusion

PA is negatively associated with depression. The risk of depression decreases with the increasing of PA, and both moderate and high levels of PA may play a protective role. Further study is warranted to clarify the sex difference in the effect of PA.

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.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Wuhan Mental Health Centre. The patients/participants provided their written informed consent to participate in this study.

Author contributions

B-LZ, X-JL, S-JC, Y-NH, S-FM, and W-CC designed the research. K-GW, S-JC, Y-NH, S-FM, W-CC, X-EH, Z-FX, and M-CL collected the data. K-GW and S-JC contributed to the data analysis. K-GW wrote the paper. S-JC reviewed the final version of the manuscript and supervised the project. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors are extremely grateful to the Wuhan Mental Health Center and the Research Center for Psychological and Health Sciences, China University of Geosciences (Wuhan) for their support.

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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2023.1179417/full#supplementary-material

References

1. Ren XW, Yu SC, Dong WL, Yin P, Xu XH, Zhou MG. Burden of depression in China, 1990-2017: findings from the global burden of disease study 2017. *J Affect Disord*. (2020) 268:95–101. doi: 10.1016/j.jad.2020.03.011

2. Vos T, Allen C, Arora M, Barber RM, Bhutta ZA, Brown A, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the global burden of disease study 2015. *Lancet*. (2016) 388:1545–602. doi: 10.1016/s0140-6736(16)31678-6

3. Chisholm D, Sweeny K, Sheehan P, Rasmussen B, Smit F, Cuijpers P, et al. Scaling-up treatment of depression and anxiety: a global return on investment analysis. *Lancet Psychiatry*. (2016) 3:415–24. doi: 10.1016/S2215-0366(16)30024-4

4. Chen W, Chen S, Zhong B. Sense of alienation and its associations with depressive symptoms and poor sleep quality in older adults who experienced the lockdown in Wuhan, China, during the covid-19 pandemic. *J Geriatr Psychiatry Neurol*. (2022) 35:215–22. doi: 10.1177/08919887221078564

5. Guo J, Feng XL, Wang XH, van Ijzendoorn MH. Coping with covid-19: exposure to covid-19 and negative impact on livelihood predict elevated mental health problems in chinese adults. *Int J Environ Res Public Health*. (2020) 17:17. doi: 10.3390/ijerph17113857

6. Zhou SJ, Wang LL, Yang R, Yang XJ, Zhang LG, Guo ZC, et al. Sleep problems among chinese adolescents and young adults during the coronavirus-2019 pandemic. *Sleep Med*. (2020) 74:39–47. doi: 10.1016/j.sleep.2020.06.001

7. Santomauro DF, Herrera AMM, Shadid J, Zheng P, Ashbaugh C, Pigott DM, et al. Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the covid-19 pandemic. *Lancet*. (2021) 398:1700–12. doi: 10.1016/S0140-6736(21)02143-7

8. Bueno-Notivol J, Gracia-García P, Olaya B, Lasheras I, López-Antón R, Santabárbara J. Prevalence of depression during the covid-19 outbreak: a meta-analysis of community-based studies. *Int J Clin Health Psychol*. (2021) 21:100196. doi: 10.1016/j.ijchp.2020.07.007

9. Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, Silva ES, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry*. (2018) 175:631–48. doi: 10.1176/appi.ajp.2018.17111194

10. Slomski A. Even low amounts of physical activity reduce depression risk. *JAMA*. (2022) 327:2066. doi: 10.1001/jama.2022.8997

11. Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: towards understanding the antidepressant mechanisms of physical activity. *Neurosci Biobehav Rev*. (2019) 107:525–39. doi: 10.1016/j.neubiorev.2019.09.040

12. Harvey SB, Øverland S, Hatch SL, Wessely S, Mykletun A, Hotopf M. Exercise and the prevention of depression: results of the hunt cohort study. *Am J Psychiatry*. (2018) 175:28–36. doi: 10.1176/appi.ajp.2017.16111223

13. Chi XL, Liang KX, Chen ST, Huang QM, Huang LY, Yu Q, et al. Mental health problems among chinese adolescents during the covid-19: the importance of nutrition and physical activity. Int J Clin. *Health Psychol*. (2021) 21:100218. doi: 10.1016/j.ijchp.2020.100218

14. Mumba MN, Nacarrow AF, Cody S, Key BA, Wang H, Robb M, et al. Intensity and type of physical activity predicts depression in older adults. *Aging Ment Health*. (2021) 25:664–71. doi: 10.1080/13607863.2020.1711861

15. Da Costa B, Chaput JP, Lopes M, Malheiros L, Silva KS. Movement behaviors and their association with depressive symptoms in brazilian adolescents: a cross-sectional study. *J Sport Health Sci*. (2022) 11:252–9. doi: 10.1016/j.jshs.2020.08.003

16. Lu CP, Chi XL, Liang KX, Chen ST, Huang LY, Guo TY, et al. Moving more and sitting less as healthy lifestyle behaviors are protective factors for insomnia, depression, and anxiety among adolescents during the covid-19 pandemic. *Psychol Res Behav Manag*. (2020) 13:1223–33. doi: 10.2147/PRBM.S284103

17. Luo YT, Yang PT, Wan ZY, Kang Y, Dong XQ, Li Y, et al. Dietary diversity, physical activity and depressive symptoms among middle-aged women: a cross-sectional study of 48,637 women in China. *J Affect Disord*. (2023) 321:147–52. doi: 10.1016/j.jad.2022.10.038

18. Verma R, Balhara YPS, Gupta CS. Gender differences in stress response: role of developmental and biological determinants. *Ind Psychiatry J*. (2011) 20:4–10. doi: 10.4103/0972-6748.98407

19. Lu J, Xu X, Huang Y, Li T, Ma C, Xu G, et al. Prevalence of depressive disorders and treatment in China: a cross-sectional epidemiological study. *Lancet Psychiatry*. (2021) 8:981–90. doi: 10.1016/S2215-0366(21)00251-0

20. Macfarlane DJ, Lee C, Flo EY, Chan KL, Chan D. Reliability and validity of the chinese version of ipaq (short, last 7 days). *J Sci Med Sport*. (2007) 10:45–51. doi: 10.1016/j.jsams.2006.05.003

21. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*. (2003) 35:1381–95. doi: 10.1249/01.MSS.0000078924.61453.FB

22. Fan M, Lyu J, He P. Chinese guidelines for data processing and analysis concerning the international physical activity questionnaire. *Zhonghua liu Xing Bing xue za zhi = Zhonghua Liuxingbingxue Zazhi*. (2014) 35:961–4.

23. Kroenke K, Spitzer RL, Williams JB. The phq-9: validity of a brief depression severity measure. *J Gen Intern Med*. (2001) 16:606–13. doi: 10.1046/j.1525-1497.2001.016009606.x

24. Morin CM. *Insomnia: Psychological assessment and management*. New York: Guilford Press (1993).

25. Zhang Q, Li L, Zhong B. Prevalence of insomnia symptoms in older chinese adults during the covid-19 pandemic: a meta-analysis. *Front Med*. (2021) 8:779914. doi: 10.3389/fmed.2021.779914

26. Zhou SJ, Zhang LG, Wang LL, Guo ZC, Wang JQ, Chen JC, et al. Prevalence and socio-demographic correlates of psychological health problems in chinese adolescents

during the outbreak of covid-19. *Eur Child Adolesc Psychiatry*. (2020) 29:749–58. doi: 10.1007/s00787-020-01541-4

27. Yuan M, Wang Z, Fei L, Zhong B. Prevalence of prolonged grief disorder and its symptoms in chinese parents who lost their only child: a systematic review and meta-analysis. Front. *Public Health*. (2022) 10:10. doi: 10.3389/fpubh.2022.1016160

28. Meng Y, Luo Y, Qin S, Xu C, Yue J, Nie M, et al. The effects of leisure time physical activity on depression among older women depend on intensity and frequency. *J Affect Disord*. (2021) 295:822–30. doi: 10.1016/j.jad.2021.08.142

29. Firth J, Stubbs B, Vancampfort D, Schuch F, Lagopoulos J, Rosenbaum S, et al. Effect of aerobic exercise on hippocampal volume in humans: a systematic review and meta-analysis. *NeuroImage*. (2018) 166:230–8. doi: 10.1016/j.neuroimage.2017.11.007

30. Legrand FD. Effects of exercise on physical self-concept, global self-esteem, and depression in women of low socioeconomic status with elevated depressive symptoms. *J Sport Exerc Psychol*. (2014) 36:357–65. doi: 10.1123/jsep.2013-0253

31. Dore I, Sylvester B, Sabiston C, Sylvestre MP, O'Loughlin J, Brunet J, et al. Mechanisms underpinning the association between physical activity and mental health in adolescence: a 6-year study. *Int J Behav Nutr Phys Act*. (2020) 17:9. doi: 10.1186/s12966-020-0911-5

32. Driver HS, Taylor SR. Exercise and sleep. *Sleep Med Rev*. (2000) 4:387–402. doi: 10.1053/smrv.2000.0110

33. Zou L, Yeung A, Quan X, Boyden SD, Wang H. A systematic review and meta-analysis of mindfulness-based (baduanjin) exercise for alleviating musculoskeletal pain and improving sleep quality in people with chronic diseases. *Int J Environ Res Public Health*. (2018) 15:206. doi: 10.3390/ijerph15020206

34. Silveira H, Moraes H, Oliveira N, Coutinho ESF, Laks J, Deslandes A. Physical exercise and clinically depressed patients: a systematic review and meta-analysis. *Neuropsychobiology*. (2013) 67:61–8. doi: 10.1159/000345160

35. Silveira H, Deslandes AC, De Moraes H, Mouta R, Ribeiro P, Piedade R, et al. Effects of exercise on electroencephalographic mean frequency in depressed elderly subjects. *Neuropsychobiology*. (2010) 61:141–7. doi: 10.1159/000279304

36. Hoshino A, Amano S, Suzuki K, Suwa M. Relationships between depression and stress factors in housework and paid work among japanese women. *Hong Kong J Occup Ther*. (2016) 27:35–41. doi: 10.1016/j.hkjot.2016.03.001

37. Pinho PDS, Araújo TMD. Association between housework overload and common mental disorders in women. *Rev Bras Epidemiol*. (2012) 15:560–72. doi: 10.1590/S1415-790X2012000300010

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 16 May 2023
DOI 10.3389/fpubh.2023.1134854

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Majed M. Alhumaid,
King Faisal University, Saudi Arabia
Okba Selmi,
University of Jendouba, Tunisia

*CORRESPONDENCE
Zubing Xiang
xzb@cqu.edu.cn

RECEIVED 31 December 2022
ACCEPTED 17 April 2023
PUBLISHED 16 May 2023

CITATION
Bian J and Xiang Z (2023) Do the various leisure forms have equal effects on mental health? A longitudinal analysis of self-selected leisure activities. *Front. Public Health* 11:1134854. doi: 10.3389/fpubh.2023.1134854

Do the various leisure forms have equal effects on mental health? A longitudinal analysis of self-selected leisure activities

Junyi Bian[1,2] and Zubing Xiang[3]*

[1]School of Physical Education, Guangzhou Sport University, Guangzhou, China, [2]Department of Human Performance and Health Education, Western Michigan University, Kalamazoo, MI, United States, [3]School of Physical Education, Chongqing University, Chongqing, China

The deteriorating trends of unbalanced income, progressive age-related health problems, and loss of traditional ties necessitate ever-flexible interventions that are helpful to overcome a decline in Chinese adults' mental health. This study aimed to test whether engagement in different domains of leisure is associated with a composite index of mental health, both concurrently and subsequently. Longitudinal data including 10,968 participants (females = 5,804) with a mean age of 46.01 years in the Chinese General Social Survey (CGSS) were analyzed using generalized estimating equations with a logit link. The results showed that face-to-face experiences, such as sports with all ORs of <1 at the significance level of $\alpha = 0.01$ and meeting with all ORs of < 1 at the significance level of $\alpha = 0.01$ except daily in-person meeting frequency, are important for protecting mental health owing to the increasing social support by building close ties. The results also indicate that online leisure with all ORs < 1 at the significance level of $\alpha = 0.01$ has positive effects on lowering the odds of depression. In addition, receptive cognitive leisure, such as watching television or movies with all ORs $<$ 1 at the significance level of $\alpha = 0.05$ level, was not consistently associated with depression. However, active cognitive leisure, such as reading with all ORs of <1 at a significance level of $\alpha = 0.01$, was associated with lower odds of depression.

KEYWORDS

leisure, classification, self, assessment, psychology

1. Introduction

Currently, China suffers from collective mental health decline. Based on the data from the Chinese Mental Health Report (1), the percentage of adults satisfied with their mental health was 31.4%, while the percentage of those dissatisfied with their mental health was 45.9%. Furthermore, the report also indicated that the total mental health condition of the population has decreased compared with that 10 years ago. Despite this, mental distress or depression is commonly undiagnosed and underestimated and is often undertreated (2). Distress causes functional impairments in daily life and is associated with increased risks of cardiovascular disease, dementia, diabetes, stroke, and both specific and unspecific mortality (3–6). Against these backgrounds, identifying ways to reduce or prevent mental health concerns is particularly important. Furthermore, the deteriorating trends of unbalanced income, progressive age-related health problems, and loss of traditional ties necessitate ever-flexible interventions that are increasingly related to maintaining or achieving a healthy lifestyle (7).

In China, participating in cultural activities and organized travel trips are popular leisure trends that may help reduce depression (8). However, these activities require physical, social, creative, and imaginative participation from the participants. Although previous studies provide strong evidence that engaging in cultural activities (such as going to galleries and museums) and organized travel is associated with lower rates of depression (9, 10), organized travel may not be easily or equally accessible to all as it may be subject to higher socioeconomic barriers unlike other activities, like reading, watching television, or meeting with relatives or friends. Furthermore, cultural activities depend on the contextual environment of a person's life, and inequalities in access may likely increase with aging. It raises the question of whether a wide range of self-selected and participatory leisure activities that can be done at home, many of which are inexpensive or free, contribute to effectively preventing depression. Leisure activity is one of the known determinants of health and wellbeing. Previous studies have compellingly indicated that exercise as a form of leisure is consistently identified as having antidepressant effects in terms of physiological and neurological functions (11, 12). However, the effects of other flexible leisure activities such as reading, watching television, sewing, and digital leisure in protecting mental health have, to date, received less attention.

The current study investigated how engaging in different forms of leisure, such as exercise, reading, sewing, watching television or movies at home, meeting friends, and digital leisure, are associated with mental health protection. Considering social ties as a well-known element in protecting mental health in the real world, one possible mechanism of how digital leisure connects with mental health is that the interpersonal virtual networks allow for the exchange of social resources, which generates a sense of control and competence, thereby creating beliefs of resilience that make stress more bearable (13, 14). These perceptions of virtual social ties are described as "buffers" against life stress, especially when life stress is high. In addition, choosing reading and watching television/movies may be alternative elements in protecting mental health because cognitive stimulation, one possible mechanism connecting leisure and mental health, improves symptoms of depression and anxiety (15). However, the mechanism behind those is still unclear, and understanding the role of leisure is an important topic that merits further exploration.

Thus, choosing certain leisure forms should imply having greater opportunities to activate social ties and maintain the levels of social ties that may be beneficial for mental health, as leisure can become a source of happiness and personal growth (16) and detachment from stressful activities (17). Therefore, this study (1) tested the concurrent and subsequent associations between different leisure forms and a composite index of mental health; (2) discerned which leisure activities, including exercise, reading, sewing, watching television or movies at home, meeting friends, and digital leisure, help the most to protect mental health; and (3) discussed the possible anti-depressive effects of specific leisure activities that seem particularly important post-pandemic, partially after witnessing the exceptional consequences of the global COVID-19 pandemic: social distancing and whole-city lockdowns.

1.1. Literature review and hypothesis development

1.1.1. Online and offline leisure and mental health: a social capital perspective

Previous research has stressed that leisure creates different contexts that can facilitate the development of companionship, friendship, and social support, thus reducing feelings of loneliness and protecting people from psychological distress (18, 19). While leisure provides many interactive contexts that can be beneficial for mental health, studies involving issues of social capital and support suggest that many of these processes occur in settings where leisure is experienced through in-person scenarios (1, 20, 21).

The social capital theory is an umbrella term that broadly refers to the resources embedded in social ties that can be accessed through individual or collective social connections (22). Processes of social capital circulation are, thus, key to activating those kinds of resources that have been conceptualized as social capital since the studies by Akdere (23). From this perspective, Spini et al. (24) stressed the importance of being actively engaged in social connections to establish forms of social support that can provide protection against mental problems. In-person social interactions fostered feelings of reciprocity and help to circulate those kinds of social resources embedded in the social ties (25), e.g., emotional and material aids provided by strong social ties. In addition, China's high-speed economic development has induced large changes in society. For instance, some traditional social ties have been lost, meaning that residents are more likely to live alone. Against this background, some individuals spend their time engaging in sedentary and domestic activities, and Alkahtani argued (26) that they have fewer opportunities to actively foster social ties, thus losing their capacity to cultivate and circulate social capital. On the one hand, existing research suggests that traditional forms of leisure involving face-to-face social ties can provide enough opportunities to create a process of social capital circulation that helps to protect mental health (25). On the other hand, online communication and digital leisure vary in style but are becoming indispensable, especially due to the pandemic, and have provided many different opportunities for participants to connect through sporting apps, outdoor adventure comments, and sharing cultural activities.

Although digital leisure has been gaining popularity, the question of whether social capital is activated by virtual social ties remains unclear, as do the relationships between digital leisure and the odds of depression. It is easy to understand that the digital world can facilitate peer communication beyond time and space. Nakagomi et al.'s (27) findings supported the role of online communication with friends in preventing clinical depression among young people. In addition, online communication could be particularly useful among older adults as, today, families are often geographically dispersed. Bano (28) attributed the positive effects of virtual interactions with others to affect wellbeing via a decreased sense of loneliness as well as increased social engagement, which are core elements of activating social resources. Although Gardiner (29) described in his study that many requests for help in and through virtual interactions often go unanswered, prevention of

social capital circulation is decreasing due to flourishing online-specific communities, such as running groups on Facebook or sharing tourism tips on Twitter. Furthermore, some studies have demonstrated that increases in virtual engagement are correlated with fewer in-person social connections, but the positive effects of digital leisure on preventing mental health should be not ignored. Thus, it is reasonable to develop a digital leisure hypothesis.

H1: Increasing in-person exercise participation is associated with a lower probability of mental depression.

H2: Increased participation in meetings with friends is associated with a lower probability of mental depression.

H3: Increased participation in digital leisure is associated with a lower probability of mental depression.

1.2. Leisure and mental health: cognitive behavioral perspective

Although leisure involving social interactions was most consistently associated with lower odds of depression, there were still associations between participating in hobbies, baking, and cooking and depression, suggesting that these activities involve another active ingredient of protecting mental health, although they do not necessarily result in social connections (29, 30). Based on a cognitive behavioral therapy perspective, effective stimulation has three critical components: collaborative construction, verbal or visible intervention, and reframing (31). Each of these components involves a simulated objective in the participant's mind, which means that the aforementioned leisure activities such as hobbies, baking, or cooking actually do not involve interacting with peers virtually or in person but instead create simulated interactions to protect mental health.

In this aspect, there has been a growing body of research that demonstrates the effects of engagement in cultural activities on reducing depression. These cultural activities are commonly split into those with active engagement, such as singing, dancing, or doing artistic activities, and those with receptive engagement, involving art that has been created and then experienced by an audience (10). Cognitive stimulation, corresponding to those forms of active and receptive cultural activities, is not ignored, although there are many physical and social components involved. Previous studies have indicated that cultural engagement (such as going to galleries and art museums) is associated with lower odds of depression (9, 32), but these activities may not be accessible to all. Participating in cultural activities may be subject to more socioeconomic barriers than other leisure activities, and inequalities in access may increase with age (33). On the contrary, due to their cognitive stimulation and similarity to cultural activities, at-home activities like reading, watching television, and sewing, which are affordable or free, can help prevent depression. Specifically, considering that there is a difference between active and receptive cognitive stimulations, developing these cognitive stimulation spheres of leisure is reasonable.

H4: Higher rates of active reading are significantly associated with a lower probability of mental depression.

H5: Higher rates of receptive TV or movie watching at home have negative effects on protecting mental health.

H6: Higher rates of sewing are associated with a lower probability of mental depression.

2. Materials and methods

2.1. Sample

Participants were drawn from the Chinese General Social Survey (CGSS), which is a nationally representative study of 10,968 individuals with a mean age of 46.01 years in China. The initial cohort was first investigated in 2011 and followed up every 2 years. We used public data from CGSS waves with which engagement in leisure activities was consistently measured (2013–2017). Those three waves of investigation datasets were treated as longitudinal investigations in at least two respects. First, this national survey sample is replenished with younger cohorts every 8 years, which means those three waves of samples should be not replenished. Second, each wave survey is strongly representative of the whole population due to strict probability sampling. Specifically, each wave investigation considered its representativeness from two aspects: economic factors as a vertical axis and geographic units as a horizontal axis. For instance, while 2,801 counties were treated as primary sampling basic units, five different sampling frames were employed depending on the economic factors such as Gross Domestic Product (GDP) and human development index (detailed information shown in Table 1). Ultimately, 125 first sampling units were conducted by simple random sampling, and the ratio between urban and rural blocks was 295:205 in the second sampling unit and the ratio of people living in urban and rural areas was 5,900:4,100, which satisfies the sampling design. Each sampling unit had a confidential interval of 95% and a sampling error of no more than 3%. The least sample size was 5,335. However, considering the issues of invalid response and response rate, the sample size of each wave was set at 10,000. Restricting the sample in the current study to participants with complete data on depression and leisure activity participation in three waves produced a final sample of 10,968 participants and 32,904 observations.

2.2. Measurement

2.2.1. Outcome

Depression was measured at every wave with a 3-item self-evaluated depression scale (SEDS), as specified in Table 2. This self-reported measurement can identify people at risk of developing depression. The total score ranges from 1 to 5, with lower scores indicating more severe symptoms. The SEDS had good internal consistency across waves (Cronbach's alpha ranged from 0.71 to 0.85). We recoded a cutoff value of three or fewer to indicate the presence of depression (34).

2.2.2. Independent variables

We selected six items from this CGSS questionnaire that were measured consistently from 2013 to 2017, including questions on a wide range of leisure activities. Participants were asked how often they (1) read books, magazines, or newspapers (*Reading*);

TABLE 1 A summary of sampling strategy.

Sampling-frame	First unit	Second unit	Third unit	Ultimate unit
Frame-1	15	60	120	1,200
Beijing	5	5 × 4 = 20	20 × 2 = 40	40 × 10 = 400
Tianjin	5	5 × 4 = 20	20 × 2 = 40	40 × 10 = 400
Shanghai	5	5 × 4 = 20	20 × 2 = 40	40 × 10 = 400
Frame-2	16	64	128	1,280
Eastern	5	5 × 4 = 20	20 × 2 = 40	40 × 10 = 400
Central	6	6 × 4 = 24	24 × 2 = 48	48 × 10 = 480
Western	5	5 × 4 = 20	20 × 2 = 40	40 × 10 = 400
Frame-3	30	30 × 4 = 120	120 × 2 = 240	240 × 10 = 2,320
Frame-4	42	42 × 4 = 168	168 × 2 = 336	336 × 10 = 3,360
Frame-5	22	22 × 4 = 88	88 × 2 = 176	176 × 10 = 1,760
Total	125	500	1,000	10,000

TABLE 2 Standardized factor loadings, composite reliability coefficients, and average variance extracted for the self-evaluated depression scale.

Construct/items	β			CR			AVE		
	2013	2015	2017	2013	2015	2017	2013	2015	2017
Item-1	0.849**	0.718**	0.727**	0.878	0.726	0.775	0.707	0.642	0.654
Item-2	0.894**	0.762**	0.703**						
Item-3	0.776**	0.567**	0.563**						

N = 10,968, β, standardized factor loadings; CR, composite reliability coefficients; AVE, average variance extracted. **$p < 0.01$. Item-1: How do you rate your mental wellbeing? Item-2: In the past 4 weeks, how often have the mental problems interfered with your work or other daily activities? Item-3: In the past 4 weeks, how often have you felt depressed?

(2) attend meetings with friends or relatives, community, or other interest groups (*Meeting*); (3) watch TV or movies at home (*Watching*); (4) play a sport or attend an exercise club (*Exercising*); (5) carry out sewing, knitting, or embroidery (*Sewing*); and (6) browse the internet for leisure (*Internet*). We collapsed the responses into four categories, representing daily engagement (once a day/several times daily), weekly engagement (once a week/several times a week), monthly engagement (once a month/several times a month), and yearly or no engagement (never/not in the last half year, and once a year/several times a year).

2.2.3. Moderated effects of demographic characteristics

We included a range of demographic and socioeconomic-related confounders. Demographic confounders were age in years and gender (men vs. women). The socioeconomic confounders were educational attainment (none, elementary school, middle and high school, vocational school, undergraduate degree, graduate degree, and above).

2.3. Statistical analyses

We first described the sociodemographic characteristics of the sample at baseline. We then investigated whether engagement in leisure activities was associated with concurrent and subsequent depression. Concurrent models included simultaneous leisure activity engagement and depression measurement, with estimates averaged across all waves (2013–2017).

Longitudinal models tested the association between activity engagement in one wave (2013–2017) and depression in the subsequent wave (2013–2017). Thus, the longitudinal model estimated the associations between leisure activity engagement and change in depression after 4 years. We fitted population-averaged panel data models using generalized estimating equations (GEE) with the logit links. This allowed us to include repeated measures, with waves clustered within an individual. We used an exchangeable correlation matrix to optimize model power and efficiency, although GEE is relatively robust to the choice of correlation structure (35). We modeled depression with a binomial distribution, logit link, and robust standard errors. All models were presented before and after adjustment for confounders. Each leisure activity was treated as a continuous variable ranging from daily to monthly to indicate whether there was overall evidence for the moderation effect of the demographic variables on the odds of depression. The missing data on exposures and confounders were imputed using multiple imputations. We used logistic regression according to variable type, generating 20 imputed data sets using all variables included in the analyses. The analyses were performed using R 4.3 and SAS 9.4.

3. Results

In total, 10,968 participants provided data on leisure activities and depression in the three waves of CGSS. More than half of the participants (52.92%) were women, 11.30% did not receive any education, and 73.36% received medium education. The mean age of the participants was 46.01 years. Overall, 16.08% of the sample size met the diagnostic criteria for depression. The prevalence of depression differed according to several socioeconomic and health-related factors, as did the frequency of engagement in leisure activities (Table 3). Specifically, the frequency of engagement differed considerably across leisure activities; moreover, 58.28% of participants participated in Watching weekly, whereas <10% of participants participated in Sewing. After Watching, the most common categories of activity were Internet and Meeting (Table 4).

TABLE 3 A summary of the sample at the baseline and percentage of the sample with depression at the baseline according to demographic characteristics.

	Overall	Depression	
		No	Yes
Overall		9,204 (83.92%)	1,764 (16.08%)
Gender			
Male	5,164 (47.08%)	4,333 (83.91%)	831 (19.09%)
Female	5,804 (52.92%)	4,871 (83.92%)	933 (16.07%)
Education			
None	1,239 (11.30%)	1,038 (83.78%)	201 (16.23%)
Elementary school	2,386 (21.75%)	2,003 (83.95%)	383 (16.05%)
Middle and high school	5,031 (45.87%)	4,200 (83.48%)	831 (16.52%)
Vocational school	63 (5.74%)	51 (80.95%)	12 (19.05%)
College and university	2,066 (18.84%)	1,756 (85.00%)	310 (15.00%)
Graduate and above	183 (1.67%)	156 (85.25%)	27 (14.75%)
Age	46.01 (16.84)		

3.1. Concurrent association

Before adjusting for confounders, we found evidence that more frequent activities, such as Reading, Meeting, Internet, and Exercising were associated with lower odds of depression (Table 5). In contrast, there was no evidence that more frequent Sewing was associated with decreased odds of depression. After adjustment for confounders, there was also no evidence that more frequent Sewing was associated with lower odds of depression. Compared to participants who did not spend time exercising, those exercising weekly had 39% [OR = 0.61, 95% CI (0.50, 0.71)] lower odds of depression, which was very similar to those who reported browsing the internet weekly [OR = 0.57, 95% CI (0.44, 0.70)]. In addition, engagement in exercise showed more of a dose–response relationship with lower odds of depression. Daily, weekly, and monthly participation in sport were respectively associated with a 43% [OR = 0.57, 95% CI (0.49, 0.67)], 39% [OR = 0.61, 95% CI (0.50, 0.71)], and 21% [OR = 0.79, 95% CI (0.60, 0.98)] decrease in the odds of depression when compared to not participating in sports or exercising.

3.2. Longitudinal association

Before adjusting for confounders, we found evidence that indicated that a higher frequency of Reading, Meeting, Internet, and Exercising was associated with lower odds of depression (Table 6), which was the same with the concurrent model. However, in the fully adjusted model, it was evidenced that daily reading was associated with subsequent lower odds of depression. Participants who read daily had 20% [OR = 0.80, 95% CI (0.64, 0.96)] lower odds of depression 4 years later and participants who met with friends or organized activities weekly had 23% [OR = 0.77, 95% CI (0.62, 0.92)] lower odds of subsequent depression. Both weekly and monthly sports and Exercising were associated with a 39% and 21% [weekly 95% CI (0.60, 0.98) and monthly 95% CI (0.5, 0.7)] reduction in the odds of depression 4 years later, respectively. The effects of higher rates of Internet were associated with lower odds of depression 4 years later. Finally, reading weekly was not statistically associated with lower odds of subsequent depression [OR = 0.85, 95% CI (0.67, 1.04)].

3.3. Moderated effects of confounders on association

Before and after adjusting for confounders, we found evidence of interactions between Watching and gender, on the one hand, and of lower odds of depression, on the other hand (Table 7). Men had more than 15% [OR = 0.85, 95% CI (0.72, 0.96)] and 18% [OR = 0.82, 95% CI (0.70, 0.95)] lower odds of depression concurrently and sequentially 4 years later, respectively.

Adjusting for age as a confounder, the more the older adults engaged with the internet, the higher their odds of depression, based on the concurrent and longitudinal models [OR= 1.01, 95% CI (1.00, 1.02)]. Longitudinally, there was one more piece of evidence showing that the association between Meeting and depression differed according to age group, but this was not present in the concurrent model (Table 8). For those who were older, meeting with friends and relatives was associated with 1% lower odds of subsequent depression [OR = 0.99, 95% CI (1.00, 1.01)].

Similarly, for educational levels (Table 9), we found evidence that the higher the participants' education levels, the higher the odds of depression, when looking at the category "Internet" [OR = 1.06, 95% CI (1.01, 1.10)], from the unadjusted model. In contrast, this evidence is not present in the adjusted and longitudinal models.

4. Discussion

We explored the associations between engagement in a wide range of leisure activities and a composite index of mental health

TABLE 4 Frequency distribution of leisure activities at baseline.

Frequency	Reading	Meeting	Watching	Exercising	Sewing	Internet
Daily	1,245 (11.35%)	324 (2.95%)	6,392 (58.28%)	1,998 (18.22%)	202 (1.84%)	4,848 (44.20%)
Weekly	1,189 (10.84%)	1,253 (11.42%)	2,565 (23.39%)	1,926 (17.56%)	333 (3.04%)	906 (8.26%)
Monthly	1,272 (11.60%)	2,926 (26.67%)	818 (7.46%)	906 (8.26%)	527 (4.80%)	242 (2.21%)
None	7,261 (66.21%)	6,464 (59.37%)	1,192(10.87%)	6,137(55.96%)	9,905 (90.35%)	4,971 (45.33%)

TABLE 5 Concurrent models testing the associations between frequency of engagement in leisure activities and the odds of depression.

	Model 1: Unadjusted			Model 2: Adjusted		
	OR	95%CI	*p*-value	OR	95%CI	*p*-value
Watching						
Daily	1.01	0.83–1.18	0.93	0.94	0.77–1.11	0.49
Weekly	0.92	0.74–1.10	0.42	0.94	0.74–1.13	0.53
Monthly	0.87	0.63–1.10	0.30	0.87	0.62–1.12	0.36
Reading						
Daily	0.87	0.71–1.03	0.14	**0.80**	**0.64–0.96**	**0.02**
Weekly	**0.80**	**0.63–0.97**	**0.04**	0.85	0.67–1.04	0.15
Monthly	**0.71**	**0.56–0.86**	**<0.01**	**0.79**	**0.62–0.95**	**0.03**
Meeting						
Daily	1.07	0.77–1.37	0.61	0.98	0.70–1.25	0.88
Weekly	**0.71**	**0.58–0.85**	**<0.01**	**0.77**	**0.62–0.92**	**<0.01**
Monthly	**0.59**	**0.50–0.68**	**<0.01**	**0.68**	**0.57–0.78**	**<0.01**
Exercising						
Daily	**0.64**	**0.54–0.73**	**<0.01**	**0.57**	**0.49–0.67**	**<0.01**
Weekly	**0.57**	**0.47–0.67**	**<0.01**	**0.61**	**0.50–0.71**	**<0.01**
Monthly	**0.72**	**0.55–0.89**	**<0.01**	**0.79**	**0.60–0.98**	**<0.01**
Sewing						
Daily	1.12	0.70–1.53	0.56	1.11	0.69–1.52	0.59
Weekly	0.95	0.64–1.24	0.73	0.92	0.62–1.21	0.60
Monthly	1.02	0.75–1.28	0.88	1.03	0.75–1.30	0.87
Internet						
Daily	**0.22**	**0.19–0.24**	**<0.01**	**0.52**	**0.43–0.61**	**<0.01**
Weekly	**0.34**	**0.26–0.40**	**<0.01**	**0.57**	**0.44–0.70**	**<0.01**
Monthly	**0.32**	**0.19–0.44**	**<0.01**	**0.51**	**0.29–0.71**	**<0.01**

N = 10,968. For all leisure activities, no engagement was the reference category. Model 2 was adjusted for gender, education, and age. The bold text indicates a p-value of <0.05.

in a large nationally representative cohort of adults in China, concurrently and consequently. The study aimed at identifying which types of leisure domains were associated with psychological distress and the possible mechanism behind them. Leisure is well-known for creating a context for social interaction, and it is vital to further investigate whether there is a clear distinction between online and offline scenarios when dealing with the rise in the popularity of online leisure (36, 37), while looking at whether the required social capital is activated equally both online and offline and exploring how different leisure domains can provide benefits to mental health through exercise, cognitive stimulations, and virtual social ties. Such questions are attracting more attention due to online leisure becoming indispensable, especially during a global pandemic.

As expected in the face-to-face and online leisure hypotheses (H1, H2, and H3), participating in sport daily, weekly, or monthly was consistently associated with lower odds of concurrent and subsequent depression (H1). In addition, engagement in sports showed more of a dose–response relationship with lower odds of depression. Meeting with friends or relatives weekly or monthly was consistently associated with lower odds of concurrent and subsequent depression (H2), but there was no evidence to support

TABLE 6 Longitudinal models testing associations between the frequency of engagement in leisure activities and the odds of depression in the subsequent waves (4 years later).

	Model 1: Unadjusted			Model 2: Adjusted		
	OR	95%CI	*p*-value	OR	95%CI	*p*-value
Watching						
Daily	1.01	0.83–1.18	0.93	0.94	0.77–1.11	0.49
Weekly	0.92	0.74–1.10	0.40	0.94	0.74–1.13	0.53
Monthly	0.87	0.63–1.10	0.28	0.87	0.62–1.12	0.36
Reading						
Daily	0.87	0.71–1.03	0.14	**0.80**	**0.64–0.96**	**0.02**
Weekly	**0.80**	**0.63–0.97**	**0.04**	0.85	0.67–1.04	0.15
Monthly	**0.71**	**0.56–0.86**	**<0.01**	**0.79**	**0.62–0.95**	**0.03**
Meeting						
Daily	1.07	0.77–1.37	0.61	0.98	0.70–1.25	0.88
Weekly	**0.72**	**0.58–0.85**	**<0.01**	**0.77**	**0.62–0.92**	**<0.01**
Monthly	**0.59**	**0.50–0.68**	**<0.01**	**0.68**	**0.57–0.78**	**<0.01**
Exercising						
Daily	**0.64**	**0.54–0.73**	**<0.01**	**0.57**	**0.49–0.67**	**<0.01**
Weekly	**0.57**	**0.47–0.67**	**<0.01**	**0.61**	**0.50–0.71**	**<0.01**
Monthly	**0.72**	**0.55–0.89**	**<0.01**	**0.79**	**0.60–0.98**	**<0.01**
Sewing						
Daily	1.12	0.70–1.53	0.58	1.11	0.69–1.52	0.59
Weekly	0.95	0.64–1.24	0.73	0.92	0.62–1.21	0.60
Monthly	1.02	0.75–1.28	0.88	1.02	0.75–1.30	0.87
Internet						
Daily	**0.22**	**0.19–0.24**	**<0.01**	**0.52**	**0.43–0.61**	**<0.01**
Weekly	**0.34**	**0.26–0.40**	**<0.01**	**0.57**	**0.44–0.70**	**<0.01**
Monthly	**0.32**	**0.19–0.44**	**<0.01**	**0.51**	**0.29–0.71**	**<0.01**

N = 10,968. For all leisure activities, no engagement was the reference category. Model 2 was adjusted for gender, education, and age. The bold text indicates a p-value of <0.05.

the association between meeting daily and depression. Moreover, leisure activities that involve social connections are particularly beneficial for protecting mental health (38, 39). Similarly, we have found that both participating in sports or attending fitness clubs and meeting friends or relatives were most strongly associated with lower odds of depression. Interestingly, experiencing leisure through browsing the internet was also strongly associated with lower odds of depression (H3). To understand these virtual interaction benefits, we can posit that virtual interactions through the internet provided feelings of support and care from virtual networks, which may involve the causal mechanism of how social capital is activated (25, 40). For example, one active benefit of the internet is the provision of social resources that can reduce loneliness (41), which helped answer the research hypothesis (H3), i.e., whether online leisure should be associated with a lower probability of mental depression due to activating social capital.

Another objective of the current study was to investigate whether leisure activities involving different types of cognitive stimulations—active vs. receptive—provide different benefits in terms of preventing depression from the cognitive therapy perspective. The results indicated that reading weekly was associated with lower odds of depression, but only concurrently and not longitudinally (H4). There was no evidence to support that sewing was associated with concurrent and sequent depression (H6), although the reason may be related to the fact that sewing is not popular in China (participatory frequency of <10%). However, we did not only find strong evidence, for example, of the relationship between exercise and depression, but we found strong evidence that the higher the frequency of reading activities, the lower the odds of depression. Monthly reading activities were associated with lower odds of depression concurrently and subsequently, which was consistent with previous research. Leisure activities involving cognitive elements have been shown to have additional effects in reducing the risk of depression in adults (42) and the more obvious effects of cognitive interventions than traditional social engagement for older adults experiencing depression (43). Although it was widely accepted that the primary reasons for Exercising and Meeting in reducing the odds of

TABLE 7 Models testing whether the association between the frequency of leisure activities and the odds of depression differs according to gender.

	Concurrent (n = 10,968)						Longitudinal (n = 10,968)					
	Model 1: Unadjusted			Model 2: Adjusted			Model 1: Unadjusted			Model 2: Adjusted		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Watching	**0.85**	**0.72–0.96**	**0.02**	**0.82**	**0.70–0.95**	**0.01**	**0.85**	**0.72–0.97**	**0.01**	**0.82**	**0.70–0.95**	**0.01**
Reading	0.90	0.79–1.01	0.08	0.94	0.82–1.06	0.34	0.90	0.79–1.01	0.08	0.94	0.83–1.16	0.34
Meeting	1.06	0.96–1.15	0.24	1.05	0.95–1.15	0.34	1.06	0.96–1.16	0.24	1.05	0.95–1.14	0.33
Exercising	1.00	0.87–1.12	0.99	0.97	0.84–1.09	0.64	1.00	0.87–1.13	0.99	0.97	0.85–1.10	0.64
Sewing	0.93	0.77–1.09	0.41	0.93	0.77–1.09	0.40	0.93	0.77–1.09	0.43	0.93	0.77–1.09	0.40
Internet	1.06	0.86–1.26	0.54	1.09	0.91–1.28	0.29	1.06	0.85–1.26	0.61	1.09	0.91–1.28	0.29

Interaction terms are reported (gender ∗ activity), the female group was the reference category, with each activity treated as continuous to indicate whether there was overall evidence for an interaction. The bold text indicates a p-value of <0.05.

TABLE 8 Models testing whether the association between the frequency of leisure activities and the odds of depression differs according to age.

	Concurrent (n = 10,968)						Longitudinal (n = 10,968)					
	Model 1: Unadjusted			Model 2: Adjusted			Model 1: Unadjusted			Model 2: Adjusted		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Watching	0.99	0.99–1.00	0.97	0.99	1.00–1.01	0.804	1.00	0.99–1.01	0.969	0.99	0.99–1.00	0.809
Reading	0.99	0.99–1.00	0.12	0.99	1.00–1.01	0.224	0.99	0.99–1.00	0.117	0.99	0.99–1.00	0.196
Meeting	1.00	1.00–1.01	0.01	1.00	1.00–1.01	0.032	**0.99**	**1.00–1.01**	**0.002**	**0.99**	**1.00–1.01**	**0.025**
Exercising	0.99	0.99–1.00	0.37	0.99	0.99–1.00	0.229	1.00	0.99–1.00	0.370	0.99	0.99–1.00	0.231
Sewing	0.99	0.99–1.00	0.43	0.99	0.99–1.00	0.461	1.00	0.99–1.00	0.411	0.99	0.99–1.00	0.453
Internet	**1.01**	**1.00–1.02**	**<0.01**	**1.01**	**1.01–1.03**	**<0.01**	**1.01**	**1.00–1.02**	**0.001**	**1.01**	**1.01–1.02**	**<0.001**

Interaction terms are reported (age ∗ activity), with each activity treated as continuous to indicate whether there was overall evidence for an interaction. The bold text indicates a p-value of <0.05.

depression were related to social interactions (44), there were still associations between Reading and depression. Although reading activities do not involve social interactions, the process of reading produces cognitive and imaginative simulations, which is a key element of treatments for depression, such as cognitive behavioral therapy (CBT), and is effective in reducing depressive symptoms (45). In addition, the relationship between Reading and depression was not a direct dose–response relationship, which needs further investigation in the future. In summary, leisure involving cognitive elements should not be limited to reading. Leisure activities containing imaginative and creative elements should be extended into daily life due to the evidence that reading activities provide positive benefits for reducing the odds of depression. In contrast, watching television or movies was not consistently associated with lower odds of depression (H5), which may be related to its sedentary and passive nature (46–48).

When considering the effects of confounders, the effect of Exercising was independent of a range of confounders. However, Watching (e.g., TV, movie at home), Meeting (friends and relatives), and Internet were not consistently associated with depression with the influence of confounders. Specifically, older adults that were sensitive to meeting with friends or relatives were associated with lower odds of depression. More frequent Internet was only associated with higher odds of subsequent depression in those with higher educational backgrounds. Men had more than 15% lower odds of depression than women concurrently [OR = 0.85, 95% CI (0.72, 0.96)], and subsequently 4 years later for Watching, which may be explained by a large proportion of housework taken by women at home traditionally in China. For confounders, we found no evidence that engagement in leisure activities differentially affected depression in men and women except for Watching, which may be related to large gender differences in the frequency of this category. We found age differences in the association between Meeting and depression. For those who were older, the frequency of meeting with friends and relatives was higher, which was associated with lower odds of subsequent depression. Similarly, the higher the educational level of participants, the higher the odds of depression.

5. Strengths and limitations

One of the strengths of the current study was the use of a large nationally representative cohort of adults, which allowed us to investigate population-averaged concurrent and longitudinal associations between leisure activities and depression while controlling for a range of confounders. However, the way in which questions were asked in CGSS limited the investigation of previous factors that influence depression. In addition, one limitation of the measurement

TABLE 9 Models testing whether the association between the frequency of leisure activities and the odds of depression differs according to education.

	Concurrent (n = 10,968)						Longitudinal (n = 10,968)					
	Model 1: Unadjusted			Model 2: Adjusted			Model 1: Unadjusted			Model 2: Adjusted		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Watching	1.00	0.98–1.03	0.61	1.01	0.98–1.03	0.37	1.00	0.98–1.03	0.60	0.99	0.99–1.00	0.37
Reading	1.01	0.99–1.03	0.25	1.01	0.99–1.03	0.26	1.01	0.99–1.03	0.26	0.99	0.99–1.00	0.27
Meeting	0.99	0.97–1.00	0.17	0.99	0.97–1.01	0.70	0.98	0.97–1.01	0.20	0.99	1.00–1.01	0.71
Exercising	0.99	0.97–1.02	0.70	0.99	0.97–1.02	0.94	1.00	0.97–1.01	0.72	0.99	0.99–1.00	0.95
Sewing	1.02	0.98–1.04	0.21	1.02	0.98–1.04	0.26	1.01	0.98–1.04	0.23	0.99	0.99–1.00	0.28
Internet	**1.06**	**1.01–1.10**	**0.01**	1.03	0.98–1.07	0.15	**1.06**	**1.00–1.10**	**0.04**	1.01	1.00–1.02	0.20

Interaction terms are reported (education ∗ activity), with each activity treated as continuous to indicate whether there was overall evidence for an interaction. The bold text indicates a p-value of <0.05.

of engagement was that leisure activities were measured by frequency, without considering other dimensions such as artistic creativity and exercise intensity. Future research should focus on the measurement of different types of creativity, which clearly explain the causality between activity engagement and depression.

6. Conclusion

Our findings indicate that engagement in a wide range of leisure activities is associated with lower odds of depression for adults. Although we found no evidence that a higher frequency of reading activities is associated with lower odds of depression, the results indicated that leisure activities involving active cognitive stimulations provide additional active benefits for reducing depression compared with receptive stimulations. Alternatively, online leisure is another source of social resources that can be helpful in overcoming depression. Given the protective nature of easily accessible activities in lowering depression, policymakers should consider how adults can be supported to engage in leisure activities involving exercise, cognitive stimulations, and virtual social ties. While the current study results have contributed to the existing body of social capital and cognitive behavior theory in the mechanism of mental health protection, an egocentric network behind depression should be not ignored. The core point behind the different modes of leisure mobilizes social resources, and a simulated objective is created and activated at first, giving up an egocentric idea, which will help to further determine which online leisure activities beneficially cultivate participation in communities or group activities that occur in real interactions. Although the potential of online leisure has been evident in our maintenance of ties with peers virtually, close in-person interaction seems to be irreplaceable, and further research on social capital and cognitive behaviors is needed to advance our understanding of how social capital is circulated between the real and digital worlds of leisure and its links with mental health.

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

JB: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, and writing—original draft. ZX: conceptualization, methodology, validation, investigation, resources, writing—review and editing, project administration, and funding acquisition. Both authors contributed to the article and approved the submitted version.

Funding

This study was supported by the National Social Science Funding in China (grant number 22XTY009).

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. *Report on National Mental Health Development in China (2019-2020).*

2. Tanner EK, Martinez IL, Harris M. Examining functional and social determinants of depression in community-dwelling older adults: implications for practice. *Geriatr Nurs.* (2014) 35:236–40. doi: 10.1016/j.gerinurse.2014.04.006

3. Almeida OP, Ford AH, Hankey GJ, Golledge J, Yeap BB, Flicker L. Depression, antidepressants and the risk of cardiovascular events and death in older men. *Maturitas.* (2019) 128:4–9. doi: 10.1016/j.maturitas.2019.06.009

4. Van Sloten TT, Sedaghat S, Carnethon MR, Launer LJ, Stehouwer CDA. Cerebral microvascular complications of type 2 diabetes: stroke, cognitive dysfunction, and depression. *Lancet Diabetes Endocrinol.* (2020) 8:325–36. doi: 10.1016/S2213-8587(19)30405-X

5. Lu Y, Wang Z, Georgakis MK, Lin H, Zheng L. Genetic liability to depression and risk of coronary artery disease, myocardial infarction, and other cardiovascular outcomes. *J Am Heart Assoc.* (2021) 10:e017986. doi: 10.1161/JAHA.120.017986

6. Xiu S, Liao Q, Sun L, Chan P. Risk factors for cognitive impairment in older people with diabetes: a community-based study. *Ther Adv Endocrinol Metab.* (2019) 10:1–11. doi: 10.1177/2042018819836640

7. Stuart H. Reducing the stigma of mental illness. *Glob Mental Health.* (2016) 3:1–14. doi: 10.1017/gmh.2016.11

8. Adams KB, Leibbrandt S, Moon H. A critical review of the literature on social and leisure activity and wellbeing in later life. *Ageing Soc.* (2011) 31:683–712. doi: 10.1017/S0144686X10001091

9. Fancourt D, Steptoe A, Cadar D. Cultural engagement and cognitive reserve: museum attendance and dementia incidence over a 10-year period. *Br J Psychiatry.* (2018) 213:661–3. doi: 10.1192/bjp.2018.129

10. Fancourt D, Tymoszuk U. Cultural engagement and incident depression in older adults: evidence from the English Longitudinal Study of Ageing. *Br J Psychiatry.* (2019) 214:225–9. doi: 10.1192/bjp.2018.267

11. Moreno-Peral P, Pino-Postigo A, Conejo-Cerón S, Bellón D, Rodríguez-Martín B, Martínez-Vizcaíno V, et al. Effectiveness of physical activity in primary prevention of anxiety: systematic review and meta-analysis of randomized controlled trials. *Int J Environ Res Public Health.* (2022) 19:1813. doi: 10.3390/ijerph19031813

12. Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neurosci Biobehav Rev.* (2019) 107:525–39. doi: 10.1016/j.neubiorev.2019.09.040

13. steinman L, Parrish A, Mayotte C, Bravo Acevedo P, Torres E, Markova M, et al. Increasing Social connectedness for underserved older adults living with depression: a pre-post evaluation of PEARLS. *Am J Geriatr Psychiatry.* (2021) 29:828–42. doi: 10.1016/j.jagp.2020.10.005

14. Ryu J, Heo J, Ellis G, Widmer MA. Leisure, eudaimonic behaviour, physical activity and well-being of older adults. *J Leisure Res.* (2022) 53:595–614. doi: 10.1080/00222216.2022.2051115

15. Harley J. The role of attention in therapy for children and adolescents who stutter: cognitive behavioural therapy and mindfulness-based interventions. *Am J Speech Lang Pathol.* (2018) 27:1139–51. doi: 10.1044/2018_AJSLP-ODC11-17-0196

16. Watters ER, Aloe AM, Wojciak AS. Examining the associations between childhood trauma, resilience, and depression: a multivariate meta-analysis. *Trauma Violence Abuse.* (2021) 152483802110293–7. doi: 10.1177/15248380211029397

17. Schultebraucks K, Choi KW, Galatzer-Levy IR, Bonanno GA. Discriminating heterogeneous trajectories of resilience and depression after major life stressors using polygenic scores. *JAMA Psychiatry.* (2021) 78:744–52. doi: 10.1001/jamapsychiatry.2021.0228

18. Nagata S, McCormick B, Piatt J. The effect of leisure coping on depressive symptoms among individuals with depression: examination of potential confounding effects of physical activity and extraversion. *Psychol Health Med.* (2019) 24:654–66. doi: 10.1080/13548506.2018.1557711

19. Kim IH, Kim C-S. "Leisure Life Satisfaction:" Will it have a beneficial impact on depression among older adults in community care settings in Korea? *J Prev Med Public Health.* (2022) 55:398–406. doi: 10.3961/jpmph.22.160

20. Mouratidis K. Built environment and leisure satisfaction: the role of commute time, social interaction, and active travel. *J Transport Geogr.* (2019) 80:102491. doi: 10.1016/j.jtrangeo.2019.102491

21. Zheng W, Huang Y, Wu L. Community and social correlates of leisure activity participation among older adults. *Leisure Stud.* (2022) 41:688–702. doi: 10.1080/02614367.2022.2043417

22. Coppe T, Thomas L, Pantić N, Froehlich DE, Sarazin M, and Raemdonck I. The use of social capital in teacher research: a necessary clarification. *Front Psychol.* (2022) 13:866571. doi: 10.3389/fpsyg.2022.866571

23. Akdere M. Social capital theory and implications for human resource development. *Singapore Manag Rev.* (2005) 27:1–24.

24. Spini D, Morselli D, Elcheroth G, Gauthier J-A, Le Goff J-M, Dasoki N, et al. The LIVES-FORS cohort survey: a longitudinal diversified sample of young adults who have grown up in Switzerland. *Longit Life Course Stud.* (2019) 10:399–410. doi: 10.1332/175795919X15628474680745

25. Lin FH, Yih DN, Shih F-M, Chu C-M. Effect of social support and health education on depression scale scores of chronic stroke patients. *Medicine.* (2019) 98:e17667. doi: 10.1097/MD.0000000000017667

26. Alkahtani S, Aljaloud K, Yakout S, Al-Daghri NM. Interactions between sedentary and physical activity patterns, lean mass, and bone density in Arab Men. *Disease Markers.* (2019) 2019:5917573–6. doi: 10.1155/2019/5917573

27. Nakagomi A, Shiba K, Kondo K, Kawachi I. Can online communication prevent depression among older people? A longitudinal analysis. *J Appl Gerontol.* (2022) 41:167–75. doi: 10.1177/0733464820982147

28. Bano S, Cisheng W, Khan AN, Khan NA. WhatsApp use and student's psychological well-being: Role of social capital and social integration. *Child Youth Serv Rev.* (2019) 103:200–8. doi: 10.1016/j.childyouth.2019.06.002

29. Gardiner C, Geldenhuys G, Gott M. Interventions to reduce social isolation and loneliness among older people: an integrative review. *Health Soc Care Community.* (2018) 26:147–57. doi: 10.1111/hsc.12367

30. Fancourt D, Steptoe A. Cultural engagement and mental health: do socio-economic status explain the association? *Soc Sci Med.* (2019) 236:112425. doi: 10.1016/j.socscimed.2019.112425

31. Johnco C, Wuthrich VM, Rapee RM. The influence of cognitive flexibility on treatment outcome and cognitive restructuring skill acquisition during cognitive behavioural treatment for anxiety and depression in older adults: results of a pilot study. *Behav Res Ther.* (2014) 57:55–64. doi: 10.1016/j.brat.2014.04.005

32. Rogers NT, Fancourt D. Cultural Engagement Is a Risk-Reducing Factor for Frailty Incidence and Progression. *J Gerontol Ser B Psychol Sci Soc Sci.* (2020) 75:571–6. doi: 10.1093/geronb/gbz004

33. Fluharty M, Paul E, Bone J, Bu F, Sonke J, Fancourt D. Difference in predictors and barriers to arts and cultural engagement with age in the United States: a cross-sectional analysis using the Health and Retirement Study. *PLoS ONE.* (2021) 16:e0261532. doi: 10.1371/journal.pone.0261532

34. Dunstan DA, Scott N. Clarification of the cut-off score for Zung's self-rating depression scale. *BMC Psychiatry.* (2019) 19:177. doi: 10.1186/s12888-019-2161-0

35. Twisk JWR. *Applied Longitudinal Data Analysis for Epidemiology: A Practical Guide.* Cambridge, England: Cambridge University Press (2003).

36. Torres EN. Online-to-offline interactions and online community life cycles: a longitudinal study of shared leisure activities. *Leisure Sci.* (2020) 42:32–50. doi: 10.1080/01490400.2017.1392913

37. Schneider J, Malinowski P, Watson PM, Lattimore P. The role of mindfulness in physical activity: a systematic review. *Obesity Rev.* (2019) 20:448–63. doi: 10.1111/obr.12795

38. Elmer T, Stadtfeld C. Depressive symptoms are associated with social isolation in face-to-face interaction networks. *Sci Rep.* (2020) 10:1444. doi: 10.1038/s41598-020-58297-9

39. Neff AJ, Lee Y, Metts CL, Wong AW. Ecological momentary assessment of social interactions: associations with depression, anxiety, pain, and fatigue in individuals with mild stroke. *Arch Phys Med Rehabil.* (2021) 102:395–405. doi: 10.1016/j.apmr.2020.08.007

40. Yoon S, Kleinman M, Mertz J, Brannick M. Is social network site usage related to depression? A meta-analysis of Facebook–depression relations. *J Affect Disord.* (2019) 248:65–72. doi: 10.1016/j.jad.2019.01.026

41. Ivie EJ, Pettitt A, Moses LJ, Allen NB. A meta-analysis of the association between adolescent social media use and depressive symptoms. *J Affect Disord.* (2020) 275:165–74. doi: 10.1016/j.jad.2020.06.014

42. Reynolds F. Managing depression through needlecraft creative activities: a qualitative study. *Arts Psychother.* (2000) 27:107–14. doi: 10.1016/S0197-4556(99)00033-7

43. Jensen A, Bonde L. The use of arts interventions for mental health and wellbeing in health settings. *Perspect Public Health.* (2018) 138:209–14. doi: 10.1177/1757913918772602

44. Axelsdóttir B, Biedilæ S, Sagatun, Åse, Nordheim LV, Larun L. Review: exercise for depression in children and adolescents-a systematic review and meta-analysis. *Child Adolesc Mental Health.* (2021) 26:347–56. doi: 10.1111/camh.12438

45. Laws KR, Darlington N, Kondel TK, McKenna PJ, Jauhar S. Cognitive Behavioural Therapy for schizophrenia - outcomes for functioning, distress and quality of life: a meta-analysis. *BMC Psychol.* (2018) 6:32. doi: 10.1186/s40359-018-0243-2

46. Huang Y, Li L, Gan Y, Wang C, Jiang H, Cao S, et al. Sedentary behaviours and risk of depression: a meta-analysis of prospective studies. *Transl Psychiatry*. (2020) 10:26–26. doi: 10.1038/s41398-020-0715-z

47. Liu H, Da S. The relationships between leisure and happiness-a graphic elicitation method. *Leisure Stud.* (2020) 39:111–30. doi: 10.1080/02614367.2019.1575459

48. Henning G, Stenling A, Bielak AAM, Bjälkebring P, Gow AJ, Kivi M, et al. Towards an active and happy retirement? Changes in leisure activity and depressive symptoms during the retirement transition. *Aging Mental Health.* (2021) 25:621–31. doi: 10.1080/13607863.2019.1709156

frontiers | Frontiers in Public Health

TYPE Review
PUBLISHED 30 May 2023
DOI 10.3389/fpubh.2023.1196199

OPEN ACCESS

EDITED BY
Yasuhiro Mochizuki,
Waseda University, Japan

REVIEWED BY
Susanna Toivanen,
Mälardalen University, Sweden
Marija Jevtic,
University of Novi Sad, Serbia

*CORRESPONDENCE
Catarina F. Martins
✉ ana_catarina_95@hotmail.com

RECEIVED 29 March 2023
ACCEPTED 28 April 2023
PUBLISHED 30 May 2023

CITATION
Martins CF, Soares JP, Cortinhas A, Silva L, Cardoso L, Pires MA and Mota MP (2023) Pet's influence on humans' daily physical activity and mental health: a meta-analysis.
Front. Public Health 11:1196199.
doi: 10.3389/fpubh.2023.1196199

Pet's influence on humans' daily physical activity and mental health: a meta-analysis

Catarina F. Martins[1]*, Jorge P. Soares[1], António Cortinhas[1], Luís Silva[1], Luís Cardoso[2,3], Maria A. Pires[2,3] and Maria P. Mota[1]

[1]Research Centre in Sports Sciences, Health and Human Development (CIDESD), Department of Sport, Exercise and Health Sciences, School of Life and Environmental Sciences (ECVA), University of Trás-os-Montes and Alto Douro (UTAD), Vila Real, Portugal, [2]Animal and Veterinary Research Centre (CECAV), Department of Veterinary Sciences, School of Agrarian and Veterinary Sciences, University of Trás-os-Montes and Alto Douro (UTAD), Vila Real, Portugal, [3]Associate Laboratory for Animal and Veterinary Sciences, University of Trás-os-Montes and Alto Douro (UTAD), Vila Real, Portugal

Abstract: The benefits of the human-animal bond on owners' health and quality of life have been the focus of research in recent decades. However, the results are still inconsistent. Thus, this study aims to investigate whether the presence of a pet, compared to a control group, influences daily physical activity levels and mental health using a meta-analytic method.

Methods: The PubMed, Web of Science, and Scopus databases were searched for all research articles that included pets as an object of study and related mental health and quality of life variables between pet owners and non-owners until April 2022. The PRISMA 2020 checklist was used, and the Downs and Back checklist was used to assess the methodological quality of the studies. Standardized mean differences and 95% confidence intervals were used to assess the difference between a group of pet owners and non-pet owners.

Results: An initial search located 11,389 studies, but only 49 studies fulfilled all requirements. Our results indicate that pets have a moderately significant positive effect on the physical activity of owners compared to non-pet owners. Among the moderating variables, the frequency of physical activity showed a highly significant effect, indicating that owners had a higher frequency of physical activity than non-owners. Moreover, our results indicate a significant impact but with a low effect size of pets on owners' mental health when compared to non-pet owners.

Conclusion: Pet ownership does not seem to influence owners' mental health, but it does influence their physical activity. Specifically, owners show a higher frequency of physical activity than non-owners.

KEYWORDS

active lifestyle, health, pet ownership, physical activity, quality of life

1. Introduction

Pets play an important role in human life and human health (1). Improvements in physical, mental, psychological, and social health have been described in several works (1–7).

Physical activity (PA) is a determinant of health and quality of life and has been indicated for the prevention and treatment of various diseases (8, 9). There is also evidence that the

strength of the relationship between owner and pet is strongly associated with increased PA (10, 11). Once again, dogs are the most commonly reported animals related to the increase in PA (7, 12) possibly due to social support (13), increased motivation to exercise (14, 15), or even the sense of responsibility to take care of the pet (16). Responsibility is often highlighted as a potential strategy to increase PA levels in older adult individuals (10, 17, 18) and in general population (19). However, confounding variables such as housing conditions, pet attachment, and the number of household members can modify the frequency of walks with the pet and interfere with the magnitude of the results.

Nowadays, mental health is one of the main global concerns, with an estimated 970 million people in the world having a mental disorder (20). A mental disorder is a syndrome characterized by cognitive, emotional, or behavioral dysfunction that reflects an impairment in the psychological, biological, or developmental processes underlying mental and behavioral functioning (20). These disorders not only have an impact on an individual's daily life but also entail substantial costs to society (21). According to the OECD, up to 13% of total health spending is directed toward mental health services (22). According to Statista Research, Portugal invested approximately 136.2 million Euros in mental health hospitals in 2019 (23). As a result, several studies have investigated the possible influence of pets on human mental health, including loneliness, depression, anxiety, stress, satisfaction with life, happiness, social support, and other factors.

Interactions with pets have positive influences on the owner, with overall positive effects on mental health, such as reducing depression and anxiety (6, 24). Moreover, owning a pet may increase social connections (25–27). The human-animal bond, strengthened by the acquisition of a pet, is associated with psychological and physical benefits in children, adults, and elders (6, 10, 25, 28, 29). These aspects have a significant overall effect on the mental health of the human population, as their continued failure or dysfunction can translate into poor mental health, possibly contributing to increased morbidity and mortality (30–32). Growing evidence indicates that pets may trigger feelings of comfort, security, and emotional support, which probably have positive effects on humans by counteracting feelings of anger, sadness, anxiety, and depression (24, 33, 34). Considering the importance of social health, evidence supports that relationships with pets confer similar support to humans (35, 36), particularly in cases of mental disorders (37). Dogs have been proposed as promoters for the initiation of shared interpersonal interactions that enhance social networks (e.g., daily walks) (38). Despite the growing literature, contradictory results have been described regarding different human dimensions, namely human health variables and quality of life (15, 39). A possible explanation may rely on the value that the family or the subject gives to the pet, which may interfere with the overall mental and physical benefits of the pet's relationship (40). Some authors have suggested a negative influence of the pet's non-psychological parameters (41, 42) such as lower psychological well-being (18, 30), depression (41), and anxiety (41) compared to Non-Pet Owners (NPOs). Moreover, pet owners (POs) showed a lower perception of health as well as a higher prevalence of disease than non-pet owners (NPOs) of different ages, which may contribute to a worse quality of life in specific situations such as the COVID-19 pandemic (43). Although some studies have pointed out this trend, Mueller et al. (4) highlighted that POs may have adopted the pet as a way to cope with depressive symptoms or other mental disorders they were already experiencing.

As mentioned, despite a large number of studies, some results are contradictory, possibly due to the different variables considered in each study and the different study designs. To our knowledge, no meta-analysis considering this evidence has been published. Therefore, this article aims to (a) estimate the levels of physical activity (PA) of pet owners (PO) and non-pet owners (NPO) and their relation with the quality of life and human health, and (b) quantify the effect of pets on mental health and, consequently, on the quality of life of human beings. The hypotheses tested in this meta-analysis are: H1: PO tends to show higher levels of daily PA than NPO. H2: Pets have a significant and positive influence on the mental health of PO. H3: PO shows better results regarding anxiety, loneliness, depression, stress, life satisfaction and happiness, social support, quality of life, health and well-being, general mental health and resilience, and mood and self-regulation (affections, emotions, relationships) than NPO.

2. Methods

2.1. Search strategy

Electronic database searches were conducted in PubMed, Web of Science, and Scopus for all articles published before April 2022, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (44, 45). The search terms were "Pets" OR "Pet" OR "Pet companion" OR "Pet owner" OR "Human-animal relationship" OR "Pet-interaction" OR "Dog walking" AND "Human health" OR "Quality of life" OR "Benefit" OR "Mental health" OR "Physical health" OR "Health" OR "Life satisfaction" OR "Well-being." The search was adapted for each database as needed, and filters were used to exclude observational studies, reviews, posters, and other studies that were not eligible for meta-analysis.

2.2. Inclusion/exclusion criteria

No studies were excluded based on the type of pet selected since the focus of this study is to investigate the influence of pet ownership on human mental health, daily physical activity, and quality of life. The inclusion criteria for article selection include reporting the impact of animals on human mental health or quality of life, having a control group without any kind of pet, statistical treatment and feasible data for meta-analysis, and writing in English, Portuguese, or Spanish. Articles are excluded if they are reviewing articles, systematic reviews, meta-analyses, or conference reports, have no focus on live animals (for example, robot pets), use pets for animal-assisted therapy, or are studies conducted with working animals. Study selection parameters were not limited to the year of publication, intra-human variability, age of participants, or sample size since the goal of this meta-analysis was to conduct a comprehensive search. However, studies that were published only in abstract form or were not accessible via inter-library loan were excluded from this meta-analysis. Study eligibility was determined individually by the group members, with each study

classified as include, exclude, or unclear. Articles that were classified as "include" or "unclear" by both reviewers were included for full-text review, and any discrepancies in the determination of study eligibility were resolved through mutual consensus.

2.3. Review strategy

After the articles were searched, duplicates were removed using Zotero. The article selection process involved screening the titles and abstracts for inclusion and exclusion criteria. In cases of doubt, the articles were read in their entirety to verify if the study design was suitable for the aim of this meta-analysis. Another reviewer then checked all the excluded and included articles for validity. Subsequently, the included articles were read in their entirety by two reviewers, and any inclusion/exclusion conflicts were resolved by a third and fourth reviewer. An acceptable concordance rate of 90% was predefined. The reviewers achieved a concordance rate of 93%, resolving 19 inclusion/exclusion conflicts.

The references of the included articles were manually searched to identify possible relevant articles that were not included in the initial search, to achieve a wider scope of relevant studies and reduce publication bias. This search was conducted from December 20th, 2021 to April 3rd, 2022.

2.4. Data extraction

Data from each study included in the meta-analysis were double-extracted by two authors into a table using Microsoft Excel software. Disagreement between the extractors, which consisted mainly of small additional details, was easily resolved between all authors.

Data extracted from each study included: title, author(s), journal, year of publication, study, characteristics (date of data collection, study design), participant characteristics (age, sample sizes), outcomes, intervention description, control condition description, adverse effects, adherence, dropouts, and results.

The identified studies were divided into two groups and assigned to two pairs of reviewers, who independently conducted data extractions and assessed the quality of the studies using the Downs and Black (DB) quality assessment tool (46). The DB tool consists of 27 criteria that assess study reporting (10 items), external validity (3 items), and internal validity, including design, bias, and power (14 items). The maximum score achievable is 27 points. For cross-sectional studies, the modified version of the DB tool was used, which includes 16 criteria that assess study reporting (9 items), external validity (2 items), and internal validity, including design, bias, and power (5 items). The maximum achievable score was 16 points. Any discrepancies in the DB scoring were resolved through consensus among the reviewers (Supplementary material A).

2.5. Data analysis

The Comprehensive Meta-Analysis V2.2.057 software was used for the meta-analysis. Design-specific meta-analyses were conducted for cohort and cross-sectional studies on mental health and PA. Preference was given to the use of mean and standard deviation, and if the not possible, mean difference with a 95% CI was used in all analyses. Separate analyses were performed for PA and mental health.

The statistical heterogeneity was assessed using the Cochran Q (47) test and I^2 statistics (48). We used the random effects model and set the significance level at $p \leq 0.05$. We evaluated the risk of publication bias by visually inspecting the funnel plot and using the Egger test (49) and Begg's test (50). Subgroup analyses of mental health were performed by grouping the age of the sample into three categories: children and adolescents (≤18), adults (≥18 to ≤60), and older adults (≥60). Subgroup analyses also included domain-specific analyses of mental health, such as loneliness, depression, anxiety, stress, life satisfaction and happiness, social support, quality of life, health and well-being, general mental health and resilience, and humor and self-regulation (affections, emotions, relationships). Subgroup analyses of PA considered the domain-specific of physical activity (measured by minutes, frequency, counts, and mets), as well as the form of data collection and defined age groupings. Notably, if a study reported results for more than one specific type or domain of PA separately (e.g., walking and gardening), all types of PA were included in the analysis as independent variables. However, if a study also reported on the wider spectrum of physical activity measures (e.g., total PA, total LTPA), only the broader measure was used to avoid duplication.

3. Results

3.1. Search and screening

A total of 11,389 records were identified in the electronic databases. After removing duplicates and articles irrelevant to the analysis, 289 full-text publications were assessed for eligibility. Based on the inclusion and exclusion criteria, 238 articles were also excluded. A total of 49 articles met the eligibility criteria and were included in this meta-analysis. Details of the search strategy are provided in Figure 1.

3.2. Included study characteristics

From a total of 320,971 participants, 10,233 were children and adolescents, 79,108 adults, and 2,308 were old adults.

Of the 49 included studies that evaluated pet ownership and its influence on mental health and daily PA parameters. Regarding mental health, 27 were concerned (4, 24, 25, 30, 43, 51–73). The distribution of these articles by subcategory of mental health can be observed in Table 1. Relative to physical activity 22 studies were considered for analysis (10, 12, 13, 16, 29, 74–77, 79–90). Additionally, 5 studies were included in both analyses (13, 74–77). Descriptive data of the included studies are presented in Tables 2, 3 for PA and mental health, respectively.

3.3. Pet influence on physical activity

The main analysis showed that pets had a significant and positive effect on the PA of owners compared to non-owners, with an effect of moderate and significant magnitude (Cohen's d = 0.554; $p = 0.000$;

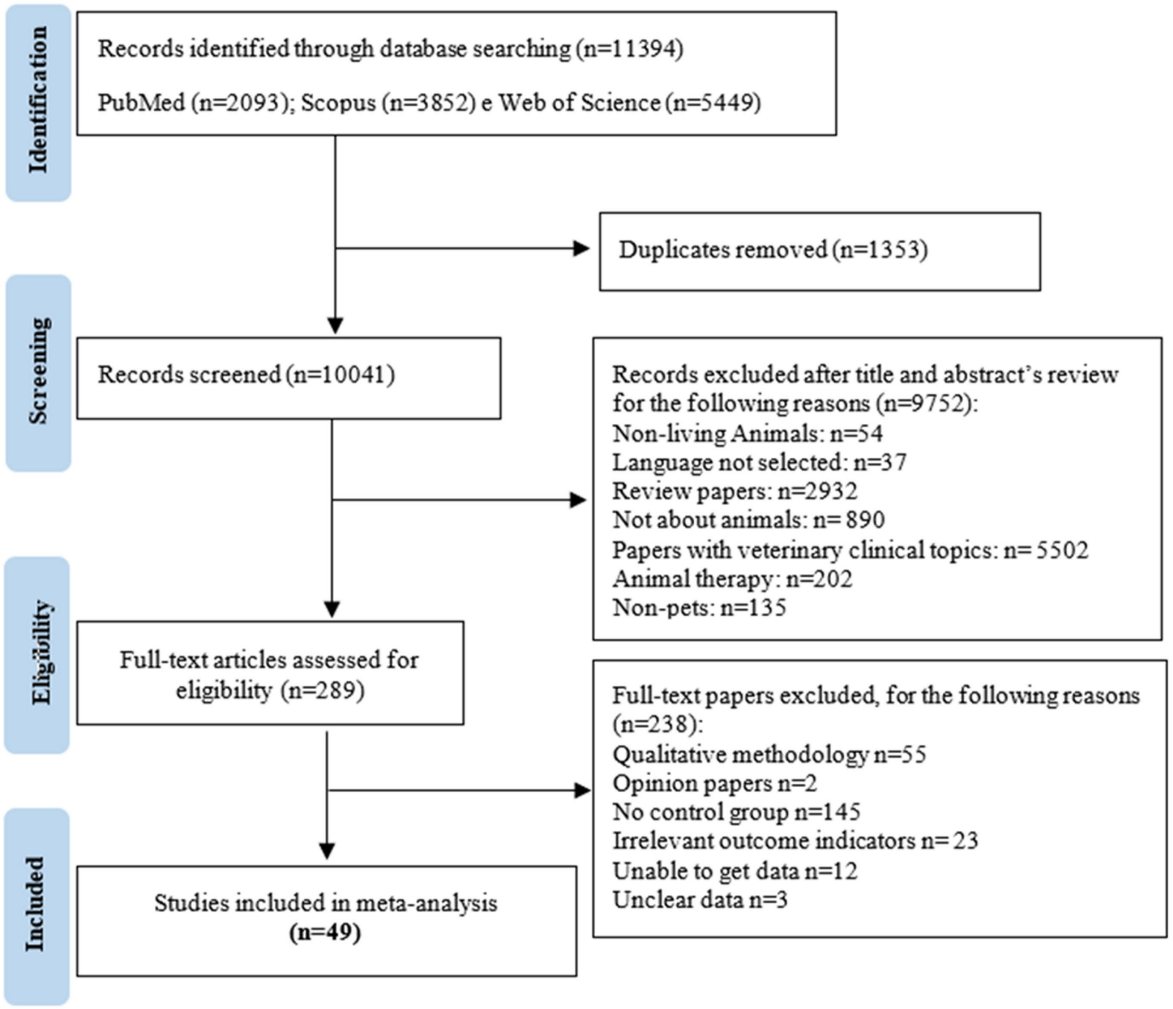


FIGURE 1
Flowchart of the search strategy to include studies.

Figure 2). The studies showed high heterogeneity (I^2 = 99.586%; p = 0.000). Although the asymmetry in the funnel plot indicated a likelihood of publication bias, it was not confirmed by Begg's (p = 0.06171) and Egger's (0.21448) tests.

Regarding the analysis of moderating variables by owner's age group there was a significant and positive influence but of low magnitude in adults (Cohen's d = 0.009; 95% CI [0.001–0.016]; p = 0.000), and older adults (Cohen's d = 0.009; 95% CI [0.135–0.184]; p = 0.000). No significant values were observed in children. The results indicated a moderate and high heterogeneity (I^2 = 99.932%, I^2 = 99.063%, respectively, for adults and older adults).

Considering the analysis of the PA moderator variables, the frequency of performing physical activity showed a high magnitude (Cohen's d = 1.386; 95% CI [1.297–1.476]; p = 0.000), with high heterogeneity (I^2 = 99.574%). The moderator variables of PA counts (Cohen's d = 0.423; 95% CI [0.295–0.551]; p = 0.000) and Met (Cohen's d = 0.147; 95% CI [0.124–0.171]; p = 0.000) showed low but significant effect magnitude. Duration did not show a significant value. The heterogeneity presented in the significant variables was high (I^2 = 99.917%, I^2 = 72.678%, respectively for met and counts).

The analysis of the moderating variables regarding the instruments used for measuring PA revealed a small effect magnitude for the objective (Cohen's d = 0.180; 95% [0.136–0.224)]; p = 0.000) and subjective measure (Cohen's d = 0.018; 95% [0.010–0.025]; p = 0.000), but significant. The heterogeneity presented was high for both objective (I^2 = 81.523%) and subjective (I^2 = 99.923%) moderating variables.

3.4. Pet influence on mental health

In the main analyses, it was found that pets have a significant and positive effect on owners. Additionally, a significant and positive effect on owners' mental health was reported, albeit of low magnitude (p = 0.021; Cohen's d = 0.068; Figure 3). The studies showed high heterogeneity (I^2 = 95.987%; p = 0.000). However, the symmetric funnel plot analysis revealed a low risk of publication bias, as evidenced by Begg's (p = 0.11060) and Egger's tests (p = 0.34245) (Supplementary material B).

Owner's age group as a moderating variable has a significant and positive influence but of low magnitude in children (Cohen's d = 0.030;

TABLE 1 Distribution of articles by subcategory of mental health.

1	2	3	4	5	6	7	8	9	Author[a]
■			■	■		■			Amiot et al. (30)
■									Antonacopoulos (51)
	■								Ballin et al. (74)
■									Black (25)
■	■	■	■	■	■				Bennett et al. (24)
	■	■	■			■			Bradley and Bennett (52)
■	■		■						Branson et al. (53)
				■		■			Brkljacic et al. (54)
					■		■		Canady and Sansone (55)
■	■				■	■			Carr et al. (75)
								■	Cloutier and Peetz (56)
				■	■	■			Curl et al. (57)
						■	■	■	Endo et al. (58)
	■	■			■	■	■	■	Feng et al. (76)
	■	■	■			■	■		Grajfoner et al. (59)
■	■				■		■		Hajek and König (60)
					■				Hill et al. (61)
				■					Kim and Chun (62)
					■	■	■	■	Mičková et al. (77)
■									Mueller et al. (78)
								■	Muldoon et al. (63)
					■				Muraco et al. (64)
■	■	■	■			■	■		Phillipou et al. (43)
					■	■			Pruchno et al. (65)
			■	■		■	■		Ramírez and Hernández (66)
				■		■	■		Reis et al. (67)
			■	■					Roux and Wright (68)
	■					■			Taniguchi et al. (13)
	■	■	■			■	■		Teo and Thomas (70)
	■	■						■	Watson and Weinstein (71)
		■							Wright et al. (72)
						■	■		Wright et al. (73)

1 – Loneliness; 2 – Depression; 3 – Anxiety; 4 – Stress; 5 – Life satisfaction and happiness; 6- Social Support; 7 – Quality of life, health and well-being; 8 – General mental health and resilience; 9 – Humor and self-regulation (affections, emotions, relationships).[a]The articles have been arranged in alphabetical order.

95% CI [0.009–0.05; $p = 0.005$]), adults (Cohen's d = 0.037; 95% CI [0.0024–0.05]; $p = 0.000$), and older adults (Cohen's d = 0.091; 95% CI [0.061–0.121]; p = 0.000). The results indicated a moderate and high heterogeneity of moderating variables by owner's age group ($I^2 = 98.397\%$, $I^2 = 77.605\%$, $I^2 = 60.934\%$, respectively for children, adults, and older adults).

Considering the analysis of moderating variables by mental health, all showed a low effect magnitude but with a significant and positive influence on the humor and self-regulation (affections, emotions, relationships; Cohen's d = 0.241; 95% CI [0.203–0.280]; $p = 0.000$), social support (Cohen's d = 0.100; 95% CI [0.064–0.137]; p = 0.000) life satisfaction and happiness (Cohen's d = 0.063; 95% CI [0.044–0.081]; p = 0.000). Loneliness had a significant influence, but a negative effect (Cohen's d = −0.036; 95% CI [−0.088–0.017]; $p = 0.005$), anxiety, loneliness depression, stress, life satisfaction and happiness, social support, quality of life, health and well-being, general mental health and resilience showed low magnitude and non-significant values. Despite exploration among the moderating variables, heterogeneity remained moderate to high ($I^2 = 0.000\%$, $I^2 = 82.205\%$, $I^2 = 65.479\%$, $I^2 = 66.963\%$, $I^2 = 83.883\%$, $I^2 = 67.735\%$, $I^2 = 740{,}739\%$, $I^2 = 76.147\%$, $I^2 = 97.371\%$, respectively for anxiety, loneliness depression, stress, life satisfaction and happiness, social support, quality of life, health and well-being, general mental health and resilience, humor and self-regulation (affections, emotions, relationships).

TABLE 2 Studies reference to physical activity.

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Ballin (74)	Sweden	DO = 199; NDO = 1,207	Older adult	Dog	"Investigated the association of DO with accelerometer-measured PA of different intensities and daily steps in 70-year-old individuals"	Accelerometer: LPA Accelerometer: MVPA Accelerometer: Steps	Mins/wk Mins/wk Counts	283.2 (77.4) 43.4 (30.3) 8,712 (3724)	266.7 (75.8) 32.6 (23.1) 7,131 (2932)	"DO was associated with higher levels of daily LPA. MVPA. and steps"	15
Byers (80)	USA	DO = 10; NDO = 21	Adults	Dog	"Understanding how owner-pet bonding can leverage increased PA for owner and pet"	Pedometer: Steps	Counts/day	1st Evaluation 8,040 (978) 2nd Evaluation 8,734 (3252)	1st Evaluation 8,349 (972) 2nd Evaluation 8,940 (2845)	"Both groups increased the number of daily steps from pre to post"	24*
Brown and Jensen (79)	USA	T = 536	Adults	Dog	"Examines whether perceived and audited walkability and activity differentiate across three dog owner and walker groups. With separate analyses across 2 years"	IPAQ: Walk to get places IPAQ: Walk for leisure Accelerometer: LPA Accelerometer: MVPA	Mins/wk Mins/wk Mins/day Mins/day	1st Evaluation 326.20 (422.06) 2nd Evaluation 281.24 (382.86) 1st Evaluation 289.83 (386.34) 2nd Evaluation 383.48 (445.86) 1st Evaluation 216.76 (52.45) 2nd Evaluation 221.41 (53.34) 1st Evaluation 19.97 (17.05) 2nd Evaluation 20.70 (17.70)	1st Evaluation 311.27 (374.55) 2nd Evaluation 300.08 (389.98) 1st Evaluation 233.27 (339.61) 2nd Evaluation 269.74 (370.29) 1st Evaluation 210.21 (60.90) 2nd Evaluation 215.57 (64.78) 1st Evaluation 20.59 (18.08) 2nd Evaluation 21.75 (18.31)	"Dog walkers reported high levels of leisure walking. But these high levels were not corroborated by objective accelerometer measures"	23*

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Brown and Rhodes (16)	Canada	DO = 70; NDO = 281	Older adults	Dog	"Examined the relationship between walking. PA levels. and potential psychological mediators between people who owned dogs and those who did not own dogs in the Capital Region District of Greater Victoria. British Columbia. Canada"	GLTEQ: Mild walking GLTEQ: Moderate walking GLTEQ: Strenuous walking GLTEQ- Walking GLTEQ- Mild PA GLTEQ- MPA GLTEQ- Strenuous PA	Freq/wk Mins/wk Mins/wk Mins/wk Freq/wk Mins/wk Mins/wk	137.79 (182.72) 136.39 (164.46) 28.43 (64.19) 300.18 (223.38) 155.62 (189.30) 164.93 (179.79) 82.71 (108.05)	59.27 (89.43) 89.55 (111.54) 19.80 (60.79) 168.38 (163.62) 96.41 (131.37) 115.21 (129.54) 72.30 (127.19)	"The analyses revealed that dog owners spent more time in mild and MPA and walked an average of 300 min per week compared to non– dog owners who walked an average of 168 min per week"	15
Carr (75)	Canada	DO = 20; NDO = 36	Adults with chronic low back pain	Dog	"Explore whether a relationship exists between dog ownership and well-being for people with chronic LBP"	GLTEQ	Mins/wk	56.95 (11.23)	56.81 (15.42)	"The two groups do not differ significantly in their physical functioning or physical health"	13

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Coleman (81)	USA	DO walker = 429; DO non-walker = 183; NDO = 1,578	Adults	Dog	"Examined how demographics PA. weight status. and neighborhood characteristics varied among households with and without dogs"	Accelerometer: MVPA	Mins/day	Owner walker 35 (24) Non-walker 27 (21)	33 (24) 33 (24)	"Dog walking was associated with a higher proportion of participants who met national recommendations for MVPA when compared to non-dog owners"	15
Corrigan (82)	USA	DO = 54; DO = 57 DO = 74; NDO = 28; NDO = 32; NDO = 33	Adults	Dog	"Determine whether there was a relationship between dog ownership and PA"	IPAC: MPA IPAC: VPA IPAC: Walking	Mins/wk Mins/wk Mins/wk	87.81 (136.23) 116.56 (116.84) 223.53 (188.36)	34.69 (41.62) 80.73 (84.1) 115.27 (119.2)	"Dog ownership was significantly associated with meeting physical activity guidelines in veterinary students"	16
Curl (17)	USA	DO = 173; NDO = 500	Older Adults	Dog	"Explored the associations between dog ownership and pet bonding with walking behavior and health outcomes in older adults"	Self-reports: Frequency MPA Self-reports: Frequency VPA	Freq/wk Freq/wk	Owner walker 2.48 (0.09) Non-walker 1.76 (0.16) Owner walker 1.69 (0.12) Non-walker 0.95 (0.16)	2.10 (0.07) 2.10 (0.07) 1.09 (0.08) 1.09 (0.08)	"Dog walking was associated with more frequent moderate and vigorous exercise and was associated with better physical health or health behaviors"	16

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Dall (10)	United Kingdom	DO = 46; NDO = 42	Older adults	Dog	"Measures of PA and sedentary behavior (SB) provide opportunities to gain insight into both the intensity and pattern of PA and SB. allowing closer scrutiny of the potential relationship between dog ownership and health"	Accelerometer: Walking Accelerometer: Walking at a moderate cadence Accelerometer: Standing Accelerometer: Sedentary	Mins/day Mins/day Hours/day Hours/day	119 (109. 131) 32 (23. 43) 4.44 (4.13. 4.75) 9.94 (9.54. 10.35)	96 (88. 106) 11 (8. 15) 4.35 (4.04. 4.66) 10.25 (9.84. 10.66)	"Owning a dog indicated a large. Potentially health improving. The average effect of 22 min additional time spent walking and 2,760 additional steps per day. With this additional walking undertaken at a moderate intensity cadence. Dog owners had significantly fewer sitting events"	14
Feng (76)	United Kingdom	DO = 50; NDO = 497	Older adults	Dog	"Examine whether dog ownership amongst community dwelling older adults is associated with objectively measured PA"	Accelerometer	Counts	180.853 (13.257)	142.71 (3469)	"Dog ownership is associated with PA in later life"	16

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Dall (83)	USA	DO = 36,984; NDO = 115,645	Postmenopausal women	Dog	"Examine cross-sectional associations between dog ownership and PA measures in a well-characterized. Diverse sample of postmenopausal women"	WHIPAQ: Walking WHIPAQ: Total WHIPAQ: Walking WHIPAQ: Total	Mins/wk Mins/wk MET hour/wk MET hour/wk	87.5 (100.7) 176.8 (182.7) 4.60 (5.92) 11.9 (13.8)	87.2 (99.9) 182.8 (178.9) 4.71 (6.03) 12.6 (13.7)	"Dog ownership is associated with increased PA in older women. Particularly among women living alone. Health promotion efforts aimed at older adults should highlight the benefits of regular dog walking for both dog owners and non-dog owners"	16
Koohsari (84)	Japan	DO = 119; NDO = 574	Adults	Dog	"Examined the associations between dog ownership with objectively-assessed sedentary behaviour and PA among a sample of middle-aged adults in Japan"	Accelerometer: Total sedentary time Accelerometer: sedentary bouts Accelerometer: LPA Accelerometer:MPA Accelerometer:VPA Accelerometer: MVPA	Mins/day Mins/day Mins/day Mins/day Mins/day Mins/day	473.1 (129.9) 155.7 (99.0) 376.9 (115.6) 74.0 (40.1) 1.9 (8.8) 69.2 (38.7)	506.3 (117.6) 175.9 (91) 344.7 (109.1) 67.3 (37.4) 1.9 (5.6) 75.9 (41.7)	"Owning a dog is associated with several types of adult sedentary behaviors. But not medium to high intensity PA"	15

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Lail (85)	Canada	DO = 115; NDO = 313	Adults	Dog	"Investigated the extent to which dog-ownership influences seasonal patterns in neighbourhood-based walking among adults living in highly-variable climate"	NPAQ: Walking for recreation (summer) NPAQ: Walking for recreation (winter) NPAQ: Walking for transportation (summer) NPAQ: Walking for transportation (winter)	Mins/wk Mins/wk Mins/wk Mins/wk	213.6 (206.8) 253.2 (211.8) 59.1 (128.2) 59.9 (112.6)	123.3 (157.7) 107.1 (135.9) 74.9 (123.7) 69.8 (119.3)	"Dog-owners reported more walking for recreation in their neighbourhoods than did non-owners. Both in summer and in winter. Dog-owners and non-owners did not differ in the amount of walking that they reported for transportation. Either in summer or in winter"	16
Machová (86)	Czech Republic	PO = 60; NPO = 51	young adult women	Any type of pet	"Compare PA levels between animal owners and non-owners and to research potential differences between owners of different kinds of animals"	IPAQ: VPA IPAQ: VPA IPAQ: MPA IPAQ: MPA IPAQ: WPA IPAQ: WPA IPAQ: Total PA IPAQ: Total PA	Mins/wk MET-min/wk Mins/wk MET-min/wk Mins/wk MET-min/wk Mins/wk MET-min/wk	77.5 (105) 1920 (3840) 60 (150) 900 (2280) 120 (120) 2,772 (2772) 294 (240) 6212 (4772)	60 (70) 1,080 (2400) 60 (78) 320 (960) 120 (120) 2,376 (2772) 210 (180) 3,990 (3363)	"Animal owners generally reported higher PA levels compared to people who do not own any pets"	13

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Michová (77)	Czech Republic	DO = 26; NDO = 18	Older adults	Dog	"To see if dog ownership affects PA. sleep and self-reported health in a group of older adult people"	Accelerometer: Activity time Accelerometer: Steps IPAQ: VPA IPAQ: MPA IPAQ: Walking IPAQ: VPA IPAQ: MPA IPAQ: Walking IPAQ: Sitting	Mins/day counts/day Mins/wk Mins/wk Mins/wk MET-Min/wk MET-Min/wk MET-Min/wk Mins/day	127 (62) 9,961 (5213) 50 (70) 73 (52) 128 (48) 1,123 (1847) 700 (589) 2,910 (1114) 353 (125)	73 (28) 5,247 (2644) 8 (29) 52 (49) 99 (58) 173 (678) 447 (619) 1904 (1143) 363 (142)	"Dog-owners reported higher total PA time (min/week). MET/min/week spent in walking. and spent calories/week than non-owners"	14
Oka and Shibata (87)	Japan	DO = 930; PO = 793; NPO = 1733	Adults	Any type of pet	"Examined the association between dog ownership and health-related PA among Japanese adults"	IPAC- MVPA IPAC- Walking IPAC- Sedentary behaviour	MET hour/wk MET hour/wk MET hour/wk	DO 17.0 (1.159) Any pet 10.9 (1.229) DO 12.4 (0.757) Any pet 10.5 (0.802) DO 6.4 (0.135) Any pet 6.9 (0.143)	11.7 (0.593) 11.7 (0.593) 9.8 (0.387) 9.8 (0.387) 6.9 (0.069) 6.9 (0.069)	"The dog owners had higher physical activity levels than owners of other kinds of pets and those without any pets. Suggesting that dogs may play a major role in promoting PA"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Richards (12)	USA	DO walker =1,012; DO non-walker =221; NDO = 2,262	Adults	Dog	"The purpose of this study is to determine whether dog owners who walk their dog participate in more PA than dog owners who do not walk their dog and non–dog owners"	Self-reports: MVPA	Mins/wk	Owner walker 200.5 (14.8) Non-walker 198.0 (13.1)	178.3 (11.0)	"Most dog owners did not walk their dog. Dog owners were not more active than non–dog owners. Except when considering the activity obtained via dog walking"	16
Schofield (88)	Australia	DO = 646; NDO = 591	Adults	Dog	"To understand whether dog owners were actually involved in walking their dog. and their feelings about the usefulness of dog ownership for PA"	TAAQ: Accumulated PA TAAQ: Walking for leisure	Mins/wk Mins/wk	334.8 (408.6) 114.9 (197.9)	346.4 (414.9) 108.2 (178.8)	"Results showed that the simple presence of a household dog displayed no relationship to the acquisition of sufficient levels of PA in the overall population"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Taniguchi (13)	Japan	PO = 1,545; NPO = 6,377	Older adults	Dog Cat	"Examined physical function. PA. social function. and psychological function of a population of community-dwelling older Japanese dog and cat owners after controlling for important confounders"	IPAC: VPA IPAC: MPA IPAC: Walking IPAC- MVPA	MET hour/wk MET hour/wk MET hour/wk MET hour/wk	14.1 (32.1) 8.5 (18.5) 25.4 (24.6) 44.7 (54.8)	14.7 (33.3) 7.9 (19.9) 23.1 (22.9) 43.2 (54.8)	"Analysis of variables related to physical function and PA showed that motor fitness scale and walking activity were significantly associated with experience of dog ownership. After adjustment for important socio-demographic and health characteristics"	16

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Thorpe (29)	USA	PO = 594; DO = 96; NDO = 198; NPO = 1939	Older adults	Any type of pet	"Understanding the relationship between pet ownership and PA"	Self-reports: Total time walking Self-reports: Frequency of non-exercise-related walking Self-reports: Frequency of exercise walking Self-reports: Frequency of non-exercise-related walking	Mins/wk Mins/wk Freq/wk Freq/wk	Any pet 69.52 (135.9) DO 75.4 (141.5) NDO 57.8 (123.6) Any pet 2.0 (4.3) DO 2.5 (5.0) NDO 1.1 (2.2) Any pet 1.9 (3.1) DO 2.0 (3.2) NDO 1.6 (2.9) Any pet 2.0 (4.3) DO 2.5 (5.0) NDO 1.1 (2.2)	61.8 (122.3) 1.2 (2.7) 1.7 (2.4) 1.2 (2.7)	"Dog owners were more likely to engage in non-exercise related walking than were non–pet owners. Dog owners reported a greater frequency and duration of walks than either non–pet or non-dog-pet owners. Most of whom had cats"	12

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Westgarth (89)	United Kingdom	DO = 166; DO = 184; NDO = 445; NDO = 18 DO = 168; DO = 186; NDO = 444; NDO = 18 DO = 162; DO = 179 NDO = 441; NDO = 17 DO = 165; DO = 183; NDO = 448; NDO = 18 DO = 169; DO = 187; NDO = 449; NDO = 18 DO = 169; DO = 187; NDO = 449; NDO = 18 DO = 169; DO = 187; NDO = 449; NDO = 18 DO = 169; DO = 187; NDO = 449; NDO = 18 DO = 17; NDO = 11 DO = 10; NDO = 36	Adults and Children	Dog	"First aim of this study was to compare the physical activity of dog owners from UK population with people that do not own a dog. A secondary aim of the study was to investigate whether DO spend more or less time than NDO in more intensive PA than walking"	NPAQ: Walk for recreation NPAQ: Walk for transport NPAQ: MVPA NPAQ: VPA NPAQ: Walk for recreation NPAQ: Walk for transport NPAQ: MVPA NPAQ: VPA Accelerometer: Steps Accelerometer: LMVPA Accelerometer: MVPA CAPANS: Walk for recreation CAPANS: Walk for recreation CAPANS: Walk for transport CAPANS: Walk for transport CAPANS: Total PA	Mins/wk Mins/wk Mins/wk Mins/wk Freq/wk Freq/wk Freq/wk Freq/wk Counts Mins/day Mins/day Freq/wk Mins/wk Freq/wk Mins/wk Mins/wk	[b]Dog walker 322.3 (301.7) DO 93 (300) Dog walker 56.8 (117.7) DO 53 (113) Dog walker 131.4 (184.3) DO 126 (180) Dog walker 51.0 (120.5) DO 51,119) Dog walker 7.9 (5.6) DO 7.3 (6.0) Dog walker 2.5 (4.6) DO 2.4 (4.5) Dog walker 3.0 (5.3) DO 2.9 (5.1) Dog walker 0.9 (1.7) DO 0.9 (1.7) Dog walker 7,523 (2710) 297.1 (70.2) 37.8 (20.3) 6.1 (6.4) 115.0 (97.9) 4.0 (4.2) 179.0 (306.9) 1035.0 (1010.0)	NDO 84 (136) NDO Walkers 7.8 (65.5) NDO 75 (123) NDO Walkers 15.8 (42.6) NDO 127 (190) NDO Walkers 80.2 (124.9) NDO 37.1 (91.4) NDO Walkers 52.2 (103.0) NDO 1.6 (2.2) NO Walkers 10.7 (1.99 NDO 3.0 (3.7) NO Walkers 15.8 (42.6) NDO 2.2 (2.9) NDO Walkers 2.0 (2.6) NDO 0.7 (1.5) NDO Walkers 0.9 (1.6) NDO 6,381 (3215) 276.1 (97.6) 30.3 (21.4) 3.4 (6.1) 61.8 (77.2) 6.4 (5.9) 143.1 (127.8) 565.6 (369.2)	"DO were far more likely than NDO to report walking for recreation. and amongst recreational walkers walked for longer per week. Other PA undertaken did not differ by dog ownership. The odds of DO meeting current physical activity guidelines of 150 min per week were four times greater than for NDO. Children with dogs reported more minutes of walking and free-time (unstructured) activity. Dog ownership is associated with more recreational walking and considerably greater odds of meeting PA guidelines. Policies regarding public spaces and housing should support dog ownership due to PA benefits"	15

(Continued)

10.3389/fpubh.2023.1196199

TABLE 2 (Continued)

Physical activity (PA)											
*The information in columns' purpose and major findings are quoted directly from the original publications.											
						Collected data					
Author (year)[a]	Country	n	Population	Pet	Purpose	Intervention methods	Evaluation exercise	Pet owner M(SD) or IC	Non-owner M (SD) or IC	Major findings	Quality score
Yabroff (90)	USA	DO = 7,348; POcat = 5,397; POcat+dog = 3,529; NPO = 25,240	Adults	Dog Cat	"Explored associations between pet ownership and PA in a large. Ethnically diverse population-based sample in California"	Self-reports: Leisure walking Self-reports: Transportation	Mins/wk Mins/wk	Dog 86.1 (1.6) Cat 61.5 (1.8) Dog; Cat 75.7 (2.3) Dog 43.2 (2.4) Cat 46.5 (4.6) Dog; Cat 46.3 (3.7)	64.6 (1.1) 55.1 (1.3)	"Dog owners were slightly less likely to walk for transportation than were non–pet owners but more likely to walk for leisure than non–pet owners in multivariate analyses"	14

NDO, non-dog owner; DO, dog owner; Intervention methods: AAQ, active Australia questionnaire; GLTEQ, Godin leisure time exercise questionnaire; MPA, moderate physical activity; MVPA, moderate a vigorous physical activity; NPAQ, neighborhood physical activity questionnaire; PA, physical activity; VPA, vigorous physical activity; Wk, week; WHIPAQ, women's health initiative physical activity questionnaire.

*Down's and Black tool uses 27 criteria.

[a]Articles arranged in alphabetical order.

[b]Columns show only the reference values.

10.3389/fpubh.2023.1196199

TABLE 3 Studies concerning mental health.

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Amiot (30)	Canada	T = 1,220	Adults	Any type of pet	"Investigate the differences that may exist between pet vs. non-pet owners in terms of their well-being during the COVID-19 pandemic"	UCLA LSS PStressS Vitality PLF COVID (impact)	2.29 (0.55) 4.35 (1.45) 2.79 (0.62) 4.22 (1.33) 4.57 (1.36) 3.60 (1.32)	2.23 (0.52) 4.53 (1.38) 2.74 (0.57) 4.34 (1.28) 4.75 (1.25) 3.44 (1.23)	"Pet owners reported lower well-being than non-pet owners on a majority of well-being indicators; this general pet ownership effect held when accounting for pet species (dogs, cats, other species) and number of pets owned. Compared to owners of other pets, dog owners reported higher well-being"	14
Antonacopoulos (51)	Canada	DO = 31; NDO = 35	Adults	Dog	"Examining the loneliness levels of adults in the general population who acquired a dog and a control group of non-dog guardians over an 8-month period using both an indirect and a direct measure of loneliness"	UCLA LS	Baseline 44.68 (13.25) 8 months 41.81 (12.10) Baseline 1.06 (1.21) 8 months 0.61 (0.80)	Baseline 46.86 (12.17) 8 months 46.91 (12.71) Baseline 1.00 (0.97) 8 months 1.23 (1.06)	"Changes in loneliness differed for owners and non-owners when assessed with a direct measure (1-item scale). Owners who adopted the dog had lower levels of loneliness from baseline to 8 months compared to non-owners. Loneliness when assessed by indirect measure, having a dog had no effect on loneliness (UCLA scale)"	22*

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Ballin (74)	Sweden	DO = 199; NDO = 1,207	Older adults	Dog	"Investigated the associations of doing with accelerometer-measured in a population-based sample of 70-year-old women and men."	GDS15	1.4 (1.7)	1.2 (1.8)	"DO was associated with higher levels of daily LPA, MVPA, and steps compared to non-owners.	15
Black (25)	USA	PO = 246; NPO = 47	Children	Any type of pet	"To investigate whether pet ownership and pet attachment are related to self-reported loneliness and social support among adolescents"	UCLA	33.7 (8.8)	39.5 (9.2)	"Pet owning adolescents had significantly lower loneliness scores and there was an inverse relationship between the level of bond with pet and levels of loneliness"	13
Bennett (24)	Australia	PO = 41; NPO = 27	Older adults	Dog; Cat; Large mamal; Bird; Fish	"To investigate whether the presence of a pet was associated with the presence and indicators of psychological well-being"	PWI-A PSS UCLA DASS-21: Depression Anxiety Stress	83.78 (13.1) 83.56 (8.2) 34.37 (9.5) 4.20 (5.0) 3.00 (3.7) 8.78 (7.4)	82.59 (11.3) 82.20 (7.1) 34.65 (6.9) 2.07 (2.5) 3.33 (3.1) 8.30 (6.5)	"Having a pet may not be associated with substantial differences in indicators of well-being in older people"	15

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Bradley and Bennett (52)	Australia	PO = 114; NPO = 31	Adults who self-identified as having a chronic pain disorder	Dog; Cat	"Understand why therapy animals relieve pain in healthcare settings, but pet owners report greater discomfort and use more painkillers than people who do not own one or more pets"	DASS-21: Depression Anxiety Stress NPRS	18.10 (12.52) 11.28 (8.15) 17.47 (10.06) 6.14 (1.69)	11.74 (9.57) 10.39 (7.75) 15.35 (8.80) 5.92 (1.8)	"There was no significant difference between reported pain, anxiety, or stress levels in owners versus non-owners. Pet owners reported more depressive symptoms than non-owners, but owners with animals perceived as more friendly reported fewer depressive symptoms"	14
Branson (53)	USA	POcat = 41; NPO = 55	Older adults	Cat	"Determine if attachment to cats was associated with psychosocial responses (stress, depression, and loneliness)"	PStressS UCLA GDS MOCA	[b]$p = 0.45$ $p = 0.83$ $p = 0.22$ $p = 0.37$		"There were no significant changes between biopsychosocial and cognitive health outcomes with cat ownership"	14
Brkljacic (54)	Croatia	PO = 658; NPO = 3,883	Adults	Any type of pet	"Provide deeper insight into the relationship between pet-related life events and the subjective wellbeing of pet owners"	GLS BES SH	7.04 (1.91) 6.92 (2.10) 4.11 (0.79)	7.03 (2.02) 6.91 (2.09) 4.14 (0.82)	"There were no differences significant in subjective well-being indices, general life satisfaction and overall happiness, between the groups"	15

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Canady and Sansone (55)	USA	PO = 153; NPO = 51	Adults	Any type of pet	"Examine whether companion animal owners report that having a companion animal would influence an important health decision, and whether existing social support and quality of the relationship with the companion animal might impact the likelihood of this occurring"	ISEL-12	35.4 (7.1)	34.5 (8.3)	"Having a pet can influence the decision to be hospitalized. It seems likely that social support acts as a buffer. Individuals with good social support entrust the care of their pets to others to receive the medical care they need"	14
Carr (75)	Canada	PO = 20; NPO = 36	Adults with chronic low back pain.	Any type of pet	"Evaluate the feasibility of surveying people with chronic low back pain to empirically assess the relationship between dog ownership and well-being for people with chronic low back pain"	NPRS ODI: Intensity ODI: Walking SF4 Depression Loneliness Emotional support Companionship	6.40 (1.67) 3.65 (0.93) 2.65 (0.93) 2.14 (0.79) 2.81 (1.38) 3.64 (0.98) 3.62 (1.15)	7.00 (1.45) 3.74 (0.95) 2.94 (0.92) 2.73 (1.10) 3.32 (1.51) 3.24 (1.26) 2.99 (1.27)	"Dog owners reported fewer depression and anxiety symptoms, and more social ties than non-dog owners. Living with a dog may be associated with improved well-being for people with chronic pain"	13

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Cloutier and Peetz (56)	Canada	PO = 54; NPO = 62	Adults	Dog; Cat; Fish	"Compared pet owners and non-pet owners perceived relational quality, by assessing a variety of relationship quality facets, and examined whether there is any evidence of an association between pet ownership and quality of relationships"	QRS Responsiveness to Partner DAS RIMS	6.41 (0.56) 5.16 (0.52) 4.84 (0.55) 6.38 (0.76)	6.06 (0.74) 4.86 (0.61) 4.41 (0.73) 6.06 (0.71)	"Pet ownership was associated with several relationship benefits (higher overall relationship quality, partner responsiveness, adjustment, and relational investment) compared to couples without pets"	14
Curl et al. (57)	USA	DO = 188; NDO = 288	Older adults	Dog	"Examine the relationship between dog ownership, dog walking, and the emotional bond with a dog to contact with neighbors and life satisfaction in a nationally representative sample of adults in the United States over the age of 50"	SE LS SRH	1.86 (2.24) 2.78 (0.85) 2.26 (1.07)	1.79 (2.37) 2.91 (0.86) 2.26 (1.04)	"Dog ownership did not have a direct or indirect relationship on life satisfaction. However, time spent in dog walking was associated with the frequency of social interactions, which itself had a positive association with life satisfaction"	15
Endo (58)	Japan	DO = 254; POcat = 109; NPO = 2,230	Children	Dog; Cat	"Examine the effect of dog and cat ownership on the longitudinal trajectory of the mental well-being of adolescents"	WHO-5 (Dog) WHO-5 (Cat)	at age 10 79.42 (16.83) at age 12 77.53 (17.60) at age 10 80.04 (15.65) at age 12 69.69 (21.06)	at age 10 78.98 (16.63) at age 12 75.11 (18.87) at age 10 78.98 (16.63) at age 12 75.11 (18.87)	"Dog ownership and cat ownership differently predicted adolescent"s well-being. The well-being trajectory of dog owners was maintained through adolescence, while that of cat owners declined"	15

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Feng (76)	United Kingdom	DO = 50; NDO = 497	Older adults	Dog	"To assess whether dog ownership in the older adult is associated with objectively measured physical activity"	HADS: Depression HADS Anxiety SF-36: Physical functioning SF-36: General health SF-36: Social functioning SF-36: Role Emotional SF-36: Mental health SF-36: Vitality SF-36: Pain SF-36: Role Physical	2.9 (2.6) 3.4 (2.8) 79 (17) 76 (17) 89 (24) 96 (12) 85 (13) 63 (22) 71 (28) 82 (27)	3.7 (2.7) 4.3 (3.2) 70 (23) 66 (21) 88 (22) 96 (11) 82 (13) 59 (20) 68 (26) 82 (25)	"The results suggest that dog ownership may motivate PA and enable older people to overcome many potential barriers to PA such as lack of social support. The effect of dog ownership on PA was independent of depression and perceived behavioral control but was mediated in part by general health and physical function"	16
Grajfoner (59)	Malaysia	PO = 202; NPO = 224	Adults	Dog; Cat	"Explore both the structure of companion animals in Malaysia and the effect of pets on mental health and wellbeing of Malaysians during the COVID-19"	WEMWBS DASS-21: Depression Anxiety Stress BRS CSE PANAS: Positive Negative	45.35 (10.58) 24.36 (9.66) 22.56 (8.79) 24.92 (9.34) 19.09 (3.19) 88.93 (16.00) 31.56 (7.63) 24.85 (7.95)	43.28 (9.81) 23.54 (9.50) 22.55 (8.91) 24.51 (9.23) 18.87 (3.17) 83.88 (18.74) 29.43 (7.16) 25.08 (6.98)	"Pet owners reported significantly better coping self-efficacy, significantly more positive emotions, and better psychological wellbeing"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Hajek and Konig (60)	Germany	DO = 63; POcat = 145; NPO = 952	Older adults	Dog; Cat	"Identify whether cat owners, dog owners, and individuals without pets differ in terms of depressive symptoms, loneliness, and social isolation among individuals in old age without a partner"	CES-D (dog) CES-D (cat) SI (dog) SI (cat) 11-DJGLS (dog) 11-DJGLS (cat) SRH (dog) SRH (cat) NPI (dog) NPI (cat) SF-36: physical health (dog) SF-36: physical health (cat)	7.3 (6.5) 7.8 (7.3) 1.6 (0.6) 1.7 (0.7) 1.7 (0.5) 1.8 (0.6) 2.7 (0.9) 2.6 (0.8) 3.5 (2.2) 3.5 (1.9) 74.3 (23.3) 75.7 (25.6)	7.2 (6.1) 7.2 (6.1) 1.7 (0.6) 1.7 (0.6) 1.8 (0.6) 1.8 (0.6) 2.6 (0.8) 2.6 (0.8) 3.4 (2.1) 3.4 (2.1) 72.0 (27.2) 72.0 (27.2)	"There was an association between owning a dog and social isolation (total sample) as well as loneliness (total sample and women)"	14
Hill (61)	Australia	PO = 392; NPO = 146	Adults	Any type of pet	"Explore the relationship between the HAB, perceived human social support, and resilience by assessing whether the HAB (human–animal bond) could moderate the impact of social support as a protective factor for resilience"	MSPSS CD-RISC	5.78 (0.96) 49.38 (11.85)	5.74 (0.98) 48.23 (11.48)	"There was no difference in levels of resilience between pet owners and non-owners, but social support was positively associated with resilience for both. The HAB was not a significant moderator between levels of social support and resilience for owners"	13

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Kim and Chun (62)	Korea	PO = 8,708; NPO = 33,979	Adults	Dog; Cat	"Examine the association between companion animal ownership and overall life satisfaction, one measure of human well-being"	GLS	56.02 (10.25)	54.79 (10.68)	"Pet ownership was associated with higher levels of overall life satisfaction"	15
Mičková (77)	Czech Republic	DO = 26; NDO = 18	Older adults	Dog	"To see if dog ownership affects physical activity, sleep, and self-reported health in a group of older adult people"	SF-36: General health SF-36: Health change SF-36: Physical functioning SF-36: Social functioning SF-36: Emotional SF-36: Pain SF-36: Vitality SF-36: Role Emotional) SF-36: Role Physical	72 (15) 47 (11) 88 (12) 90 (18) 80 (12) 78 (19) 67 (15) 86 (29) 85 (27)	46 (14) 43 (14) 72 (22) 76 (18) 69 (13) 62 (22) 47 (6) 83 (26) 71 (33)	"A positive effect on their overall health assessed by SF-36 was observed in most of the monitored parameters. The results suggest that dog walking affects the overall PA of older adults and it brings positive effects on the quality of life"	14
Mueller (78)	USA	PO = 910; NPO = 310	Children	Any type of pet	"Contribute to the emerging research on companion animals and mental health during the pandemic by assessing the relationships between pet ownership, pet attachment, loneliness, and stress coping for adole	LS	Time 1 1.43 (0.52) Time 2 1.62 (0.60)	Time 1 1.47 (0.53) Time 2 1.49 (0.52)	"The results of this study do not support the presence of a buffering effect of companion animals on loneliness for adolescents"	16

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Muldoon (63)	United Kingdom	DO = 2,784; PO = 1992 NPO = 1887	Children	Any type of pet	"To see if within the broader population of children and adolescents, to what extent attachment to dogs: (a) is stronger than attachment to other pets; (b) differs from emotional connections to other animals; and (c) is associated with any specific welfare benefits"	SAPS (dog) SAPS (pet)	[b]d = 0.68 d = 0.25		"Pets, especially dogs, have an impact on well-being when a strong emotional bond is present"	14
Muraco (64)	USA	PO = 1,039; NPO = 1,326	Adults LGBT	Any type of pet	"Understanding whether having a pet is related to perceived social support and social network dimension"	PSS	3.19 (0.76)	2.99 (0.8)	"There is evidence that pets can increase feelings of social support for people with disabilities and limited social networks"	14
Phillipou (43)	Australia	PO = 138; NPO = 125	Adults	Dog; Cat	"Explore the mental health effects of pet ownership during the COVID-19 pandemic lockdown"	DASS-21: Depression Anxiety Stress UCLA BRS EUROHISQoL	13.15 (10.79) 6.38 (7.48) 13.64 (9.43) 9.1 (3.09) 3.2 (0.99) 27.2 (7.27)	11.57 (10.35) 6.14 (7.66) 13.15 (8.82) 8.53 (2.65) 3.3 (0.89) 28.81 (6.61)	"Contrary to expectations, the results suggest that during a specific situation such as a pandemic, pets may contribute to an increased burden on owners and contribute to a worse quality of life"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Pruchno (65)	USA	DO = 1,160; POcat = 947; POdog+ cat = 441; NPO = 2,954	Adults	Dog; Cat	"Examined the associations among human social relationships, owning a dog or a cat, and successful aging"	SS (Dog) SS (Cat) SS (Dog; cat) SSA (Dog) SSA (Cat) SSA (Dog; cat)	4.3 (0.8) 4.2 (0.9) 4.2 (0.9) 23.7 (4.3) 23.1 (4.7) 23.1 (4.4)	4.2 (0.8) 4.2 (0.8) 4.2 (0.8) 23.4 (4.4) 23.4 (4.4) 23.4 (4.4)	"Findings carry practical implications for supporting pet ownership of older people, suggesting that dogs have a positive association with successful aging"	14
Ramírez and Hernández (66)	USA	DO = 377; NDO = 225	Adults	Dog	"Compared the perceived health, perceived stress, life satisfaction, happiness and psychosomatic symptoms in two equivalent groups that differed only in dog ownership"	LSS SHS PHQ PStressS SF-12: Mental health SF-12: Physical health	16.0 (2.8) 22.7 (3.4) 5.3 (3.9) 18.0 (7.3) 51.0 (8.2) 52.8 (6.9)	15.6 (3.0) 22.5 (3.7) 6.0 (3.9) 20.0 (7.2) 48.7 (8.7) 51.9 (7.5)	"Dog owners perceived themselves as healthier but not happier than non-dog owners"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Reis (67)	Portugal	DO = 1764; POcat = 739; POdog+ cat = 901 PO = 520; NPO = 1,211	Children	Any type of pet	"Identify in a large national representative sample of Portuguese adolescents, the percentage of adolescents that have pets, what kind of feelings pets provide, differences by gender and age (through school grades) and to verify whether adolescent health, well-being, life satisfaction, and psychological symptoms are associated with having a pet (in particular dogs or cats)"	Kidscreen-10 (Dog) Kidscreen-10 (cat) Kidscreen-10 (Dog; cat) Kidscreen-10 (pets) LSS (Dog) LSS (Cat) LSS (Dog; cat) LSS (pets) PS (Dog) PS (Cat) PS (Dog; cat) PS (pets)	39.41 (6.62) 38.30 (6.98) 38.44 (6.64) 39.05 (6.70) 7.50 (1.96) 7.18 (1.99) 7.34 (1.94) 7.43 (1.95) 6.55 (1.41) 6.38 (1.46) 6.39 (1.45) 6.54 (1.41)	39.03 (6.79) 39.03 (6.79) 39.03 (6.79) 39.03 (6.79) 7.42 (1.93) 7.42 (1.93) 7.42 (1.93) 7.42 (1.93) 6.52 (1.42) 6.52 (1.42) 6.52 (1.42) 6.52 (1.42)	"Having a dog was associated with a higher socio-economic status. Better perception of well-being. More life satisfaction and less psychological symptoms"	15
Roux and Wright (68)	Africa	PO = 3,108; NPO = 221	Adults	Dog; Cat	"Investigate whether pet attachment was related to perceived stress and life satisfaction in a sample of South Africans"	PSS SWLS	17.9 (7.16) 23.4 (6.79)	18.1 (6.09) 22.9 (7.11)	"Dog owners were significantly more attached to their dogs. Significantly more satisfied with their lives and had significantly less stress than cat owners"	14

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Taniguchi (13)	Japan	PO = 1,545; NPO = 6,377	Older adults	Dog; Cat	"Evaluated physical function. PA. social function. and psychological function of a population of community-dwelling older Japanese dog and cat owners":	GDS-5 WHO-5	1.2 (1.3) 62.5 (23.3)	1.3 (1.3) 60.2 (24.4)	"Caring for a dog or cat might be an effective health promotion strategy to increase physical activity and facilitate social participation among older adults"	16
Teo and Thomas (70)	Australia	DO = 332; PO = 332; NPO = 176	Adults	Any type of pet	"Compare multi-faceted QOL. psychological distress. and psychopathology of pet owners and non-pet owners"	DASS-21 Depression(dog) Depression (pets) Anxiety (dog) Anxiety (pets) Stress (dog) Stress (pets) BSI (dog) BSI (pets) WHOQOL (dog) WHOQOL (pets)	8.67 (8.87) 7.85 (9.50) 6.01 (6.86) 5.37 (7.21) 11.08 (8.29) 8.65 (7.80) 0.79 (0.62) 0.67 (0.59) 58.30 (9.04) 58.44 (8.71)	7.05 (8.36) 7.05 (8.36) 5.56 (6.12) 5.56 (6.12) 8.78 (7.57) 8.78 (7.57) 0.66 (0.58) 0.66 (0.58) 58.54 (9.82) 58.54 (9.82)	"Pet owners and non-owners did not differ significantly in terms of well-being"	14
Watson and Weinstein (71)	USA	PO = 42; NPO = 42	Adults women	Dog; Cat	"Explore the potential psychological benefits of pet ownership among working women"	BDI STAI STAXI: state STAXI: trait	5.5 (4.1) 32.5 (10.2) 10.9 (2.5) 17.5 (4.6)	6.0 (4.5) 35.9 (9.4) 11.0 (1.7) 18.8 (4.2)	"Results revealed that there were no significant differences between owners" and non-owners"	13
Wright (72)	United Kingdom	DO = 14; NDO = 26	Children with autism	Dog	"Investigate the potential of dogs to improve family functioning in families with children with autism and explore the effects of pet dogs on anxiety in these children"	CAS	Baseline 0.33 (0.05) Follow-Up 0.30 (0.04)	Baseline 0.26 (0.03) Follow-Up 0.23 (0.03)	"Acquisition of a dog may be associated with improvements in family functioning and child anxiety"	23*

(Continued)

10.3389/fpubh.2023.1196199

TABLE 3 (Continued)

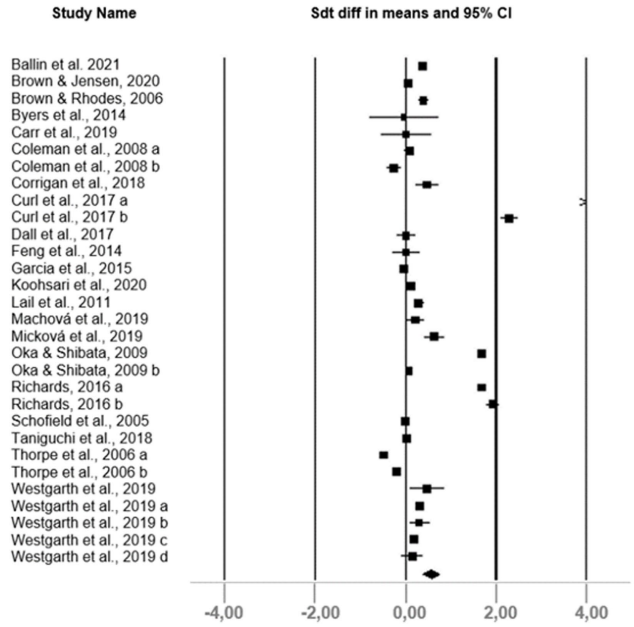
Mental Health										
*The information in columns' purpose and major findings are quoted directly from the original publications.										
							Collected data			
Author (year)[a]	Country	N	Population	Pet	Purpose	Intervention methods	Pet owner M(SD)	Non-pet owner M(SD)	Major findings	Quality score
Wright (73)	USA	DO = 36; POcat = 15; NDO = 47; NPO = 9	Adults LGBT	Dog; Cat	"Understanding the relationship between pet companionship and quality of life outcomes in sexual minority prostate cancer survivors"	SF-12	46.05 (10.34) 50.8 (11.4)	48.5 (10.26) 51.4 (8.34)	"Pet companionship may be a net stressor for gay and bisexual men following prostate cancer treatment"	14

PO, pet owner; NPO, Non-pet owner; N, sample size; SD, standard deviation; M, mean. instruments: BDI, beck depression inventory; BES, subjective happiness scale; CAS, children's anxiety scale; CD-RISC, the Connor-Davidson resilience scale; CES-D, depression scale; DAS, dyadic adjustment scale; DASS-21, depression anxiety stress scale; GDS-5, geriatric depression scale; GHQ-30, 30-item general health questionnaire; GLS, general life satisfaction; HADS, hospital anxiety and depression score; ISEL-12, interpersonal support evaluation; LS, loneliness scale; LSS, life satisfaction scale; MOCA, the Montreal cognitive assessment; MSPSS, multidimensional scale of perceived social support; NPI, number of physical illnesses; NPRS, numeric pain rating scale; ODI, Oswestry disability index; PHQ, patient health questionnaire; PLF, presence of life meaning; PS, psychological symptoms; PSS, perceived social support; PStressS, perceived stress scale; PWI-A, personal wellbeing index-adult; QRS, quality of relationship scale; RIMS, Rusbult investment model scale; SAPS, short attachment to pets scale; SE, social engagement; SF4, anxiety and depression scale (PROMIS); SF-12, short form health survey; SF-36, health survey; SH, subjective health; SHS, subjective happiness scale; SI, social isolation; SRH, self-rated health; SS, social support; SSA, subjective successful aging; STAI, StateTrait anxiety inventory; STAXI, state–trait anger expression inventory; SWLS, satisfaction with life scale; UCLA, loneliness scale; WHO-5, Weel-being index; 11-JGLS, 11-item De Jong Gierveld- Loneliness scale; PSS, perceived stress scale.*Down's and Black tool uses 27 criteria.

[a]Articles arranged in alphabetical order.

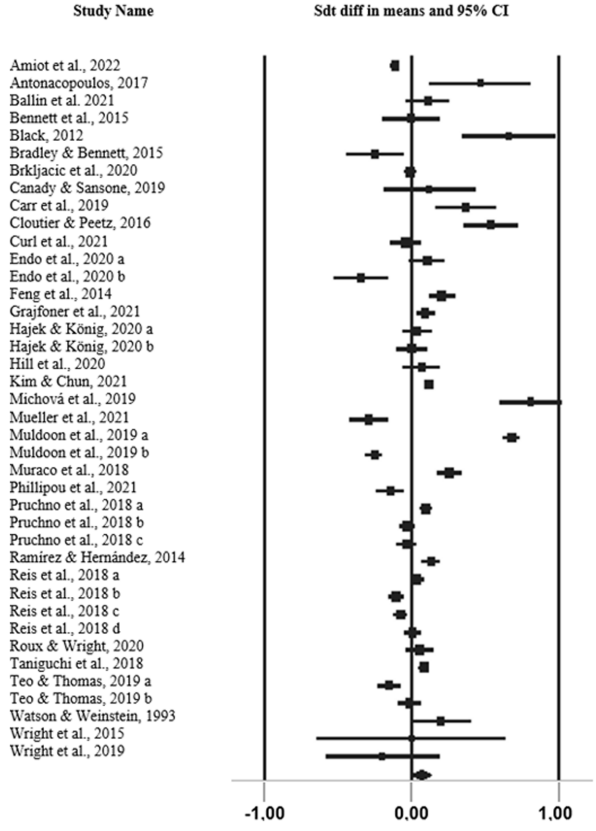
[b]General results selected due to the absence of mean and standard deviation measures.

10.3389/fpubh.2023.1196199



Study Name	Std diff in means	Standard error	Variance	Lower limit	Upper Limit	Z-Value	P- Value
	Statistics for each study						
Ballin et al. 2021	0,393	0,044	0,002	0,306	0,480	8,841	0,000
Brown & Jensen, 2020	0,054	0,031	0,001	-0,006	0,114	1,757	0,079
Brown & Rhodes, 2006	0,396	0,051	0,003	0,296	0,496	7,782	0,000
Byers et al., 2014	-0,033	0,384	0,148	-0,786	0,720	-0,086	0,932
Carr et al., 2019	0,010	0,279	0,078	-0,537	0,557	0,036	0,972
Coleman et al., 2008 a	0,083	0,054	0,003	-0,023	0,190	1,530	0,126
Coleman et al., 2008 b	-0,253	0,078	0,006	-0,406	-0,100	-3,236	0,001
Corrigan et al., 2018	0,485	0,129	0,017	0,232	0,738	3,760	0,000
Curl et al., 2017 a	5,629	0,126	0,016	5,382	5,876	44,694	0,000
Curl et al., 2017 b	2,283	0,094	0,009	2,099	2,467	24,340	0,000
Dall et al., 2017	0,016	0,110	0,012	-0,200	0,232	0,145	0,885
Feng et al., 2014	0,012	0,148	0,022	-0,279	0,302	0,078	0,938
Garcia et al., 2015	-0,025	0,004	0,000	-0,033	-0,017	-5,900	0,000
Koohsari et al., 2020	0,132	0,041	0,002	0,052	0,213	3,217	0,001
Lail et al., 2011	0,294	0,055	0,003	0,186	0,402	5,320	0,000
Machová et al., 2019	0,228	0,096	0,009	0,041	0,416	2.387	0,001
Micková et al., 2019	0,633	0,112	0,012	0,414	0,852	5,668	0,000
Oka & Shibata, 2009	1,672	0,048	0,002	1,578	1,767	34,628	0,000
Oka & Shibata, 2009 b	0,079	0,026	0,001	0,028	0,129	3,062	0,002
Richards, 2016 a	1,685	0,043	0,002	1,601	1,770	39,035	0,000
Richards, 2016 b	1,926	0,076	0,006	1,778	2,074	25,476	0,000
Schofield et al., 2005	0,004	0,040	0,002	-0,075	0,083	0,090	0,928
Taniguchi et al., 2018	0,035	0,014	0,000	0,007	0,062	2,445	0,014
Thorpe et al., 2006 a	-0,486	0,019	0,000	-0,523	-0,449	-25,699	0,000
Thorpe et al., 2006 b	-0,181	0,048	0,002	-0,274	-0,087	-3,792	0,000
Westgarth et al., 2019	0,472	0,192	0,037	0,096	0,848	2,458	0,014
Westgarth et al., 2019 a	0,306	0,046	0,002	0,217	0,396	6.699	0,000
Westgarth et al., 2019 b	0,304	0,113	0,013	0.083	0,525	2,694	0,007
Westgarth et al., 2019 c	0,195	0,044	0,002	0,108	0,282	4.404	0,000
Westgarth et al., 2019 d	0,147	0,125	0,016	-0,098	0,391	1.177	0,239
	0,554	0,092	0,008	0,374	0.734	6,026	0,000

FIGURE 2
Forest plot of pet influence in physical activity ownership.



Study Name	Std diff in means	Standard error	Variance	Lower limit	Upper Limit	Z-Value	P-Value
	Statistics for each study						
Amiot et al., 2022	-0,113	0,017	0,000	-0,145	-0,081	-6,834	0,000
Antonacopoulos, 2017	0,470	0,177	0,031	0,122	0,818	2,648	0,008
Ballin et al. 2021	0,112	0,077	0,006	-0,038	0,262	1,463	0,143
Bennett et al., 2015	-0,005	0,101	0,010	-0,203	0,194	-0,045	0,964
Black, 2012	0,654	0,161	0,026	0,338	0,971	4,052	0,000
Bradley & Bennett, 2015	-0,245	0,102	0,010	-0,444	-0,046	-2,411	0,016
Brkljacic et al., 2020	-0,009	0,024	0,001	-0,057	0,039	-0,370	0,712
Canady & Sansone, 2019	0,121	0,162	0,026	-0,196	0,438	0,750	0,453
Carr et al., 2019	0,369	0,106	0,011	0,160	0,577	3,467	0,001
Cloutier & Peetz, 2016	0,537	0,095	0,009	0,351	0,722	5,663	0,000
Curl et al., 2021	-0,040	0,054	0,003	-0,147	0,066	-0,747	0,455
Endo et al., 2020 a	0,106	0,066	0,004	-0,024	0,235	1,595	0,111
Endo et al., 2020 b	-0,341	0,098	0,010	-0,534	-0,149	-3,476	0,001
Feng et al., 2014	0,205	0,047	0,002	0,113	0,297	4,361	0,000
Grajfoner et al., 2021	0,093	0,034	0,001	0,026	0,160	2,710	0,007
Hajek & König, 2020 a	0,039	0,053	0,003	-0,065	0,143	0,729	0,466
Hajek & König, 2020 b	-0,001	0,053	0,003	-0,106	0,103	-0,027	0,979
Hill et al., 2020	0,070	0,069	0,005	-0,065	0,204	1,015	0,310
Kim & Chun, 2021	0,116	0,012	0,000	0,093	0,140	9,661	0,000
Michová et al., 2019	0,806	0,108	0,012	0,595	1,017	7,491	0,000
Mueller et al., 2021	-0,293	0,066	0,004	-0,422	-0,163	-4,433	0,000
Muldoon et al., 2019 a	0,680	0,031	0,001	0,620	0,740	22,195	0,000
Muldoon et al., 2019 b	-0,250	0,032	0,001	-0,313	-0,187	-7,752	0,000
Muraco et al., 2018	0,256	0,042	0,002	0,174	0,337	6,143	0,000
Phillipou et al., 2021	-0,142	0,050	0,003	-0,241	-0,043	-2,815	0,005
Pruchno et al., 2018 a	0,097	0,025	0,001	0,049	0,145	3,949	0,000
Pruchno et al., 2018 b	-0,034	0,026	0,001	-0,085	0,018	-1,269	0,204
Pruchno et al., 2018 c	-0,034	0,036	0,001	-0,105	0,037	-0,944	0,345
Ramírez & Hernández, 2014	0,133	0,034	0,001	0,065	0,200	3,852	0,000
Reis et al., 2018 a	0,040	0,022	0,000	-0,003	0,082	1,842	0,065
Reis et al., 2018 b	-0,109	0,027	0,001	-0,162	-0,056	-4,039	0,000
Reis et al., 2018 c	-0,073	0,025	0,001	-0,123	-0,023	-2,883	0,004
Reis et al., 2018 d	0,007	0,030	0,001	-0,052	0,067	0,245	0,807
Roux & Wright, 2020	0,051	0,049	0,002	-0,046	0,147	1,032	0,302
Taniguchi et al., 2018	0,086	0,020	0,000	0,047	0,125	4,288	0,000
Teo & Thomas, 2019 a	-0,156	0,042	0,002	-0,238	-0,074	-3,728	0,000
Teo & Thomas, 2019 b	-0,014	0,042	0,002	-0,096	0,068	-0,341	0,733
Watson & Weinstein, 1993	0,200	0,109	0,012	-0,014	0,415	1,831	0,067
Wright et al., 2015	0,000	0,331	0,110	-0,650	0,650	0,000	1,000
Wright et al., 2019	-0,199	0,197	0,039	-0,584	0,187	-1,011	0,312
	0,068	0,030	0,001	0,010	0,126	2,300	0,021

FIGURE 3
Forest plot of pet influence on mental health.

4. Discussion

To our knowledge, this is the first comprehensive meta-analysis to investigate the influence of pet ownership on owners' daily PA levels and mental health. The main findings indicate a moderate positive impact of pets on PA compared to non-pet owners (NPO).

Among the PA moderating variables, frequency showed a highly significant effect, indicating that pet owners have a higher frequency of physical activity than NPO. However, no significant impact of pet ownership on mental health compared to NPO was found. One of the most promising results of this meta-analysis is the evidence that pet owners are more physically active than NPO, which may be related to pet care such as walking and going outside. A previous study (19) found that dog owners walk moderately more than non-dog owners. Of all the analyzed studies, five were conducted in dogs and other different species (13, 29, 77, 87, 90). The analysis of these studies showed that the benefits related to PA were more evident in dog owners than in owners of other pets. These findings led us to analyze PA specifically regarding dog owners DO and NDO.

About the moderating variables of PA (frequency, duration, counts, and mets), PO significantly had a higher frequency of walking. However, duration was not significant, as found in a previous meta-analysis (19). Owners with a stronger attachments to their dogs were more likely to walk with them, but at a shorter distance than owners with weaker pet attachments (17). These results may be based on the owner's commitment to meet the pet's needs, which may lead to an increase in the owner's willingness and frequency to take a walk, even if it is not perceived, as opposed to non-owners. On the other hand, it is possible that dog characteristics, such as age and breed, could influence the relationship between physical activity and mental health outcomes (92). For example, younger dogs may require more physical activity than older dogs, which could demand more attention and owners' general activity. Moreover, it is known that some breeds have higher exercise requirements than others (92). Future studies could take into account factors such as age, breed, and dogs' physical activity needs, and how they influence health outcomes of pet owners.

Objective and subjective measurement methods revealed a significant, but low effect size. For the assessment of owners' PA, most previous studies have used subjective physical activity measures, with only eight studies using objective assessment measures (10, 74, 76, 77, 80, 81, 84, 89). One of the limitations of subjective measures is that they are based on the perception or recall of PA performed before the date of completing the questionnaire, which may generate bias in the results or overestimation compared to objective measures (93). Comparative studies comparing the two measurement methods have found that the results obtained through the IPAQ are not reflected in the PA measurements with the accelerometer (77, 79). Despite our results covering both methodologies, subjective measures were the most commonly reported method among studies, similar to the meta-analysis conducted in 2013 (19). Although studies conducted with objective measures have been increasing, more studies that examine the application of these methods are needed, particularly studies that quantify both pet and owner levels of PA. Moreover, such an analysis would allow us to establish a more reliable role of pets in owners' PA and possibly define guidelines for the population that can benefit the most from owning a pet.

Besides the relationship between pet ownership and physical health, there may also be a relationship with mental health. There is some evidence that suggest that physical activity and pet ownership can both have positive effects on mental health outcomes (11). Engaging in regular physical activity has been shown to be associated with improved mental health, including decreased symptoms of depression and anxiety, as well as increased feelings of well-being and self-esteem (32). Thus, it is possible that physically active pet owners may have better mental health outcomes compared to non-pet owners, as they may benefit from both the physical activity and the social support and companionship provided by their pets (28, 94). However, more research is needed to fully understand the complex relationship between physical activity, pet ownership, and mental health outcomes.

Regarding the relationship between mental health and pet ownership, this meta-analysis included 135 results from 32 studies, whose methodological quality ranged from good to excellent. Despite the significant influence of pets on owners' mental health, it must be considered that the effect size was low. The high heterogeneity of the sample characteristics, the variables used to measure mental health, and other methodological issues might explain this low effect size. Nevertheless, this result has already been described in previous systematic reviews (91, 95).

To better understand the heterogeneity found, various moderating variables related to mental health were considered (95). Among these moderating variables, only loneliness, social support, life satisfaction, happiness, and mood and self-regulation were significantly related to pet ownership.

Regarding loneliness and social support, this meta-analysis suggests that PO are more likely to experience loneliness than NPO, but owning a pet can confer greater social support to the owner. Despite the differences between these concepts, they complement each other. Loneliness refers to the discrepancy between actual and desired social relationships. Social isolation (included in the social support moderating variable of this meta-analysis) arises in the absence of such contact with society (96). Kretzler (3) suggests that a pet tends to be associated with an increased frequency of social interactions, allowing for the increase of social and community ties (57), which may favor increased feelings of belonging and decreased loneliness and social isolation (70). Among the activities shared between pets and owners, walking and visits to parks appear to be most strongly associated with the social support felt by owners (13). Dogs are the most frequently reported pets in these activities (13, 57, 75) and seem to produce better results compared to other pets (65, 96). However, these differences between species are mostly dependent on the type of activities performed with the pet. Therefore, it may be important to consider other types of daily life activities with pets in future studies, as they may also promote greater social support for owners and decrease feelings of loneliness.

The literature suggests that pets may play a beneficial role in providing social support and companionship, particularly for older adult individuals who live alone (24, 51). However, while pets may serve as a form of social support, they cannot completely alleviate feelings of loneliness. Despite these findings, the low effect size of the relationship between pet ownership and mental health can be attributed to the high heterogeneity of the samples. Studies with individuals with chronic low back pain (75), members of the LGBT community (64), and those experiencing the COVID-19 pandemic (43, 78) have further demonstrated the high variability of samples. Certain contexts may even contribute to increased inconsistencies and incoherence in the role of pets in social isolation and feelings of loneliness. For instance, during the COVID-19 pandemic, social isolation was not significantly associated with pet ownership, but

loneliness may have been reduced (3). Further research is needed to fully understand the impact of pets on social support and levels of loneliness.

This meta-analysis also indicates that pets may promote greater life satisfaction and happiness in their owners. The concept of life satisfaction is subjective and may depend on individuals' experiences. Curl (57) reported that pet owners experience greater social engagement and life satisfaction, especially in the older adult population. Additionally, pet owners who experienced the death of a pet during the previous year were significantly less happy and satisfied compared to those who did not have a pet and those who did not experience the death of a pet (54). On the other hand, it is also plausible to consider that owners' personalities, conditions of the pets' presence, as well as expenses associated with the pet's care, might influence owners' life satisfaction. Therefore, it is important to understand the relationship between pet ownership and life satisfaction and happiness, considering different variables such as life satisfaction before and after the adoption of the pet.

This meta-analysis also shows that the presence of a pet may lead to better mood, coping skills, affection, and relationships, particularly regarding humor and emotions. Moreover, having a pet throughout life was predictive of more positive relationships (56). However, high heterogeneity was found, which could be explained by the attachment to the pet, as the human-animal bond may differ among members of the same family, influencing their responses to the same questionnaire. Most analyzed studies did not control for this variable, which makes it difficult to understand the possible influence of the human-animal bond. Therefore, in future studies, it will be important to consider this variable.

Concerning the remaining moderator variables, no significant effect of pets was found, and the magnitude of the effect was low. These results may be due, in part, to the diversity of instruments and methodological procedures used in the included studies. In fact, in the different studies analyzed the variable mental health and resilience were quantified by using different scales, which most frequently was the Short Form Health Survey with 36 items (43, 59, 61), with Whight (73) using a reduced version with 12 items, the Moca (53), Patient Health Questionnaire (66), Psychological Symptoms (67), and BSI- Brief Symptom Inventor (70) were also used, along with 3 other studies (43, 59, 61) that assessed resilience. This fact may cause bias and variability, as it depends on the reading and interpretation of the self-administered questionnaire. Therefore, the high variety of instruments used to measure the same or different mental health variables was probably the main reason for the high heterogeneity observed. Similar results were observed for the depression and anxiety variables.

Therefore, 12 studies were included in this meta-analysis that explored the effect of pet presence on depressive symptoms (13, 24, 43, 52, 53, 59, 60, 70, 71, 74–76), and 8 studies on anxiety (24, 43, 52, 59, 70–72, 76). However, no significant effect was observed, which is consistent with other reported literature (91, 95). Symptoms of anxiety and depression are frequently analyzed together since they are highly comorbid and share common etiological processes (97). In this meta-analysis, only one study (72) analyzed anxiety independently of depression. In the remaining studies, the authors used the same instrument to analyze both variables: the Depression, Anxiety, and Stress scale (24, 43, 52, 59, 70) and the Hospital Anxiety and Depression Scale (76).

Regarding the influence of pets on the owner's quality of life, health, and well-being, no significant results were found, contradicting a previous systematic review that reported the potential benefits of pets to impact owner well-being (28). Once again, different scales and procedures were used in the reviewed studies. Quality of life was measured in 17 studies using subjective health items (57, 96), the European Health Interview Surveys-Quality of Life questionnaire (43), the Warwick-Edinburgh Mental Well-Being Scale (59), the Kidscreen-10 index (67), items from the SF-36 scale (vitality, pain, and role physical) (30, 76, 77), and items from the shortened version SF-12 (physical health) (66, 73). The physical health scales were used in studies on physical illnesses (52, 65, 75, 96). The World Health Organization Quality of Life Instrument (70) and the Well-being Index (58) was also used to measure well-being.

Quality of life, health, and well-being questionnaires may be subject to bias due to the subjectivity of interpretation inherent in the different dimensions evaluated. Moreover, the confounding factors considered by the authors, depending on the study goal, are different in each study, which could also be a limitation of our analysis.

Overall, although this meta-analysis did not aim to understand the effect of different pet species on mental health, it is worth mentioning that they seem to have an influence. Pruchno (65) found a higher positive association between quality-of-life outcomes and dog ownership than cat ownership, while Hajek (96) found a similar association regarding social isolation and loneliness. In another study with Portuguese adolescents, pets were associated with a better perception of well-being, more life satisfaction, and overall mental health. However, when analyzed by species, dogs showed more evident results (67). This may also contribute to explaining the high heterogeneity of the obtained results.

5. Limitations

This meta-analysis has identified several limitations and methodological issues that limit the generalizability of the results. These flaws include the absence of randomized controlled trials and a small number of longitudinal studies. Additionally, there is a lack of studies that compare health-related variables before and after pet ownership. It is also important to differentiate between participants, distinguish between the main and secondary responsible owners, and to sure attachment to the pet. Furthermore, it would be valuable to include other moderating variables such as age group, gender, economic factors, social status, ethnicity, and pet species to reduce the heterogeneity of the analysis. Finally, the use of diverse instruments to assess mental health and physical activity increases the heterogeneity of the results.

6. Conclusion

In general, pet ownership has been found to have a positive influence on owners' physical activity, with pet owners showing a higher frequency of physical activity than non-owners. However, pets do not seem to have a significant impact on owners' mental health. There were some moderating variables related to mental health, such as loneliness, social support, life satisfaction, happiness, mood, and self-regulation, which were significantly associated with pet ownership but with low effect sizes. This suggests that pet owners may have higher levels of social support, life satisfaction, happiness, mood, and self-regulation and lower levels of loneliness than non-owners.

The results of this meta-analysis provide a nuanced understanding of the potential impact of pets on owners' mental health and physical activity from a one health perspective.

We suggest that future researchers explore theoretical frameworks and methodological approaches that can explain the uniqueness of the relationships between pets and people, and how these influence them.

Author contributions

CM, JS, MM, MP, and LC: the conception of the research, the design of the research protocol, and review of the final draft of the manuscript. CM, JS, and MM: literature review and manuscript drafting. CM and MM: publication search. CM, JS, MM, and AC: publication screening and data extraction. LC and LS: third and fourth reviews. AC: statistical analysis. CM, AC, JS, and LS: data analysis and interpretation of results. All authors contributed to the article and approved the submitted version.

Funding

This work was funded by the R&D&I project "oneHcancer – One health approach in animal cancer," operation no.: NORTE-01-0145-FEDER-000078, co-funded by the European Regional Development Fund (ERDF) through NORTE 2020 (North Portugal Regional Operational Program 2014/2020).

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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1196199/full#supplementary-material

References

1. Day MJ. Human-animal health interactions: the role of one health. *Am Fam Physician*. (2016) 93:345–6.

2. Fine AH. *Handbook on animal-assisted therapy: Foundations and guidelines for animal-assisted interventions*. *Fourth* ed. Amsterdam; Boston: Elsevier Academic Press (2015). 427 p.

3. Kretzler B, König HH, Hajek A. Pet ownership, loneliness, and social isolation: a systematic review. *Soc Psychiatry Psychiatr Epidemiol*. (2022) 57:1935–57. doi: 10.1007/s00127-022-02332-9

4. Mueller MK, Gee NR, Bures RM. Human-animal interaction as a social determinant of health: descriptive findings from the health and retirement study. *BMC Public Health*. (2018) 18:305. doi: 10.1186/s12889-018-5188-0

5. Powell L, Chia D, McGreevy P, Podberscek AL, Edwards KM, Neilly B, et al. Expectations for dog ownership: perceived physical, mental and psychosocial health consequences among prospective adopters. *PLoS One*. (2018) 13:e0200276. doi: 10.1371/journal.pone.0200276

6. Purewal R, Christley R, Kordas K, Joinson C, Meints K, Gee N, et al. Companion animals and child/adolescent development: a systematic review of the evidence. *Int J Environ Res Public Health*. (2017) 14:234. doi: 10.3390/ijerph14030234

7. Westgarth C, Christley RM, Christian HE. How might we increase physical activity through dog walking? A comprehensive review of dog walking correlates. *Int J Behav Nutr Phys Act*. (2014) 11:83. doi: 10.1186/1479-5868-11-83

8. Gualdi-Russo E, Zaccagni L. Physical activity for health and wellness. *Int J Environ Res Public Health*. (2021) 18:7823. doi: 10.3390/ijerph18157823

9. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scand J Med Sci Sports*. (2006) 16:3–63. doi: 10.1111/j.1600-0838.2006.00520.x

10. Dall PM, Ellis SLH, Ellis BM, Grant PM, Colyer A, Gee NR, et al. The influence of dog ownership on objective measures of free-living physical activity and sedentary behaviour in community-dwelling older adults: a longitudinal case-controlled study. *BMC Public Health*. (2017) 17:496. doi: 10.1186/s12889-017-4422-5

11. WHO. *Guidelines on physical activity and sedentary behaviour. WHO*. Geneva: Genebra: World Health Organization (2020).

12. Richards EA. Does dog walking predict physical activity participation: results from a national survey. *Am J Health Promot*. (2016) 30:323–30. doi: 10.1177/0890117116646335

13. Taniguchi Y, Seino S, Nishi M, Tomine Y, Tanaka I, Yokoyama Y, et al. Physical, social, and psychological characteristics of community-dwelling elderly Japanese dog and cat owners. *PLoS One*. (2018) 13:e0206399. doi: 10.1371/journal.pone.0206399

14. Cutt H, Giles-Corti B, Knuiman M, Burke V. Dog ownership, health and physical activity: a critical review of the literature. *Health Place*. (2007) 13:261–72. doi: 10.1016/j.healthplace.2006.01.003

15. Matchock RL. Pet ownership and physical health. *Curr Opin Psychiatry*. (2015) 28:386–92. doi: 10.1097/YCO.0000000000000183

16. Brown SG, Rhodes RE. Relationships among dog ownership and leisure-time walking in western Canadian adults. *Am J Prev Med*. (2006) 30:131–6. doi: 10.1016/j.amepre.2005.10.007

17. Curl A, Bibbo J, Johnson R. Dog walking, the human-animal bond and older adults' physical health. *Gerontologist*. (2017) 57:930–9. doi: 10.1093/geront/gnw051

18. Toohey AM, Hewson JA, Adams CL, Rock MJ. Pets, social participation, and aging-in-place: findings from the Canadian longitudinal study on aging. *Can J Aging*. (2018) 37:200–17. doi: 10.1017/S0714980818000107

19. Christian HE, Westgarth C, Bauman A, Richards EA, Rhodes RE, Evenson KR, et al. Dog ownership and physical activity: a review of the evidence. *J Phys Act Health*. (2013) 10:750–9. doi: 10.1123/jpah.10.5.750

20. WHO (2022). World mental health report: Transforming mental health for all [Internet]. Report No.: ISBN: 9789240049338. Available from: https://www.who.int/publications-detail-redirect/9789240049338 [Accessed December 12, 2022].

21. Knapp M, Wong G. Economics and mental health: the current scenario. *World Psychiatry*. (2020) 19:3–14. doi: 10.1002/wps.20692

22. OECD (2018). Health at a glance: Europe 2018: state of health in the EU cycle [internet]. OECD. (Health at a Glance: Europe). Available at: https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-europe-2018_health_glance_eur-2018-en [Accessed November 14, 2021].

23. Statista Research Department (2022). Health care expenditure for mental health hospitals in Portugal from 2010 to 2019 [internet]. Statista. Available at: https://www.statista.com/statistics/1298445/portugal-health-care-expenditure-mental-health-hospital/ [Accessed December 19, 2022].

24. Bennett P, Trigg J, Godber T, Brown C. An experience sampling approach to investigating associations between pet presence and indicators of psychological wellbeing and mood in older Australians. *Anthrozoös*. (2015) 28:403–20. doi: 10.1080/08927936.2015.1052266

25. Black K. The relationship between companion animals and loneliness among rural adolescents. *J Pediatr Nurs*. (2012) 27:103–12. doi: 10.1016/j.pedn.2010.11.009

26. Hawkins RD, Hawkins EL, Tip L. "I can't give up when i have them to care for": People's experiences of pets and their mental health. *Anthrozoös*. (2021) 34:543–62. doi: 10.1080/08927936.2021.1914434

27. Turner DC, Rieger G, Gygax L. Spouses and cats and their effects on human mood. *Anthrozoös*. (2003) 16:213–28. doi: 10.2752/089279303786992143

28. Gee NR, Mueller MK. A systematic review of research on pet ownership and animal interactions among older adults. *Anthrozoös*. (2019) 32:183–207. doi: 10.1080/08927936.2019.1569903

29. Thorpe R, Kreisle R, Glickman L, Simonsick E, Newman A, Kritchevsky S. Physical activity and pet ownership in year 3 of the health ABC study. *J Aging Phys Act*. (2006) 14:154–68. doi: 10.1123/japa.14.2.154

30. Amiot CE, Gagné C, Bastian B. Pet ownership and psychological well-being during the COVID-19 pandemic. *Sci Rep*. (2022) 12:6091. doi: 10.1038/s41598-022-10019-z

31. Hughes AM, Braun L, Putnam A, Martinez D, Fine A. Advancing human–animal interaction to counter social isolation and loneliness in the time of COVID-19: a model for an interdisciplinary public health consortium. *Animals*. (2021) 11:2325. doi: 10.3390/ani11082325

32. Merkouri A, Graham TM, O'Haire ME, Purewal R, Westgarth C. Dogs and the good life: a cross-sectional study of the association between the dog–owner relationship and owner mental wellbeing. *Front Psychol*. (2022) 13:903647. doi: 10.3389/fpsyg.2022.903647

33. Hui Gan GZ, Hill AM, Yeung P, Keesing S, Netto JA. Pet ownership and its influence on mental health in older adults. *Aging Ment Health*. (2020) 24:1605–12. doi: 10.1080/13607863.2019.1633620

34. Kogan LR, Currin-McCulloch J, Bussolari C, Packman W, Erdman P. The psychosocial influence of companion animals on positive and negative affect during the COVID-19 pandemic. *Animals*. (2021) 11:2084. doi: 10.3390/ani11072084

35. Brooks H, Rushton K, Walker S, Lovell K, Rogers A. Ontological security and connectivity provided by pets: a study in the self-management of the everyday lives of people diagnosed with a long-term mental health condition. *BMC Psychiatry*. (2016) 16:409. doi: 10.1186/s12888-016-1111-3

36. Headey B, Grabka MM. Pets and human health in Germany and Australia: national longitudinal results. *Soc Indic Res*. (2007) 80:297–311. doi: 10.1007/s11205-005-5072-z

37. Zimolag U, Krupa T. Pet ownership as a meaningful community occupation for people with serious mental illness. *Am J Occup Ther*. (2009) 63:126–37. doi: 10.5014/ajot.63.2.126

38. Bradshaw J. *The animals among us: The new science of anthrozoology*. *First* ed. London: Allen Lane (2017).

39. Herzog H. The impact of pets on human health and psychological well-being: fact, fiction, or hypothesis? *Curr Dir Psychol Sci*. (2011) 20:236–9. doi: 10.1177/0963721411415220

40. Crawford EK, Worsham NL, Swinehart ER. Benefits derived from companion animals, and the use of the term 'attachment'. *Anthrozoös*. (2006) 19:98–112. doi: 10.2752/089279306785593757

41. Fraser G, Huang Y, Robinson K, Wilson MS, Bulbulia J, Sibley CG. New Zealand pet owners' demographic characteristics, personality, and health and wellbeing: more than just a fluff piece. *Anthrozoös*. (2020) 33:561–78. doi: 10.1080/08927936.2020.1771060

42. Maharaj N, Haney CJ. A qualitative investigation of the significance of companion dogs. *West J Nurs Res*. (2015) 37:1175–93. doi: 10.1177/0193945914545176

43. Phillipou A, Tan EJ, Toh WL, van Rheenen T, Meyer D, Neill E, et al. Pet ownership and mental health during COVID-19 lockdown. *Aust Vet J*. (2021) 99:423–6. doi: 10.1111/avj.13102

44. Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. *Ann Intern Med*. (2015) 162:777–84. doi: 10.7326/M14-2385

45. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. (2021) 372:n71. doi: 10.1136/bmj.n71

46. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. (1998) 52:377–84. doi: 10.1136/jech.52.6.377

47. Cohen J. The statistical power of abnormal-social psychological research: a review. *J Abnorm Soc Psychol*. (1962) 65:145–53. doi: 10.1037/h0045186

48. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. (2003) 327:557–60. doi: 10.1136/bmj.327.7414.557

49. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. (1997) 315:629–34. doi: 10.1136/bmj.315.7109.629

50. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. *Biometrics*. (1994) 50:1088–101. doi: 10.2307/2533446

51. Antonacopoulos N. A longitudinal study of the relation between acquiring a dog and loneliness. *Soc Anim*. (2017) 25:319–40. doi: 10.1163/15685306-12341449

52. Bradley L, Bennett P. Companion-animals' effectiveness in managing chronic pain in adult community members. *Anthrozoös*. (2015) 28:635–47. doi: 10.1080/08927936.2015.1070006

53. Branson SM, Boss L, Padhye NS, Gee NR, Trötscher TT. Biopsychosocial factors and cognitive function in cat ownership and attachment in community-dwelling older adults. *Anthrozoös*. (2019) 32:267–82. doi: 10.1080/08927936.2019.1569908

54. Brkljačić T, Sučić I, Lučić L, Glavak Tkalić R, Kaliterna Lipovčan L. The beginning, the end, and all the happiness in between: pet owners' wellbeing from pet acquisition to death. *Anthrozoös*. (2020) 33:71–87. doi: 10.1080/08927936.2020.1694313

55. Canady B, Sansone A. Health care decisions and delay of treatment in companion animal owners. *J Clin Psychol Med Settings*. (2019) 26:313–20. doi: 10.1007/s10880-018-9593-4

56. Cloutier A, Peetz J. Relationships' best friend: links between pet ownership, empathy, and romantic relationship outcomes. *Anthrozoös*. (2016) 29:395–408. doi: 10.1080/08927936.2016.1181361

57. Curl A, Bibbo J, Johnson R. Neighborhood engagement, dogs, and life satisfaction in older adulthood. *J Appl Gerontol*. (2021) 40:1706–14. doi: 10.1177/0733464820953725

58. Endo K, Yamasaki S, Ando S, Kikusui T, Mogi K, Nagasawa M, et al. Dog and cat ownership predicts adolescents' mental well-being: a population-based longitudinal study. *Int J Environ Res Public Health*. (2020) 17:884. doi: 10.3390/ijerph17030884

59. Grajfoner D, Ke GN, Wong RMM. (2021). The effect of pets on human mental health and wellbeing during COVID-19 lockdown in Malaysia. *Animals (Basel)*. 11:2689. doi: 10.3390/ani11092689

60. Hajek A, König HH. How do cat owners, dog owners and individuals without pets differ in terms of psychosocial outcomes among individuals in old age without a partner? *Aging Ment Health*. (2020) 24:1613–9. doi: 10.1080/13607863.2019.1647137

61. Hill L, Winefield H, Bennett P. Are stronger bonds better? Examining the relationship between the human–animal bond and human social support, and its impact on resilience. *Aust Psychol*. (2020) 55:729–38. doi: 10.1111/ap.12466

62. Kim J, Chun BC. Association between companion animal ownership and overall life satisfaction in Seoul, Korea. *PLoS One*. (2021) 16:e0258034. doi: 10.1371/journal.pone.0258034

63. Muldoon J, Williams J, Lawrence A, Currie C. The nature and psychological impact of child/adolescent attachment to dogs compared with other companion animals. *Soc Anim*. (2019) 27:55–74. doi: 10.1163/15685306-12341579

64. Muraco A, Putney J, Shiu C, Fredriksen-Goldsen K. Lifesaving in every way: the role of companion animals in the lives of older lesbian, gay, bisexual, and transgender adults age 50 and over. *Res Aging*. (2018) 40:859–82. doi: 10.1177/0164027517752149

65. Pruchno R, Heid AR, Wilson-Genderson M. Successful aging, social support, and ownership of a companion animal. *Anthrozoös*. (2018) 31:23–39. doi: 10.1080/08927936.2018.1406199

66. González Ramírez MT, Landero Hernández R. Benefits of dog ownership: comparative study of equivalent samples. *J Vet Behav*. (2014) 9:311–5. doi: 10.1016/j.jveb.2014.08.002

67. Reis M, Ramiro L, Camacho I, Tomé G, Brito C, Gaspar de Matos M. Does having a pet make a difference? Highlights from the HBSC Portuguese study. *Eur J Dev Psychol*. (2018) 15:548–64. doi: 10.1080/17405629.2017.1317242

68. le Roux MC, Wright S. The relationship between pet attachment, life satisfaction, and perceived stress: results from a south African online survey. *Anthrozoös*. (2020) 33:371–85. doi: 10.1080/08927936.2020.1746525

69. Serpell J. Beneficial effects of pet ownership on some aspects of human health and behaviour. *J R Soc Med*. (1991) 84:717–20. doi: 10.1177/014107689108401208

70. Teo JT, Thomas SJ. Psychological mechanisms predicting wellbeing in pet owners: Rogers' core conditions versus bowlby's attachment. *Anthrozoös*. (2019) 32:399–417. doi: 10.1080/08927936.2019.1598660

71. Watson N, Weinstein M. Pet ownership in relation to depression, anxiety, and anger in working women. *Anthrozoös*. (1993) 6:135–8. doi: 10.2752/089279393787002295

72. Wright H, Hall S, Hames A, Hardiman J, Mills R, PAWS Project Team, et al. Pet dogs improve family functioning and reduce anxiety in children with autism spectrum disorder. *Anthrozoös*. (2015) 28:611–24. doi: 10.1080/08927936.2015.1070003

73. Wright MM, Schreiner P, Rosser BRS, Polter EJ, Mitteldorf D, West W, et al. The influence of companion animals on quality of life of gay and bisexual men diagnosed with prostate cancer. *Int J Environ Res Public Health*. (2019) 16:4457. doi: 10.3390/ijerph16224457

74. Ballin M, Antonsson O, Rosenqvist V, Nordström P, Nordström A. Association of dog ownership with accelerometer-measured physical activity and daily steps in 70-year-old individuals: a population-based cross-sectional study. *BMC Public Health*. (2021) 21:2313. doi: 10.1186/s12889-021-12401-4

75. Carr ECJ, Wallace JE, Pater R, Gross DP. Evaluating the relationship between well-being and living with a dog for people with chronic low back pain: a feasibility study. *Int J Environ Res Public Health*. (2019) 16:1472. doi: 10.3390/ijerph16081472

76. Feng Z, Dibben C, Witham M, Donnan P, Vadiveloo T, Sniehotta F, et al. Dog ownership and physical activity in later life: a cross-sectional observational study. *Prev Med*. (2014) 66:101–6. doi: 10.1016/j.ypmed.2014.06.004

77. Mičková E, Machová K, Daďová K, Svobodová I. Does dog ownership affect physical activity, sleep, and self-reported health in older adults? *Int J Environ Res Public Health*. (2019) 16:3355. doi: 10.3390/ijerph16183355

78. Mueller MK, Richer AM, Callina KS, Charmaraman L. Companion animal relationships and adolescent loneliness during covid-19. *Animals*. (2021) 11:1–14. doi: 10.3390/ani11030885

79. Brown BB, Jensen WA. Dog ownership and walking: perceived and audited walkability and activity correlates. *Int J Environ Res Public Health*. (2020) 17:1385. doi: 10.3390/ijerph17041385

80. Byers C, Wilson C, Stephens M, Goodie J, Netting F, Olsen C. Owners and pets exercising together: canine response to veterinarian-prescribed physical activity. *Anthrozoös*. (2014) 27:325–33. doi: 10.2752/175303714X14036956449224

81. Coleman KJ, Rosenberg DE, Conway TL, Sallis JF, Saelens BE, Frank LD, et al. Physical activity, weight status, and neighborhood characteristics of dog walkers. *Prev Med*. (2008) 47:309–12. doi: 10.1016/j.ypmed.2008.05.007

82. Corrigan VK, Pierce BJ, Hosig K. Dog ownership, physical activity, and health-related quality of life in veterinary students: a cross-sectional study. *J Vet Med Educ* (2018) 45:51–63. doi: 10.3138/jvme.0616-106r1 1943-7218.

83. Garcia DO, Wertheim BC, Manson JE, Chlebowski RT, Volpe SL, Howard BV, et al. Relationships between dog ownership and physical activity in postmenopausal women. *Prev Med*. (2015) 70:33–8. doi: 10.1016/j.ypmed.2014.10.030

84. Koohsari MJ, Shibata A, Ishii K, Kurosawa S, Yasunaga A, Hanibuchi T, et al. Dog ownership and adults' objectively-assessed sedentary behaviour and physical activity. *Sci Rep*. (2020) 10:17487. doi: 10.1038/s41598-020-74365-6

85. Lail P, McCormack GR, Rock M. Does dog-ownership influence seasonal patterns of neighbourhood-based walking among adults? A longitudinal study. *BMC Public Health*. (2011) 11:148. doi: 10.1186/1471-2458-11-148

86. Machová K, Daďová K, Chaloupková H, Svobodová I. Does having a pet influence the physical activity of their young female owners? *BMC Public Health*. (2019) 19:1672. doi: 10.1186/s12889-019-7962-z

87. Oka K, Shibata A. Dog ownership and health-related physical activity among Japanese adults. *J Phys Act Health*. (2009) 6:412–418, doi: 10.1123/jpah.6.4.412 1543-5474.

88. Schofield G, Mummery K, Steele R. Dog ownership and human health-related physical activity: an epidemiological study. *Health Promot J Austr*. (2005) 16:15–9. doi: 10.1071/HE05015

89. Westgarth C, Christley RM, Jewell C, German AJ, Boddy LM, Christian HE. Dog owners are more likely to meet physical activity guidelines than people without a dog: an investigation of the association between dog ownership and physical activity levels in a UK community. *Sci Rep*. (2019) 9:5704. doi: 10.1038/s41598-019-41254-6

90. Yabroff K, Troiano R, Berrigan D. Walking the dog: is pet ownership associated with physical activity in California? *J Phys Act Health*. (2008) 5:216–28. doi: 10.1123/jpah.5.2.216

91. Hughes MJ, Verreynne ML, Harpur P, Pachana NA. Companion animals and health in older populations: a systematic review. *Clin Gerontol*. (2020) 43:365–77. doi: 10.1080/07317115.2019.1650863

92. Hielscher-Zdzieblik B, Froboese I, Serpell J, Ganslosser U. Impact of dog's age and breed on dog owner's physical activity: a German longitudinal study. *Animals*. (2022) 12:1314. doi: 10.3390/ani12101314

93. Lee PH, Macfarlane DJ, Lam T, Stewart SM. Validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review. *Int J Behav Nutr Phys Act*. (2011) 8:115. doi: 10.1186/1479-5868-8-115

94. Goh YX, Tan JSQ, Syn NL, Tan BSW, Low JY, Foo YH, et al. Association between pet ownership and physical activity levels, atopic conditions, and mental health in Singapore: a propensity score-matched analysis. *Sci Rep*. (2020) 10:19898. doi: 10.1038/s41598-020-76739-2

95. Scoresby KJ, Strand EB, Ng Z, Brown KC, Stilz CR, Strobel K, et al. Pet ownership and quality of life: a systematic review of the literature. *Vet Sci*. (2021) 8:332. doi: 10.3390/vetsci8120332

96. Hajek A, Kretzler B, König HH. Multimorbidity, loneliness, and social isolation: a systematic review. *Int J Environ Res Public Health*. (2020) 17:8688. doi: 10.3390/ijerph17228688

97. Garber J, Brunwasser SM, Zerr AA, Schwartz KTG, Sova K, Weersing VR. Treatment and prevention of depression and anxiety in youth: test of crossover effects. *Depress Anxiety*. (2016) 33:939–59. doi: 10.1002/da.22519

frontiers | Frontiers in Public Health

TYPE Brief Research Report
PUBLISHED 31 May 2023
DOI 10.3389/fpubh.2023.1168702

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Katie Moraes de Almondes,
Federal University of Rio Grande do Norte, Brazil
Nejmeddine Ouerghi,
Tunis El Manar University, Tunisia

*CORRESPONDENCE
Ryan D. Burns
ryan.d.burns@utah.edu

RECEIVED 17 February 2023
ACCEPTED 15 May 2023
PUBLISHED 31 May 2023

CITATION
Burns RD, Bilic A, Bai Y, Brusseau TA, Lucero JE and King Jensen JL (2023) Bidirectional associations of physical activity, sleep, and self-reported mental health in young adults participating in an online wellness intervention during the COVID-19 pandemic. *Front. Public Health* 11:1168702. doi: 10.3389/fpubh.2023.1168702

Bidirectional associations of physical activity, sleep, and self-reported mental health in young adults participating in an online wellness intervention during the COVID-19 pandemic

Ryan D. Burns*, Anna Bilic, Yang Bai, Timothy A. Brusseau, Julie E. Lucero and Jessica L. King Jensen

Department of Health and Kinesiology, College of Health, University of Utah, Salt Lake City, UT, United States

Purpose: The purpose of this study was to examine the bidirectional associations of physical activity (PA), sleep, and mental health in young adults participating in an online wellness intervention from October 2021 to April 2022.

Methods: Participants were a sample of undergraduate students from one US university (N=89; 28.0% freshman; 73.0% female). The intervention was a 1-h health coaching session that was delivered either once or twice by peer health coaches on Zoom during COVID-19. The number of coaching sessions was determined by random allocation of participants to experimental groups. Lifestyle and mental health assessments were collected at two separate assessment timepoints after each session. PA was assessed using the International Physical Activity Questionnaire–Short Form. Weekday and weekend sleep were assessed by two one-item questionnaires and mental health was calculated from five items. Cross-lagged panel models (CLPMs) examined the crude bidirectional associations of PA, sleep, and mental health across four-time waves (i.e., T1 through T4). To control for individual unit effects and time-invariant covariates, linear dynamic panel-data estimation using maximum likelihood and structural equation modeling (ML-SEM) was also employed.

Results: ML-SEMs showed that mental health predicted future weekday sleep (β=0.46, p<0.001) and weekend sleep predicted future mental health (β=0.11, p=0.028). Although CLPMs showed significant associations between T2 PA and T3 mental health (β=0.27, p=0.002), no associations were observed when unit effects and time-invariant covariates were accounted for.

Conclusion: Self-reported mental health was a positive predictor of weekday sleep and weekend sleep positively predicted mental health during the online wellness intervention.

KEYWORDS

behavior, exercise, health, mental health, sleep, young adult

1. Introduction

Physical activity (PA) and sleep are two health behaviors that have been shown to correlate with mental health (1–3). Mechanisms for these positive associations between health behaviors and mental health included improved stress control, lowered cortisol, healthier sleep habits, and lowered susceptibility to anxiety and depression via release of endogenous opioids and neurohormones within the central nervous system (4–7). A population that is consistently under stress during much of the year and may suffer from poor mental health are young adults enrolled in college courses ("university students") (8, 9). This population is burdened by the academic stressors of being a university student in addition to the lifespan transition period of emerging adulthood, which often consists of significant and sudden changes in the physical and social environment (10–13). These changes can negatively affect a young adult's emotional health and their well-being. Problems with higher stress and poorer health behaviors may have been exacerbated during the COVID-19 pandemic (9). A potential way to mitigate declines in mental health in university students is tailored health behavior programming (14–18).

Some health behavior interventions have shown evidence to improve mental health and wellbeing in university students (14, 15). Indeed, interventions that have targeted multiple behaviors have shown the strongest evidence to improve mental health (16, 17). However, past interventions that involved targeting multiple health behaviors may have yielded high levels of participant burden because of high durations or frequencies of health education or coaching sessions, burdens that for university students may have been magnified because of their demanding academic and work schedules. Having an in-person modality for intervention delivery may have also added additional burden due to increased transportation needs. We previously implemented a brief one-hour Zoom-based intervention that yielded improvements in university students' sleep, physical activity, nutrition, stress management, and substance use during COVID-19 (14). However, other health behavior interventions delivered during COVID-19 showed null results for improving aspects of mental health in young adults. An 8-week mind–body physical activity intervention that used yoga poses and walking meditation and was delivered asynchronously online on Canvas for 10 min, 3 days per week did not significantly associate with better stress or wellbeing in a sample of college students (19). Additionally, an intervention study conducted by Philippot et al. (20) that used high-intensity interval training delivered *via* the use of online videos to a sample of university students for 4-weeks yielded no significant improvements in anxiety symptoms. Given these conflicting findings, further investigation is warranted.

Interventions that target multiple behaviors have outcomes that may intercorrelate and predict one another across time. Thus, change in one targeted behavior during an intervention could influence other targeted behaviors at a future timepoint, independent of an intervention's influence (i.e., independent of experimental group allocation). PA and sleep are two health behaviors that can determine mental health (21, 22), however, no study has examined the longitudinal bidirectional associations among PA, sleep, and mental health during a multi-behavioral online intervention. Examining longitudinal bidirectional associations can help determine the directionality of association, help identify targets to improve health behaviors and mental health and may provide information on how multiple behavioral outcomes intercorrelate independent of an intervention's effect. Therefore, the purpose of this study was to examine the bidirectional associations of PA, sleep, and mental health in a sample of university students who participated in an online wellness intervention delivered during the 2021–2022 academic year, which overlapped with the COVID-19 pandemic. The current study's intervention expanded on our previous intervention implementing multiple brief (1-h) peer health coaching sessions to university students during COVID-19 using a randomized controlled research design. The details of this study are elsewhere. The present study was a secondary analysis of data obtained from the intervention that aimed to examine how the various behavioral and mental health outcomes longitudinally intercorrelated with each other across time. Given past work in this area, it was hypothesized that PA and weekday and weekend sleep would show a moderate and positive bidirectional association with self-reported mental health.

2. Materials and methods

2.1. Participants

Participants were a non-probability convenience sample of young adults recruited from one university in the western US who participated in the online peer health coaching intervention. Recruitment strategies included written and oral advertising (e.g., posters) and by peer referrals (e.g., word of mouth). Interested participants completed informed consent online followed by a screening survey used to determine study eligibility. The inclusion criterion included being a current undergraduate student enrolled at the host institution and there were no exclusion criteria for participating in this study. A total of 173 students expressed study interest and 89 students were enrolled. The analytic sample was mostly female (73.0%), not Hispanic/Latino (80.9%), was White (73.0%), had mothers who obtained at least a Bachelor's degree (43.8%), did not participate in University athletics (89.9%), and was not in a fraternity or sorority (92.1%). More specific descriptive demographic statistics of the analyzed sample are presented in Supplementary Table S1. Participants received $10 per survey completed, for a total of $40 potentially earned during the study. All study procedures were approved by the University's Institutional Review Board.

2.2. Intervention

The intervention was a one-hour program delivered by peer health coaches in a one-on-one setting on Zoom during the 2021–2022 academic year. Briefly, the program consisted of a pre-session self-administered survey which asked participants about their wellness and substance use behaviors and a one-on-one peer health coach session in which the participant received individualized feedback on their health habits and set two wellness goals (22). Online follow-up questionnaires were administered after each session.

Participants were randomly assigned to one of two possible sequences: a one coaching session sequence or a two-session sequence. Following a step-wedged randomized controlled research design, participants in the one-session sequence completed two

repeated follow-up assessments prior to their coaching session and two additional follow-up assessments. Participants in the two-session sequence completed one coaching session with two follow-up assessments followed by a second coaching session with two additional follow-up assessments. Two weeks separated each follow-up assessment.

Each assessment timepoint was designated as a time wave (T) within the analyses, with T1 representing the first assessment, T2 representing the second assessment, etc. A variable indicating whether participants received one or two coaching was used as a time-invariant covariate within the statistical models. A total of 57 participants completed at least one health coach session and 21 participants completed two sessions. Group comparisons were not made given that this study was a secondary analysis of specific behavioral outcomes. Specific group comparisons will be reported within a separate study.

2.3. Assessments

2.3.1. Physical activity

The PA variable was weekly metabolic equivalent of task minutes (MET-min) calculated from the validated International Physical Activity Questionnaire (IPAQ)-short form questionnaire (23). The MET-min was a metric of PA volume that indicated the amount of energy expended during a minute at rest. Higher MET-min scores indicated higher levels of PA. Calculated MET-min for walking, moderate PA, and vigorous PA were summed to calculate a total MET-min score that was used for data analysis.

2.3.2. Sleep

Two items asked about how many hours of sleep the participants accrued during both weeknights and weekend nights. The two items were part of the same assessment questionnaire. The weekday sleep item asked "Over the last 2 weeks, what is the average amount of sleep you have gotten on a weeknight (excluding naps)? Note: Please select the response closest to your answer." The weekend sleep item asked "Over the last 2 weeks, what is the average amount of sleep you have gotten on a weekend night (excluding naps)? Note: Please select the response closest to your answer." Responses ranged from less than 4 h to 10 or more hours. Scores above 10 or more hours a day were dropped for analysis due to the non-linear association between sleep duration and health outcomes (24).

2.3.3. Mental health

Mental Health was calculated from five items each with a 5-point response scale (1 = All the time, 5 = None of the time). The items were from the validated SF-36 Health Survey Questionnaire (25). The mental health items were the 5 items from SF-36 that were part of the wellbeing area and mental health dimension of the questionnaire, which showed a high degree of test–retest reliability (25). The items asked, "Have you been a very nervous person?," "Have you felt so down in the dumps that nothing could cheer you up?," "Have you felt calm and peaceful?," Have you felt downhearted and blue?," and "Have you been a happy person?." Items were reversed coded where necessary so that high scores reflected good mental health. Internal consistency across the five items was acceptable with Cronbach's alpha ranging from alpha = 0.76–0.88 across waves. The average of the five responses were used for data analysis. The 4 items on the SF-36 Health Survey Questionnaire that measured vitality were not included in the assessments.

2.4. Covariates

Covariates included in the adjusted analyses consisted of self-reported participant university status year (freshman, sophomore, junior, senior), sex (male, female, other/no-response), race/ethnicity, mother's highest education level, and experimental group (one coaching session, two coaching sessions; see Section 2.2). The race/ethnicity variable was collapsed into a binary White/Non-White variable to maintain a high group sample size.

2.5. Statistical analysis

To examine the crude bidirectional associations of PA, sleep, and mental health, cross-lagged panel models (CLPMs) were employed with four assessment waves (Ts) across the course of the wellness intervention. CLPMs analyzed reciprocal associations between multiple observed variables measured at multiple Ts (26). The CLPMs were constructed as structural equation models using Stata's "sem builder." Each CLPM had three variables, PA, sleep, and mental health that were observed at the four Ts. Specific paths within each cross-lagged model included autoregressive paths of each variable associating with itself at the next T (e.g., T1 PA associating with T2 PA) and cross-lagged associations where a respective variable associated with another at the next T (e.g., T1 PA associating with T2 mental health). Standardized covariance coefficients among the three variables were computed at T1. Separate CLPMs were run using weekday and weekend sleep. Full Information Maximum Likelihood (FIML) was utilized to conduct available case analysis in the presence of missing data. Reporting of the results included the standardized regression coefficients (β-coefficients) with corresponding 95% Confidence Intervals.

CLPMs have limitations when attempting to make causal inferences because it does not effectively control for unobserved individual unit effects, which may yield errors that are correlated with predictor variables (instrumental variables problem), in addition to uncertainty about the treatment of initial conditions (27, 28). It is also difficult to control for observed time-invariant covariates using the CLPM approach. To account for these issues, linear dynamic panel-data estimation using maximum likelihood and structural equation modeling (ML-SEM) was employed (28). ML-SEM models contained a latent variable α that controlled for individual unit effects, eliminating the instrument variables problem. With ML-SEM, the initial conditions were treated as exogenous and did not need to be modeled, and coefficients for observed time-invariant predictors were estimated. For the ML-SEM models, coefficients for the effects of a predictor (x) on an outcome (y) were constrained to be equal across time. ML-SEM models were carried out in Stata using the "xtdpdml" command. Further details regarding ML-SEM and specifically the "xtdpdml" command have been communicated elsewhere (27).

Separate ML-SEM models were run using the directional associations observed from the CLPMs to determine if the associations held using the more rigorous analytical approach. Observed

10.3389/fpubh.2023.1168702

TABLE 1 Descriptive statistics of the analyzed variables (means and standard deviations) collected during the 2021–2022 academic school year.

Wave	Variable	Total Sample (N=89) M (SD)	Females (n=65) M (SD)	Males (n=21) M (SD)
T1	Total MET-mins	2,179 (1,763)	2,006 (1,657)	2,780 (1,996)
	Weekday sleep (hours)	6.9 (1.0)	6.8 (1.10)	7.1 (1.0)
	Weekend sleep (hours)	7.7 (1.4)	7.8 (1.3)	7.3 (1.5)
	Mental health (1–5 scale)	3.6 (0.8)	3.5 (0.9)	3.6 (0.6)
T2	Total MET-mins	2,645 (2,075)	2,323 (1,970)	**3,474*(2,160)**
	Weekday sleep (hours)	6.9 (1.0)	7.0 (1.1)	6.8 (1.1)
	Weekend sleep (hours)	7.6 (1.1)	**7.8**(1.0)**	7.1 (1.1)
	Mental health (1–5 scale)	3.6 (0.9)	3.6 (0.9)	3.6 (0.9)
T3	Total MET-mins	2,669 (2,930)	2,540 (3,213)	3,012 (2,148)
	Weekday sleep (hours)	7.1 (0.9)	7.2 (0.8)	7.0 (0.9)
	Weekend sleep (hours)	7.7 (1.0)	7.8 (1.0)	7.3 (1.0)
	Mental health (1–5 scale)	3.6 (0.9)	3.5 (0.9)	4.0 (0.9)
T4	Total MET-mins	2,909 (3,567)	2,687 (3,772)	3,780 (2,793)
	Weekday sleep (hours)	7.3 (1.1)	7.4 (1.1)	7.0 (1.3)
	Weekend sleep (hours)	7.8 (1.2)	**7.9*(1.1)**	7.1 (1.2)
	Mental health (1–5 scale)	3.7 (1.0)	3.7 (1.1)	3.8 (0.8)

T, assessment timepoint; MET-min, weekly metabolic equivalent of task minutes; bold denotes statistical significance, *$p < 0.05$, **$p < 0.01$.

time-invariant covariates within the ML-SEMs included participant status year, sex, race/ethnicity, mother's highest education level, and experimental group. FIML was still used within each ML-SEM to conduct available case analysis in the presence of missing data. Model fit was determined using the Root Mean Square Error of Approximation (RMSEA; acceptable fit ≤ 0.08, excellent fit ≤ 0.05 and p-close > 0.05), the Tucker-Lewis Index (TLI; acceptable fit ≥ 0.90, excellent fit ≥ 0.95), Comparative Fit Index [CFI; acceptable fit ≥ 0.90, excellent fit ≥ 0.95 and coefficient of determination (R^2)] (29, 30). All analyses had an alpha level of $p < 0.05$ and were carried out using Stata version 17 statistical software package (College Station, Texas, United States).

3. Results

3.1. Descriptive statistics

Descriptive statistics of the analyzed variables at each T are communicated in Table 1. Males reported more MET-min at T2 (mean difference = 1,150 MET-min, $p = 0.049$) and females reported more weekend sleep at T2 (mean difference = 0.7 h, $p = 0.011$) and at T4 (mean difference = 0.8 h, $p = 0.036$). No other significant differences between the sexes were observed.

3.2. Cross-lagged panel models

Figures 1, 2 show the CLPMs for PA, weekday sleep, and mental health and for PA, weekend sleep, and mental health, respectively. For the CLPM using PA, weekday sleep, and mental health, significant cross-lagged path coefficients were observed for T2 PA positively predicting T3 mental health ($p = 0.002$), T1 mental health positively predicting T2 weekday sleep ($p = 0.014$), and T3 mental health positively predicting T4 weekday sleep ($p < 0.001$). All autoregressive paths were significant within the model but tended to be strongest for the mental health variable.

For the CLPM using PA, weekend sleep, and mental health, significant cross-lagged path coefficients were observed for T2 PA positively predicting T3 mental health ($p = 0.004$), T1 weekend sleep positively predicting T2 mental health ($p = 0.019$), and T1 mental health positively predicting T2 weekend sleep ($p = 0.023$). All autoregressive paths were significant within the model but tended to be strongest for the weekend sleep and mental health variables.

3.3. Dynamic panel models using maximum likelihood

The results of three ML-SEMs were reported in Table 2. Three ML-SEM models were constructed based on the results from the CLPMs with weekday sleep, weekend sleep, and mental health as respective outcomes. All models adjusted for unit effects and the time-invariant covariates of status year, sex, race/ethnicity, mother's education level, and experimental group. An example path diagram showing the structure of the model with the weekday sleep outcome and mental health predictor was provided in Supplementary Figure S1. Using the weekday sleep outcome, mental health was a significant positive predictor of future weekday sleep ($p < 0.001$); however, using the weekend sleep outcome, mental health was not significant predictor of future weekend sleep ($p = 0.372$). Weekend sleep was the only outcome that showed significant and positive autoregressive effects across Ts ($p < 0.001$). Using the mental health outcome, weekend sleep positively predicted future mental health ($p = 0.028$);

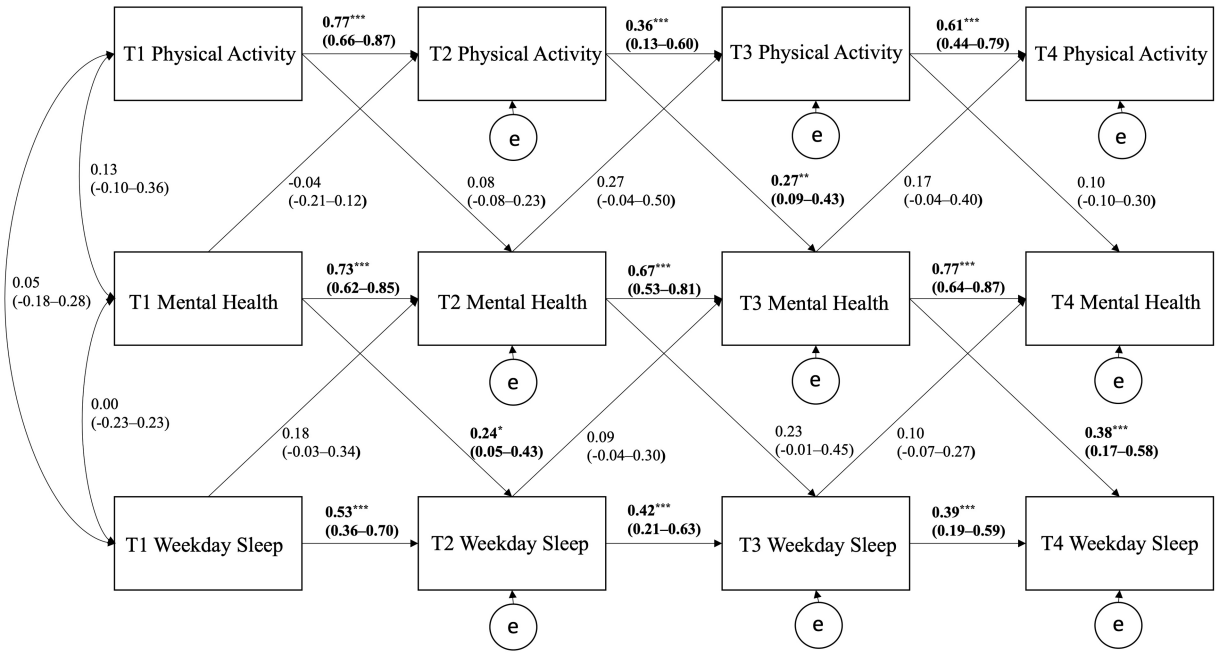


FIGURE 1
Cross-lagged panel model showing the autoregressive and cross-lagged associations of physical activity, weekday sleep, and mental health. Curved arrows are covariances; horizontal straight arrows are autoregressive direct paths; diagonal straight arrows are cross-lagged paths; e stands for error/residual in the regression equation; bold denotes statistical significance, *p<0.05, **p<0.01, ***p<0.001.

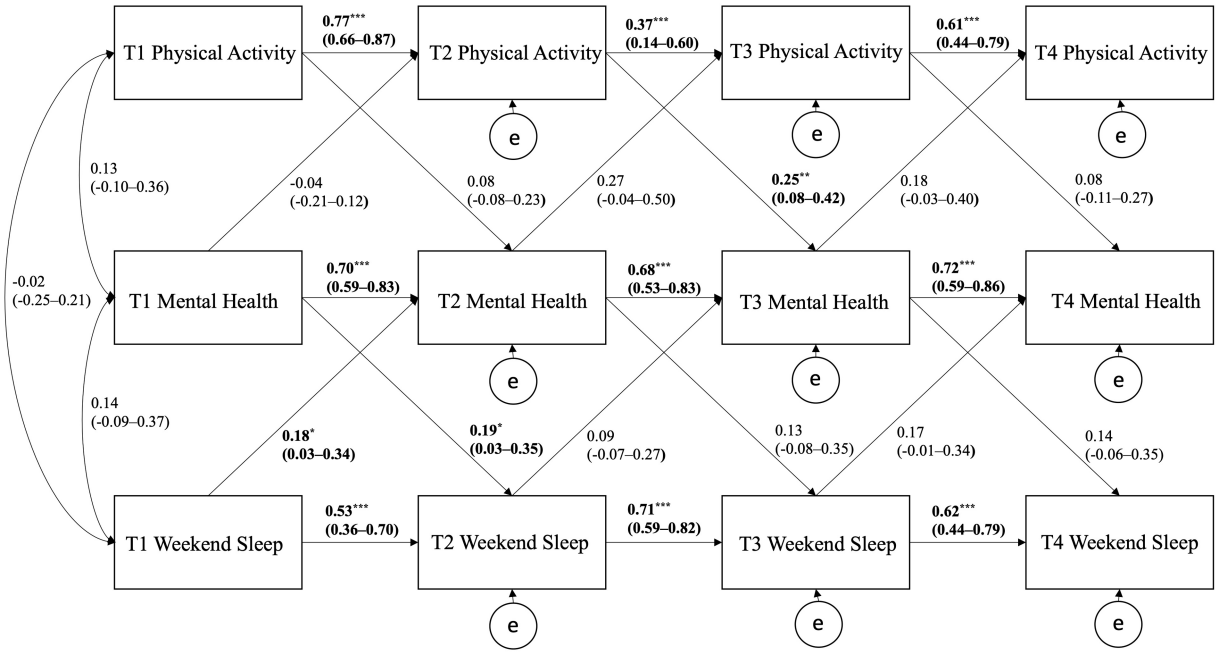


FIGURE 2
Cross-lagged panel model showing the autoregressive and cross-lagged associations of physical activity, weekend sleep, and mental health. Curved arrows are covariances; horizontal straight arrows are autoregressive direct paths; diagonal straight arrows are cross-lagged paths; e stands for error/residual in the regression equation; bold denotes statistical significance, *p<0.05, **p<0.01, ***p<0.001.

however, PA and weekday sleep did not significantly predict future mental health within the ML-SEM. ML-SEM model fit was acceptable using the weekday sleep outcome and the mental health lagged predictor (RMSEA = 0.06, 90%CI: 0.00–0.10, p-close = 0.345; CFI = 0.92, TLI = 0.88; R^2 = 0.82), excellent for the weekend sleep outcome and the mental health lagged predictor (RMSEA = 0.00,

TABLE 2 Standardized estimates from the dynamic panel model using maximum likelihood for the outcome of weekday sleep and mental health.

Outcome		β-coefficient	95% CI	*p*-value
Weekday sleep	Lag weekday sleep	0.09	−0.14 to 0.32	0.450
	Lag mental health	**0.46*****	0.21–0.71	<0.001
Weekday sleep	Lag weekend sleep	**0.33*****	0.17–0.49	<0.001
	Lag mental health	0.11	−0.14 to 0.37	0.372
Mental health	Lag mental health	0.24	−0.02 to 0.50	0.07
	Lag PA	0.0	−0.0 to 0.0	0.406
	Lag weekday sleep	−0.05	−0.17 to 0.07	0.458
	Lag weekend sleep	**0.11***	0.01–0.21	0.028

Models adjusted for current university status, sex, race/ethnicity, mother's highest education level, and experimental group. PA, physical activity; 95% CI, 95% Confidence Interval; bold denotes statistical significance, *$p < 0.05$, ***$p < 0.001$.

90%CI: 0.00–0.07, *p*-close = 0.821; CFI = 1.00, TLI = 1.00; $R^2 = 0.73$), and acceptable using the mental health outcome with PA, weekday sleep, and weekend sleep lagged predictor variables (RMSEA = 0.06, 90%CI: 0.00–0.10, *p*-close = 0.329; CFI = 0.94, TLI = 0.92; $R^2 = 0.85$).

4. Discussion

The purpose of this study was to examine the bidirectional associations of PA, sleep, and mental health in a sample of young adults participating in an online wellness intervention. This was a secondary analysis of data obtained from an online wellness intervention during COVID-19. After controlling for individual unit effects and time-invariant covariates, weekday and weekend sleep had a bidirectional longitudinal association with mental health. Although PA associated with mental health within the CLPMs, these significant associations were eliminated using the more rigorous analytical approach (ML-SEM). Additionally, weekend sleep showed the strongest autoregressive associations compared to the other analyzed variables. A discussion of these findings is provided further.

Salient results from this study included a bidirectional association between self-reported sleep and mental health across the online wellness intervention. Sleep is a health behavior known to have positive influences on many mental health outcomes (31–33). A healthy quality and quantity of sleep has been associated with lower anxiety and depression in addition to better cognitive functioning (34–36); these improvements in mental health can further lead to better academic performance and work productivity in young adults. Indeed, within the context of the 24-h movement behavior framework, past observational research has suggested sleep is the health behavior that seems to have the strongest associations with variables of mental and emotional health compared to other behaviors such as PA and screen use (37–39). A previous study that performed polysomnography (PSG) found that children with generalized anxiety disorder reported higher rate of sleep problems compared to healthy controls (6). Another recent study found that depression and anxiety were associated with cortisol, a stress hormone, secretion around sleep onset (7). As shown in these previous studies and the current study's findings, mental health plays a large role in predicting sleep. However, most prior research examining multiple 24-h movement behaviors have been cross-sectional in design and the associations between health behaviors and outcomes have been examined outside the context of an online wellness intervention (21, 40, 41).

A novel aspect of this study was that mental health predicted future weekday sleep during an online wellness intervention. The Repair and Restoration Theory of Sleep posits that sleeping is needed to revitalize and restore important physiological processes that facilitate proper physical and mental functioning (42). A lack of sleep would theoretically lead to less restoration and poorer mental health, including higher levels of stress, that can subsequently lead to poorer sleep and thus initiate a vicious cycle and a bidirectional association between sleep and mental health (42, 43). This theory is supported by research showing that many functions in the body such as muscle repair, tissue growth, protein synthesis, and release of many of the important hormones for growth occur primarily during sleep (42). Indeed, previous work has shown that using ecological momentary assessment, it was found that sleep and daily mood are reciprocally related but varies greatly by individual levels of mental health (44). This finding supports the Repair and Restoration Theory and a bidirectional association because poor daily mood also affects restorative sleep, especially during the pandemic, as COVID-19 related worry was associated with poor sleep in young adults, possibly by disrupting normal sleep habits (longer sleep latency, more sleep disruptions) (45). Our current study showed that mental health was a positive predictor of weekday sleep and weekend sleep positively predicted mental health, suggesting that the bidirectional associations between sleep and mental health may be determined by day of the week in college students. Mental health predicting future weekday sleep has important implications for college students as maintaining good mental health can lead to better sleep that may further positively affect their work and academic performance. Interventions aiming to improve weekday sleep may want to consider using methods to improve college students' mental health. Various approaches are available to improve mental health in young adults; however, incorporating stress reduction techniques and mindfulness activities into daily routines has been shown as an efficient and effective way to lower anxiety and improve mood (46–48).

Interestingly, weekend sleep positively predicted future mental health. Weekend sleep was also the behavior that was the most stable throughout the intervention, as indicated by the strongest autoregressive coefficients within both the CLPMs and ML-SEM models. These phenomena may be because college students tend not to have academic classes on the weekends and may have off-days at

their places of employment. This may facilitate more regularity in sleep behaviors in young adults on the weekends compared to the weekdays; however, previous work has suggested that socioeconomic status and other demographic variables may moderate this association (49).

Healthy sleep during the weekend may improve mental health through facilitating adequate physical recovery in addition to regulating neurochemicals and neurohormones in the brain that further regulate mood (44, 50–52). A previous study found that brief interventions in addressing health habits using a contract and/or a consultation strategy have the potential to influence positive changes in multiple health behaviors (15). Future research may want to focus on employing wellness interventions as well as investigations into the impact of weekday-to-weekend sleep differences on health outcomes among students, as it is found that the sleep differences can lead to negative mental health outcomes (53). Another recent study that performed a bidirectional relationship between sleep and depression demonstrated self-reported low sleep quality was a predictor of depression or depressive symptoms in college students (54). Similarly, it was found that sleep quantity and quality were critical determinants of health and well-being, and the implementation of intervention programs that target depression, stress management, and healthy sleep patterns are necessary in young adults (55). Better mental health, as discussed previously, may also improve weekday sleep. This potential positive cycle between mental health, weekday sleep, and weekend sleep should be targets for future intervention work as the interrelationships may yield additive benefits on health outcomes.

Another interesting finding from this study was that after individual unit effects and time invariant covariates were accounted for, PA did not show any longitudinal association with mental health. Higher levels of PA have previously been shown to associate with lowered anxiety and depression, and better overall mental health within young adults (56–58). However, much of this prior research has been cross-sectional in design and PA has been mostly examined in isolation without consideration of other health behaviors. When other 24-h movement behaviors were considered, prior research has shown conflicting evidence regarding the statistical significance and strength of PA's associations with mental health variables (59–62). There are studies suggesting a mediated mechanism linking higher PA to better sleep and mental health (63, 64).

Other explanations for the differences in the observed magnitude and significance of these associations may be the specific mental health variables examined, the types of physical activities participated in, environmental factors that influence PA behavior during the time of assessment, different assessment methods for PA (self-report vs. objective/device-based), and research design (59, 65–68). Future research should examine these associations further using objective assessments of PA to determine if different intensities or patterns of PA behavior in different contexts can be a positive determinant of mental health independent of the quality and quantity of sleep.

Limitations included the use of self-report data collection methods for all the analyzed variables that increased risk of recall and social desirability bias. Data were collected on young adults from one US university during the 2021–2022 school year and during COVID-19, during an online wellness intervention; therefore, caution should be used when generalizing the results to younger or older age groups, students from other universities, and during non-pandemic climates. We also did not collect data on potential stressors or mediators of effect on each of the outcomes. This study was a secondary analysis of data collected during the online wellness intervention; therefore, experimental group comparison was not an aim of the study, however, experimental group was used as a time-invariant covariate within the ML-SEM models to control for the number of coaching sessions. There were no exclusion criteria for participating in this study; therefore, certain participant characteristics or conditions may have contributed to selection bias, have confounded the findings and threatened internal validity, and potentially may make it difficult to reproduce the results within other samples of participants. Finally, data were analyzed from a pilot study and thus the obtained sample size was not necessarily powered to detect weak associations or small effect sizes. Future research should examine the current study's associations using larger samples sizes to determine if the associations observed between PA and mental health can reach statistical significance.

The interconnectedness of sleep and mental-health play large roles in a young adult's overall wellbeing. Young adults in the wellness intervention self-reported on mental health, sleep, and other health habits *via* Zoom-based peer interactions with health coaches. Current study's findings revealed that mental health was a positive predictor of weekday sleep, during which weekend sleep positively predicted mental health. The results of this study support prior research in this area regarding the positive bidirectional associations between sleep and mental health. Caution should be made not to overinterpret the results based on the current study's use of self-report assessments. Caution also must be made when generalizing the results outside the context of an online wellness intervention implemented during a pandemic climate. Interventions targeting weekday sleep should focus on improving mental health and if targeting mental health, weekend sleep can be targeted. Future research should still be undertaken using larger sample sizes and use objective assessments to enhance the internal validity of the results. Self-reported sleep and mental health had a bidirectional association with each other during an online wellness intervention in young adults delivered during COVID-19.

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 Utah Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RB: conceptualization, investigation, methodology, formal analysis, writing—original draft, writing—review and editing. AB: data curation, writing—original draft, writing—review and editing. YB: conceptualization, methodology, data curation, investigation, writing—original draft, writing—review and editing. TB: supervision,

project administration, writing—original draft, writing—review and editing. JL: investigation, writing—original draft, writing—review and editing. JK: conceptualization, investigation, methodology, project administration, funding acquisition, writing—original draft, writing—review and editing. All authors contributed to the article and approved the submitted version.

Funding

This research was supported by the Salt Lake County Health Department, Salt Lake City, UT, United States, with software support from the University of Utah Clinical and Translational Science Institute funded by NCATS/NIH (UL1TR002538).

Acknowledgments

The authors would like to thank the college students who participated in this study, the peer health coaches who delivered the intervention, and the research assistants that helped collect data.

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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1168702/full#supplementary-material

References

1. Hosker DK, Elkins RM, Potter MP. Promoting mental health and wellness in youth through physical activity, nutrition, and sleep. *Child Adolesc Psychiatr Clin N Am*. (2019) 28:171–93. doi: 10.1016/j.chc.2018.11.010

2. Vankim NA, Nelson TF. Vigorous physical activity, mental health, perceived stress, and socializing among college students. *Am J Health Promot*. (2013) 28:7–15. doi: 10.4278/ajhp.111101-QUAN-395

3. Wickham SR, Amarasekara NA, Bartonicek A, Conner TS. The big three health behaviors and mental health and well-being among young adults: a cross-sectional investigation of sleep, exercise, and diet. *Front Psychol*. (2020) 11:579205. doi: 10.3389/fpsyg.2020.579205

4. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics*. (2016) 138:e20161642. doi: 10.1542/peds.2016-1642

5. Forbes EE, Bertocci MA, Gregory AM, Ryan ND, Axelson DA, Birmaher B, et al. Objective sleep in pediatric anxiety disorders and major depressive disorder. *J Am Acad Child Adolesc Psychiatry*. (2008) 47:148–55. doi: 10.1097/chi.0b013e31815cd9bc

6. Alfano CA, Reynolds K, Scott N, Dahl RE, Mellman TA. Polysomnographic sleep patterns of non-depressed, non-medicated children with generalized anxiety disorder. *J Affect Disord*. (2013) 147:379–84. doi: 10.1016/j.jad.2012.08.015

7. Forbes EE, Williamson DE, Ryan ND, Birmaher B, Axelson DA, Dahl RE. Peri-sleep-onset cortisol levels in children and adolescents with affective disorders. *Biol Psychiatry*. (2006) 59:24–30. doi: 10.1016/j.biopsych.2005.06.002

8. Baghurst T, Kelley BC. An examination of stress in college students over the course of a semester. *Health Promot Pract*. (2014) 15:438–47. doi: 10.1177/1524839913510316

9. Barbayannis G, Bandari M, Zheng X, Baquerizo H, Pecor KW, Ming X. Academic stress and mental well-being in college students: correlations, affected groups, and COVID-19. *Front Psychol*. (2022) 13:886344. doi: 10.3389/fpsyg.2022.886344

10. Matud MP, Díaz A, Bethencourt JM, Ibáñez I. Stress and psychological distress in emerging adulthood: a gender analysis. *J Clin Med*. (2020) 9:2859. doi: 10.3390/jcm9092859

11. Huang Y, Heflin CM, Validova A. Material hardship, perceived stress, and health in early adulthood. *Ann Epidemiol*. (2021) 53:69–75.e3. doi: 10.1016/j.annepidem.2020.08.017

12. Sabourin S, Irwin J. Prevalence of sufficient physical activity among parents attending a university. *J Am Coll Heal*. (2008) 56:680–5. doi: 10.3200/JACH.56.6.680-685

13. Richardson T, Elliott P, Roberts R, Jansen M. A longitudinal study of financial difficulties and mental health in a national sample of British undergraduate students. *Community Ment Health J*. (2017) 53:344–52. doi: 10.1007/s10597-016-0052-0

14. Pfledderer CD, Bai Y, Brusseau TA, Burns RD, King Jensen JL. Changes in college students' health behaviors and substance use after a brief wellness intervention during COVID-19. *Prev Med Rep*. (2022) 26:101743. doi: 10.1016/j.pmedr.2022.101743

15. Werch CE, Bian H, Moore MJ, Ames S, DiClemente CC, Weiler RM. Brief multiple behavior interventions in a college student health care clinic. *J Adolesc Health*. (2007) 41:577–85. doi: 10.1016/j.jadohealth.2007.06.003

16. Hutchesson MJ, Whatnall MC, Yazin N, Fenton S, Duncan MJ, Kay-Lambkin FJ, et al. Health behavior interventions for university students measuring mental health outcomes: a scoping review. *Front Public Health*. (2022) 10:1063429. doi: 10.3389/fpubh.2022.1063429

17. Bourke M, Patten RK, Dash S, Pascoe M, Craike M, Firth J, et al. The effect of interventions that target multiple modifiable health behaviors on symptoms of anxiety and depression in young people: a meta-analysis of randomized controlled trials. *J Adolesc Health*. (2022) 70:208–19. doi: 10.1016/j.jadohealth.2021.08.005

18. Ghrouz AK, Noohu MM, Dilshad Manzar M, Warren Spence D, BaHammam AS, Pandi-Perumal SR. Physical activity and sleep quality in relation to mental health among college students. *Sleep Breath*. (2019) 23:627–34. doi: 10.1007/s11325-019-01780-z

19. Strehli I, Burns RD, Bai Y, Ziegenfuss DH, Block ME, Brusseau TA. Development of an online mind-body physical activity intervention for young adults during COVID-19: a pilot study. *Int J Environ Res Public Health*. (2023) 20:4562. doi: 10.3390/ijerph20054562

20. Philippot A, Moulin P, Charon MH, Balestra C, Dubois V, de Timary P, et al. Feasibility of online high-intensity interval training (HIIT) on psychological symptoms in students in lockdown during the COVID-19 pandemic: a randomized controlled trial. *Front Psych*. (2022) 13:904283. doi: 10.3389/fpsyt.2022.904283

22. Rollo S, Antsygina O, Tremblay MS. The whole day matters: understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. *J Sport Health Sci*. (2020) 9:493–510. doi: 10.1016/j.jshs.2020.07.004

21. Guerrero MD, Barnes JD, Walsh JJ, Chaput JP, Tremblay MS, Goldfield GS. 24-hour movement behaviors and impulsivity. *Pediatrics*. (2019) 144:e20190187. doi: 10.1542/peds.2019-0187

22. Werch CE, Moore MJ, Bian H, DiClemente CC, Ames SC, Weiler RM, et al. Efficacy of a brief image-based multiple-behavior intervention for college students. *Ann Behav Med*. (2008) 36:149–57. doi: 10.1007/s12160-008-9055-6

23. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*. (2003) 35:1381–95. doi: 10.1249/01.MSS.0000078924.61453.FB

24. Fan L, Hao Z, Gao L, Qi M, Feng S, Zhou G. Non-linear relationship between sleep duration and metabolic syndrome: a population-based study. *Medicine (Baltimore)*. (2020) 99:e18753. doi: 10.1097/MD.0000000000018753

25. Brazier JE, Harper R, Jones NM, O'Cathain A, Thomas KJ, Usherwood T, et al. Validating the SF-36 health survey questionnaire: new outcome measure for primary care. *BMJ*. (1992) 305:160–4. doi: 10.1136/bmj.305.6846.160

26. Kenny DA. Cross-lagged panel correlation: a test for spuriousness. *Psychol Bull*. (1975) 82:887–903. doi: 10.1037/0033-2909.82.6.887

27. Zyphur MJ, Allison PD, Tay L, Voelkle MC, Preacher KJ, Zhang Z, et al. From data to causes I: building a general cross-lagged panel model (GCLM). *Organ Res Methods*. (2020) 23:651–87. doi: 10.1177/1094428119847278

28. Williams R, Allison PD, Moral-Benito E. Linear dynamic panel-data estimation using maximum likelihood and structural equation modeling. *Stata J*. (2018) 18:293–326. doi: 10.1177/1536867X1801800201

29. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equ Model*. (1999) 6:1–55. doi: 10.1080/10705519909540118

30. Xia Y, Yang Y. RMSEA, CFI, and TLI in structural equation modeling with ordered categorical data: the story they tell depends on the estimation methods. *Behav Res*. (2019) 51:409–28. doi: 10.3758/s13428-018-1055-2

31. Blackwelder A, Hoskins M, Huber L. Effect of inadequate sleep on frequent mental distress. *Prev Chronic Dis*. (2021) 18:E61. doi: 10.5888/pcd18.200573

32. Scott AJ, Webb TL, Martyn-St James M, Rowse G, Weich S. Improving sleep quality leads to better mental health: a meta-analysis of randomised controlled trials. *Sleep Med Rev*. (2021) 60:101556. doi: 10.1016/j.smrv.2021.101556

33. Taylor DJ, Gardner CE, Bramoweth AD, Williams JM, Roane BM, Grieser EA, et al. Insomnia and mental health in college students. *Behav Sleep Med*. (2011) 9:107–16. doi: 10.1080/15402002.2011.557992

34. Okano K, Kaczmarzyk JR, Dave N, Gabrieli JDE, Grossman JC. Sleep quality, duration, and consistency are associated with better academic performance in college students. *NPJ Sci Learn*. (2019) 4:16. doi: 10.1038/s41539-019-0055-z

35. Nyer M, Farabaugh A, Fehling K, Soskin D, Holt D, Papakostas GI, et al. Relationship between sleep disturbance and depression, anxiety, and functioning in college students. *Depress Anxiety*. (2013) 30:873–80. doi: 10.1002/da.22064

36. Wang X, Chen H, Liu L, Liu Y, Zhang N, Sun Z, et al. Anxiety and sleep problems of college students during the outbreak of COVID-19. *Front Psych*. (2020) 11:588693. doi: 10.3389/fpsyt.2020.588693

37. Liang K, de Lucena Martins CM, Chen ST, Clark CCT, Duncan MJ, Bu H, et al. Sleep as a priority: 24-hour movement guidelines and mental health of Chinese college students during the COVID-19 pandemic. *Healthcare (Basel)*. (2021) 9:1166. doi: 10.3390/healthcare9091166

38. Burns RD, Bai Y, Pfledderer CD, Brusseau TA, Byun W. Movement behaviors and perceived loneliness and sadness within Alaskan adolescents. *Int J Environ Res Public Health*. (2020) 17:6866. doi: 10.3390/ijerph17186866

39. Kitano N, Kai Y, Jindo T, Tsunoda K, Arao T. Compositional data analysis of 24-hour movement behaviors and mental health in workers. *Prev Med Rep*. (2020) 20:101213. doi: 10.1016/j.pmedr.2020.101213

40. Sampasa-Kanyinga H, Colman I, Goldfield GS, Janssen I, Wang J, Tremblay MS, et al. 24-hour movement behaviors and internalizing and externalizing behaviors among youth. *J Adolesc Health*. (2021) 68:969–77. doi: 10.1016/j.jadohealth.2020.09.003

41. Brown DMY, Kwan MYW. Movement behaviors and mental wellbeing: a cross-sectional isotemporal substitution analysis of Canadian adolescents. *Front Behav Neurosci*. (2021) 15:736587. doi: 10.3389/fnbeh.2021.736587

42. Brinkman JE, Reddy V, Sharma S. Physiology of sleep In: . *StatPearls*. Treasure Island, FL: StatPearls Publishing (2022)

43. Alvaro PK, Roberts RM, Harris JK. A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. *Sleep*. (2013) 36:1059–68. doi: 10.5665/sleep.2810

44. Triantafillou S, Saeb S, Lattie EG, Mohr DC, Kording KP. Relationship between sleep quality and mood: ecological momentary assessment study. *JMIR Ment Health*. (2019) 6:e12613. doi: 10.2196/12613

45. Hyun S, Hahm HC, Wong GTF, Zhang E, Liu CH. Psychological correlates of poor sleep quality among U.S. young adults during the COVID-19 pandemic. *Sleep Med*. (2021) 78:51–6. doi: 10.1016/j.sleep.2020.12.009

46. Strehli I, Ziegenfuss DH, Block ME, Burns RD, Bai Y, Brusseau TA. "I felt grounded and clear-headed": qualitative exploration of a mind-body physical activity intervention on stress among college students during COVID-19. *Inquiry*. (2022) 59:469580221126307. doi: 10.1177/00469580221126307

47. Minian N, Gayapersad A, Saiva A, Dragonetti R, Kidd SA, Strudwick G, et al. An e-mental health resource for COVID-19-associated stress reduction: mixed methods study of reach, usability, and user perceptions. *JMIR Ment Health*. (2022) 9:e39885. doi: 10.2196/39885

48. Sibinga EM, Kerrigan D, Stewart M, Johnson K, Magyari T, Ellen JM. Mindfulness-based stress reduction for urban youth. *J Altern Complement Med*. (2011) 17:213–8. doi: 10.1089/acm.2009.0605

49. Marco CA, Wolfson AR, Sparling M, Azuaje A. Family socioeconomic status and sleep patterns of young adolescents. *Behav Sleep Med*. (2011) 10:70–80. doi: 10.1080/15402002.2012.636298

50. Åkerstedt T, Ghilotti F, Grotta A, Zhao H, Adami HO, Trolle-Lagerros Y, et al. Sleep duration and mortality - does weekend sleep matter? *J Sleep Res*. (2019) 28:e12712. doi: 10.1111/jsr.12712

51. Goldstein AN, Walker MP. The role of sleep in emotional brain function. *Annu Rev Clin Psychol*. (2014) 10:679–708. doi: 10.1146/annurev-clinpsy-032813-153716

52. Bjorvatn B, Grønli J, Hamre F, Sørensen E, Fiske E, Bjørkum AA, et al. Effects of sleep deprivation on extracellular serotonin in hippocampus and frontal cortex of the rat. *Neuroscience*. (2002) 113:323–30. doi: 10.1016/s0306-4522(02)00181-1

53. Kim J, Noh JW, Kim A, Kwon YD. The impact of weekday-to-weekend sleep differences on health outcomes among adolescent students. *Children (Basel)*. (2022) 9:52. doi: 10.3390/children9010052

54. Dinis J, Bragança M. Quality of sleep and depression in college students: a systematic review. *Sleep Sci*. (2018) 11:290–301. doi: 10.5935/1984-0063.20180045

55. Wallace DD, Boynton MH, Lytle LA. Multilevel analysis exploring the links between stress, depression, and sleep problems among two-year college students. *J Am Coll Heal*. (2017) 65:187–96. doi: 10.1080/07448481.2016.1269111

56. Zulyniak S, Williams JVA, Bulloch AGM, Lukmanji A, Patten SB. Physical activity and mental health: a cross-sectional study of Canadian youth. *J Can Acad Child Adolesc Psychiatry*. (2020) 29:241–52.

57. Ströhle A, Höfler M, Pfister H, Müller A-G, Hoyer J, Wittchen H-U. Physical activity and prevalence and incidence of mental disorders in adolescents and young adults. *Psychol Med*. (2007) 37:1657–66. doi: 10.1017/S003329170700089X

58. Pascoe MC, Bailey AP, Craike M, Carter T, Patten RK, Stepto NK, et al. Single session and short-term exercise for mental health promotion in tertiary students: a scoping review. *Sports Med Open*. (2021) 7:72. doi: 10.1186/s40798-021-00358-y

59. Duncan MJ, Riazi NA, Faulkner G, Gilchrist JD, Leatherdale ST, Patte KA. The association of physical activity, sleep, and screen time with mental health in Canadian adolescents during the COVID-19 pandemic: a longitudinal isotemporal substitution analysis. *Ment Health Phys Act*. (2022) 23:100473. doi: 10.1016/j.mhpa.2022.100473

60. Divine A, Blanchard C, Benoit C, Downs DS, Rhodes RE. The influence of sleep and movement on mental health and life satisfaction during the transition to parenthood. *Sleep Health*. (2022) 8:475–83. doi: 10.1016/j.sleh.2022.06.013

61. Bell SL, Audrey S, Gunnell D, Cooper A, Campbell R. The relationship between physical activity, mental wellbeing and symptoms of mental health disorder in adolescents: a cohort study. *Int J Behav Nutr Phys Act*. (2019) 16:138. doi: 10.1186/s12966-019-0901-7

63. Barham WT, Buysse DJ, Kline CE, Kubala AG, Brindle RC. Sleep health mediates the relationship between physical activity and depression symptoms. *Sleep Breath*. (2022) 26:1341–9. doi: 10.1007/s11325-021-02496-9

64. Werneck AO, Silva DR, Malta DC, Lima MG, Souza-Júnior PRB, Azevedo LO, et al. The mediation role of sleep quality in the association between the incidence of unhealthy movement behaviors during the COVID-19 quarantine and mental health. *Sleep Med*. (2020) 76:10–5. doi: 10.1016/j.sleep.2020.09.021

65. McKercher CM, Schmidt MD, Sanderson KA, Patton GC, Dwyer T, Venn AJ. Physical activity and depression in young adults. *Am J Prev Med*. (2009) 36:161–4. doi: 10.1016/j.amepre.2008.09.036

66. Hale GE, Colquhoun L, Lancastle D, Lewis N, Tyson PJ. Review: physical activity interventions for the mental health and well-being of adolescents - a systematic review. *Child Adolesc Ment Health*. (2021) 26:357–68. doi: 10.1111/camh.12485

67. Ai X, Yang J, Lin Z, Wan X. Mental health and the role of physical activity during the COVID-19 pandemic. *Front Psychol*. (2021) 12:759987. doi: 10.3389/fpsyg.2021.759987

68. Wunsch K, Kasten N, Fuchs R. The effect of physical activity on sleep quality, well-being, and affect in academic stress periods. *Nat Sci Sleep*. (2017) 9:117–26. doi: 10.2147/NSS.S132078

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 31 May 2023
DOI 10.3389/fpsyg.2023.1196066

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Lucas Murrins Marques,
University of São Paulo, Brazil
Elena Mainer Pardos,
Universidad San Jorge, Spain

*CORRESPONDENCE
Dicle Aras
✉ daras@ankara.edu.tr
Mehmet Gülü
✉ mehmetgulu@kku.edu.tr

RECEIVED 29 March 2023
ACCEPTED 05 May 2023
PUBLISHED 31 May 2023

CITATION
Aras D, Samil Onlu A, Durmus T, Cengiz C, Guler D, Guler Y, Ugurlu A, Aldhahi MI and Gülü M (2023) A brief body scan mindfulness practice has no positive effect on the recovery of heart rate variability and cognitive tasks in female professional basketball players. *Front. Psychol.* 14:1196066. doi: 10.3389/fpsyg.2023.1196066

A brief body scan mindfulness practice has no positive effect on the recovery of heart rate variability and cognitive tasks in female professional basketball players

Dicle Aras[1]*, Aysberg Samil Onlu[2], Tugay Durmus[1], Caner Cengiz[3], Damla Guler[3], Yagmur Guler[4], Alkan Ugurlu[5], Monira I. Aldhahi[6] and Mehmet Gülü[7]*

[1]Department of Coaching Education, Faculty of Sport Sciences, Ankara University, Ankara, Türkiye, [2]Ankara University Graduate School of Health Sciences, Movement and Training Sciences Master's Program, Ankara, Türkiye, [3]Department of Physical Education and Sports, Faculty of Sport Sciences, Ankara University, Ankara, Türkiye, [4]Department of Recreation, Faculty of Sport Sciences, Yalova University, Yalova, Türkiye, [5]Department of Physical Education and Sports Education, Faculty of Sport Sciences, Akdeniz University, Antalya, Türkiye, [6]Department of Rehabilitation Sciences, College of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia, [7]Department of Sports Management, Faculty of Sport Sciences, Kirikkale University, Kirikkale, Türkiye

Introduction: In this study, we examined the acute effects of a short video-based body scan mindfulness practice on the heart rate variability (HRV) and cognitive performance of professional female basketball players after the first half of a simulated basketball game.

Methods: In this crossover randomized controlled trial, nine professional athletes completed a physical loading protocol on two separate days. The protocol consisted of a 10-min Yo-Yo Intermittent Recovery Test Level 1 in the first quarter, followed by a 10-min basketball game in the second quarter. Immediately afterward, they were asked to engage in a 10-min mindfulness practice or watch a 10-min nature-based documentary as a type of mental intervention. Their HRV, Rating of Perceived Exertion (RPE), National Aeronautics and Space Administration Task Load Index 2 (NASA TLX-2), and Go/No-Go test scores were recorded immediately before and after the physical loading and after the mental intervention.

Results: The physical demand, effort, and frustration level subscales of the NASA TLX-2 and the RPE scores were found to be significantly higher after the physical loading, and they returned to the baseline level after both types of mental intervention. The Go/No-Go test scores did not differ depending on the measurement time. All time- and frequency-domain heart rate variability parameters, except the low-to-high frequency ratio, were found to be significantly high immediately after the physical loading protocol. However, these parameters returned to their initial levels after both types of mental intervention.

Discussion: Completing the tests involved in the study protocol successfully induced physical fatigue, as evidenced by consistent measurement tools, but the one-time and short-term mindfulness practice had no additional benefits for the recovery of heart rate variability, cognitive tasks, or subjective assessment methods, such as RPE and NASA TLX-2, in basketball players with no previous experience of mindfulness practice.

KEYWORDS

basketball, cognitive task, heart rate variability, Go/No-Go test, mindfulness, NASA TLX, RPE

1. Introduction

Basketball is a sport that involves frequent short-term and short-distance accelerations and decelerations, explosive changes of direction, jumps, and player-to-player contacts, all of which can increase the risk of musculoskeletal injuries during training and competitions (Montgomery et al., 2008). Basketball players compete at an average physiological intensity above the lactate threshold and 85% of their maximum heart rate during a 40-min match (Stojanović et al., 2018). This sport also has one of the longest seasons in professional sports, which can further exacerbate the physical demands and physiological stress placed on athletes during both pre-season and competition periods. These high-intensity movement demands and physiological stressors can result in fatigue (Klusemann et al., 2013). Fatigue is a multidimensional concept that can be defined as a decrease in maximum performance (Coutts et al., 2007; Kellmann, 2010; Knicker et al., 2011; Joyce and Lewindon, 2014). Physical fatigue is characterized by a decrease in strength/power output in muscle cells and motor units, a reduction in muscle performance, and a deterioration in quick decision-making and technical and motor skills (Knicker et al., 2011). However, the effect of fatigue on sport performance is not solely limited to the neuromuscular system (Van Cutsem et al., 2017), and cognitive fatigue is also recognized as a predominant factor (Weinberg and Gould, 2019). Cognitive fatigue is defined as a psycho-biological condition that results from prolonged cognitive load (Desmond and Hancock, 2001; Job and Dalziel, 2001), and it can lead to altered attentional focus, slower reaction times, increased errors in reactions, and decreased use of visual cues in athletes, especially in high-intensity and intermittent sports such as basketball (Baker et al., 2015; Van Cutsem et al., 2017). Since both physiological and cognitive factors play a decisive role in fatigue (Bühlmayer et al., 2017), the speed and efficiency of recovery are important parameters for basketball players (Alaphilippe et al., 2012).

A mindfulness-based regimen is a self-regulatory approach in which a person is fully conscious of their moment-to-moment experiences and actively engages with the present moment without judgment (Kabat-Zinn, 2003; Creswell, 2017). Mindfulness practices involve paying attention to the body and becoming aware of all the various sensations and thoughts that arise during actions (Neale, 2006). Since mindfulness is associated with high levels of wellbeing (Brown and Ryan, 2003), it has been used in various fields, including sports, to enhance team cohesion, reduce anxiety and stress, prevent burnout by reducing fatigue, and mitigate the negative effects of previous adverse situations by promoting present-moment awareness (Kee, 2019; Li et al., 2019). A systematic review study stated that chronic mindfulness practice can enhance sports performance (Sappington and Longshore, 2015). Similarly, in a meta-analytical review, Bühlmayer et al. (2017) reported that mindfulness practice or mindfulness-based interventions have beneficial effects on athletic parameters and can reduce physiological stress in athletes. Macdonald and Minahan (2018) investigated the effects of 8 weeks of mindfulness training on cortisol levels in highly trained wheelchair basketball players and found a decrease in cortisol levels. They suggested that mindfulness training could be helpful in sports. However, all of these studies examined the chronic effects of mindfulness, and the studies examining the acute effects are scarce. A study by Wolch et al. (2021) investigated the effects of brief mindfulness practices on free-throw shooting performance in young basketball players and found no significant difference in performance. In a similar study, Shaabani et al. (2020) observed that brief mindfulness interventions had a beneficial impact on the free-throw performance of basketball players by mitigating the effects of ego depletion (Shaabani et al., 2020). However, due to the limited number of studies and differences in the protocols applied, further studies are needed to better understand the effects of mindfulness on sport performance.

The effects of both physical and mental fatigue could be measured. From a physiological perspective, the optimal level of variability, flexibility, and adaptability observed in the fundamental regulatory systems of the human body is considered an indicator of healthy functioning and overall wellbeing (Shaffer et al., 2014). Heart rate variability (HRV) is frequently used as a non-invasive method that provides information concerning the functioning of the autonomic nervous system (Anon, 1996). Thus, HRV measurements have been used in the field of exercise and sports to calculate heart-based risks, determine stress levels created by training loads, examine the recovery process after loading, and adjust the intensity of the training load (Aras et al., 2022). Studies on the relationship between mindfulness and HRV have also shown that both one-time and multiple-applied mindfulness practices have positive effects on HRV (Ditto et al., 2006; Krygier et al., 2013).

Even though it has been reported in the literature that mindfulness practice has positive chronic effects on athletes (Sappington and Longshore, 2015; Bühlmayer et al., 2017), the

number of studies examining its acute effects on the recovery parameters of basketball players is limited. Therefore, the purpose of the present research was to investigate the acute effects of a 10-min body scan mindfulness practice on HRV, cognitive task performance, and subjective scales, as measured by the National Aeronautics and Space Administration Task Load Index 2 (NASA TLX-2) and the Rating of Perceived Exertion (RPE), after the first half of a simulated basketball game in professional female basketball players. According to the general approach in the literature, it was expected that a brief body scan mindfulness practice would result in a greater recovery of HRV parameters and lead to a reduction in both the number of errors and the duration of cognitive work when compared to the control situation.

2. Materials and methods

2.1. Study design

In this crossover randomized controlled trial, the acute effect of a 10-min mindfulness practice on the recovery of HRV and on cognitive functions was examined. Ethical approval was obtained from the Ankara University Institutional Ethical Committee (2022-SBB-0443). All participants visited the measurement site on three separate occasions. During the first visit, which was a paid familiarization session, the measurement process was explained, and informed consent forms were collected from the participants.

On the second visit, the HRV measurement was conducted. The HRV device remained attached to the person throughout the day during all measurements. Immediately before the physical loading phase, they were given the Rating of Perceived Exertion (RPE) and the National Aeronautics and Space Administration Task Load Index 2 (NASA TLX- 2). Then, they performed a 10-min Yo-Yo Intermittent Recovery Test Level 1 in the first quarter. After 1 min of passive rest, a basketball game was played in the second quarter. When they finished the physical loading phase, they again filled out the RPE and NASA TLX-2 and performed the Go/No-Go test. At the end of the tests, they attended the mindfulness practice or documentary-watching program. In the third meeting, the same process was repeated, only changing the mindfulness practice or documentary-watching phase (Figure 1).

2.2. Participants

A total of nine female professional basketball players with a mean age of 20.83 ± 0.75 years, a body weight of 64.62 ± 2.52 kg, body height of 169.00 ± 6.57 cm, a body mass index of 22.70 ± 1.84 kg/m^2, and a percentage body fat 26.07 ± 2.81 participated in the research voluntarily. The participants were included only if they performed actively in a professional league and regularly attended training sessions 3 days a week for at least the last 3 months. Subjects with any chronic disease such as diabetes mellitus, heart disease, arthritis, hypertension, or musculoskeletal injury in the muscle, ligaments, bones, cartilage, or tendons were excluded from the study. Participants who practiced mindfulness or meditation in their daily lives were also excluded from the study so that the one-time effect could be investigated objectively.

2.3. Procedures

2.3.1. HRV measurement

All HRV data were collected using a Polar H10 heart rate monitor (Polar, Finland). The HRV monitors were placed on the chests of the subjects and were not removed until the measurement was finished. The HRV data were recorded using the Elite HRV 5.5.5. application and converted into quantitative HRV data using Kubios HRV Standard 3.5.0. software. The parameters used in the present research were the interval between two R-peaks of the QRS complex in ms (mean RR), mean HR, the standard deviation of NN intervals (SDNN), the root mean square of successive RR interval differences (RMSSD), the baseline width of the RR interval histogram displaying NN intervals (TINN), high frequency (HF), low frequency (LF), and the LF: HF ratio. These parameters were recorded before the physical loading, after the physical loading, and after the mental intervention. All the data were collected between 3 and 5 p.m. The participants were also warned not to exercise or consume alcohol within the 24 h before the test. Participants' caffeine intake was also limited within the previous 12 h of the test.

2.3.2. Go/No-Go test

The Go/No-Go test, each containing 25 stimuli, was administered to all participants three times in a row. The total application time and number of errors were recorded. The tests were carried out on the computer (https://www.psytoolkit.org/experiment-library/experiment_go-no-go.html) after the physical loading and mental intervention. According to the test rules, the participants were asked to follow the warnings on the screen and press the space key as soon as they saw the green (Go) warning. When they saw the red (No-Go) warning, they were asked to wait. Since basketball players must adapt to changing situations in a very short time in all offensive and defensive movements, the Go/No-Go test was used to determine cognitive functions in the current research because of its structural similarity.

2.3.3. RPE and NASA TLX-2

As subjective evaluation methods, RPE and NASA TLX-2 measurements were applied three times: before the physical loading, after the physical loading, and after the mental intervention. The RPE was evaluated using a 6–20 scale (Borg, 1982). The NASA TLX-2 included mental demand, physical demand, temporal demand, performance, effort, and frustration level subscales (Hart and Staveland, 1988). The participants were asked to fill in a scale consisting of 5-point intervals to evaluate their work on these sub-headings, and scores from 0 to 100 were recorded for each subscale.

2.3.4. Physical loading

The physical loading process consisted of two parts. In the first quarter, to cause physical fatigue through intense intermittent

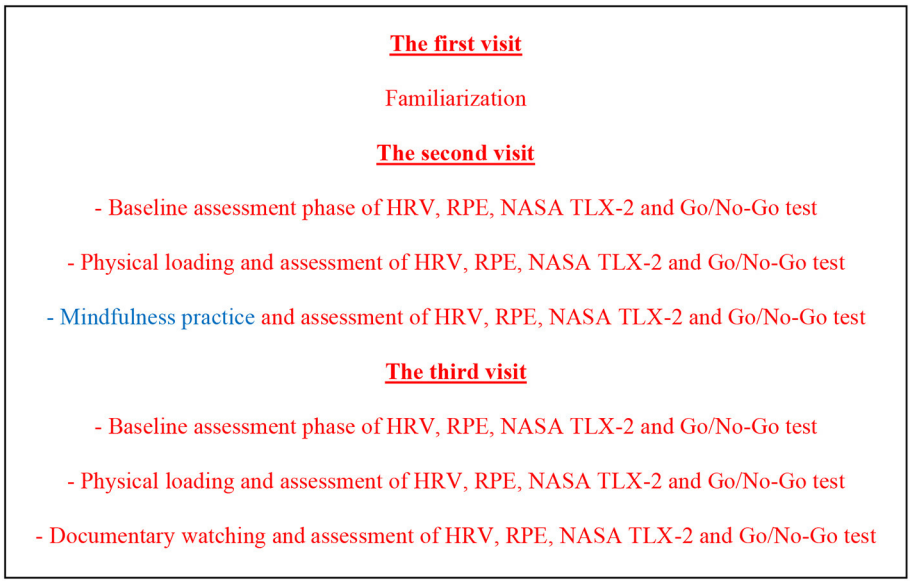


FIGURE 1
Study design process.

exercise, players performed a 10-min Yo-Yo Intermittent Recovery Test Level 1 (Bangsbo et al., 2008). The test started with a speed level of 10 km/h and increased progressively for 10 min. After the completion of the Yo-Yo test, the participants were allowed to rest for 1 min. In the second quarter, the participants played a 10-min basketball game. The aim of the second part of the physical loading process was to induce physical fatigue among the female players and increase their cognitive fatigue by challenging them with quick and demanding decision-making tasks.

2.3.5. Mental intervention

As a mental intervention, a 10-min video-based mindfulness practice was carried out. The practice was recorded by an international yoga, meditation, and mindfulness instructor. Body scan mindfulness practice was based on body awareness and breathing control. The players watched a nature-based documentary for 10 min as a control for mindfulness practice on the other measurement day. In both interventions, videos were projected onto the wall in the locker room of the gym to simulate the match environment. The subjects were asked to sit in the most comfortable position possible. They were also asked to follow all directions and not speak during the interventions.

2.3.6. Mindfulness state

The participants' own assessments were used to determine the state of mindfulness. They were asked to grade the following questions on a five-point Likert scale: (1) I focus on my breathing and (2) I feel in touch with my body (Hafenbrack et al., 2014). The means of the two expressions were compared.

2.4. Statistical analyses

All analyses were performed using SPSS v.22 software (SPSS Inc., Chicago, IL, USA). After calculating the descriptive statistics, the distribution and homogeneity of the data were tested. The Shapiro–Wilk test was conducted to evaluate the normality distribution as the number of subjects was below 50. Repeated Measures ANOVA or Friedman tests were used to compare the mean differences at different times, depending on the distribution. Bonferroni for pairwise comparisons was utilized. For in-group statistics, the Friedman test was performed, and the mean difference was calculated using either the paired samples t-test or the Wilcoxon test. An alpha value of 0.05 was accepted for all statistical analyses.

3. Results

In accordance with the state of mindfulness results, both questions were significantly different after the 10-min mindfulness practice. The participants graded the first question after DW as 1.5 $\pm$ 0.55 and after MP as 4.17 $\pm$ 0.75 ($p < 0.026$). They answered the second question after DW 1.33 $\pm$ 0.52 and after MP 4.33 $\pm$ 0.52 ($p < 0.026$).

There was no significant difference between the groups in HRV values, depending on the physical or mental intervention (Table 1). However, all parameters, except the LF: HF value, showed that the sympathetic effect increased significantly after the physical loading. The mean RR in DW was lower after the physical loading than before the physical loading (0.008) and after the mental intervention (0.030). Similarly, the same results were obtained in MP (0.010 and 0.012, respectively). The mean HR was also higher than the first measurement (0.003, 0.028) in DW and in MP (0.028, 0.002). The RMSSD and SDNN measurements taken

10.3389/fpsyg.2023.1196066

TABLE 1 The HRV test results and their mean comparisons.

		Before physical loading	After physical loading	After mental intervention	*P*_	n^2
Mean RR	DW	689.50 ± 89.41	420.83 ± 54.63^t	612.50 ± 85.77	0.000**	0.994
	MP	706.33 ± 157.34	396.33 ± 42.53^t	586.17 ± 81.92	0.000**	0.982
	*P*_	0.824	0.406	0.598		
Mean HR	DW	88.33 ± 12.01	144.50 ± 18.29^t	99.83 ± 16.09	0.009**	0.995
	MP	90.00 ± 27.44	152.83 ± 16.98^t	103.83 ± 14.52	0.006**	0.982
	*P*_	0.522	0.406	0.631		
SDNN	DW	47.53 ± 17.93	8.08 ± 5.97^t	39.20 ± 14.42	0.000**	0.928
	MP	54.60 ± 24.4	8.15 ± 4.68^t	35.32 ± 13.54	0.006**	0.882
	*P*_	0.337	0.983	0.641		
RMSSD	DW	36.18 ± 20.8	5.63 ± 5.24^t	22.50 ± 8.87	0.006**	0.876
	MP	40.92 ± 24.22	3.60 ± 0.51^t	15.30 ± 5.52	0.030*	0.844
	*P*_	0.724	0.748	0.109		
TINN	DW	197.67 ± 63.3	35.00 ± 30.9^t	193.00 ± 65.45	0.000**	0.953
	MP	249.50 ± 112.71	29.57 ± 15.25^t	166 ± 65.06	0.000**	0.883
	*P*_	0.349	0.707	0.490		
HF	DW	465.00 ± 335.3	4.67 ± 4.84^t	204.83 ± 120.12	0.019*	0.733
	MP	667.00 ± 485.33	2.17 ± 1.72^t	111.83 ± 93.61	0.020*	0.704
	*P*_	0.421	0.261	0.166		
LF	DW	1,360.50 ± 858.59	39.50 ± 43.2^t	1,310.50 ± 1,413.89	0.006**	0.642
	MP	2,408.83 ± 1,583.29	41.83 ± 45.78^t	947.83 ± 527.31	0.006**	0.780
	*P*_	0.184	0.929	0.873		
LF: HF	DW	3.92 ± 0.95	12.31 ± 13.35	6.34 ± 2.88	0.234	
	MP	6.71 ± 3.30	15.03 ± 15.38	7.12 ± 2.55	0.309	
	*P*_	0.074	0.750	0.630		

DW, documentary watching; MP, mindfulness practice; SDNN, standard deviation of NN intervals. RMSSD, root mean square of successive RR interval differences; TINN, baseline width of the RR interval histogram displaying NN intervals; HF, high frequency; LF, low frequency; LF:HF, LF: HF ratio. *$p < 0.05$, **$p < 0.01$.

***P*_**: The ***P*_** value in the column represents the average comparison of the values obtained at different times in a single group. The ***P*_** value in the row represents the average comparison of two different groups.

^{t}indicates the measurement time at which the difference originates.

after the physical loading were lower than the recordings before the physical loading and after the mental intervention in DW (0.028 for RMSSD; 0.018 and 0.024 for SDNN, respectively) and in MP (0.013 and 0.028 for RMSSD; 0.001 and 0.028 for SDNN, respectively). In addition, the measurement observed after the mindfulness practice was significantly lower than the measurement taken before the physical loading in RMSSD and SDNN (0.046 in both). The TINN was observed to be lower after the physical loading compared to the values taken before and after the mental intervention in the DW and MP groups (0.010 and 0.015; 0.012 and 0.004, respectively).

Frequency-domain parameters also showed close results. The HF was recorded lower after the physical loading than before the physical loading and after the mental intervention in DW (0.020, 0.009, respectively) and MP (0.020, 0.034, respectively). Additionally, there was also a significant change between the first and last HF values in both mental intervention groups (0.043 in the DW group and 0.024 in the MP group). Finally, the LF values followed a similar pattern, with exposure to physical loading resulting in lower LF values in both intervention groups compared to before physical activity levels and after mental intervention levels (0.014 and 0.028 for the DW group; 0.042 and 0.021 for the MP group).

When the Go/No-go test results were examined, no significant difference was found between the groups or in-group results depending on physical loading (Table 2).

Table 3 shows representation of RPE and NASA TLX-2 scores. No RPE scores differed significantly in the subjective measurements used in the study. However, there were differences in RPE and some NASA TLX-2 scores, depending on the application time. The RPE score recorded after the physical loading was higher than that before the physical loading and after the mental intervention in both the DW (0.000 and 0.001, respectively) and MP groups (0.003 and 0.003, respectively). The NASA TLX-2, physical demand score, was higher after the physical loading than before the physical loading and after the mental intervention in the DW (0.002) and MP groups (0.027 and 0.026, respectively). The effort score was

TABLE 2 The Go/No-go test results and their mean comparisons.

		Before physical loading	After physical loading	After mental intervention	*P*_
Test duration	DW	45.71 ± 3.11	46.67 ± 2.66	47.20 ± 3.68	0.731
	MP	44.85 ± 2.14	46.11 ± 3.89	44.55 ± 4.17	0.364
	*P*_	0.318	0.764	0.268	
Number of errors	DW	1.94 ± 1.90	2.17 ± 1.17	1.83 ± 1.17	0.739
	MP	2.02 ± 2.63	2.00 ± 1.67	3.17 ± 2.14	0.272
	*P*_	0.417	0.845	0.240	

DW, documentary watching; MP, mindfulness practice.
P_: The ***P***_ value in the column represents the average comparison of the values obtained at different times in a single group. The ***P***_ value in the row represents the average comparison of two different groups.

again higher after physical loading than pre-physical loading and post-mental intervention in the DW (0.002) and MP groups (0.006 and 0.028, respectively). Finally, in the DW group, frustration levels were recorded to be higher after the physical loading than before the physical loading (0.004) and after mental intervention (0.035). This parameter was also found to be significantly higher after physical loading (0.025) in the MP group.

4. Discussion

This study was intended to investigate the acute effects of a brief mindfulness practice on HRV, cognitive task performance, and self-perceived physical exertion in professional female basketball players. For this purpose, the participants underwent a 10-min video-based body scan mindfulness intervention immediately after half-time during a simulated basketball game. To fulfill the purpose, the authors administered two different mental interventions: mindfulness practice (MP) and documentary watching (DW).

As a result, it was observed that RPE increased after physical fatigue and reached its baseline level after the passive recovery phase, regardless of the type of MI. In this case, mindfulness practice had no additional effect on RPE. Similar results were also observed on some subscales of the NASA TLX-2 inventory. The subscales for mental demand, temporal demand, and performance remained unchanged, whereas the subscales for physical demand, effort, and frustration increased following physical fatigue and subsequently returned to their baseline levels after MI, regardless of the type of MI. In this study, DW or MP had almost the same effects on an increased rating of perceived exertion, perception of physical demand, effort, and frustration level among the participants. Another factor that was measured in the study was the state of mindfulness, which was used to assess the effectiveness of the mindfulness practice. The results indicate that the intervention was successful in enhancing the participants' mindfulness awareness.

The HRV parameters observed in the current research show that 20 min of physical loading caused physical fatigue. All time- and frequency-domain HRV parameters, except the LF: HF ratio, indicated a clear increase in sympathetic activity. There was a significant decrease in mean RR (0.000 in both), SDNN (0.000 in DW and 0.006 in MP), RMSSD (0.006 in DW and 0.030 in MP), TINN (0.000 in both), HF (0.019 in DW and 0.020 in MP), and LF (0.006 in both) and an increase in mean HR (0.009 in the DW group and 0.006 in the MP group). Moreover, in the LF: HF ratio, an increase was ∼215.05% in the DW group and ∼123.99% in the MP group, even though the LF: HF ratio was not significant. This proves the consistency of the HRV measurement and the efficiency of the physical loading phase. These results are consistent with those from NASA TLX-2 and RPE. Another remarkable result was that the 10-min passive resting time was adequate to recover almost all of the HRV parameters. The mean RR, mean HR, TINN, and LF reached their initial levels at the end of the 10 min. On the contrary, the SDNN, RMSSD (0.046 in both groups), and HF (0.043 in the DW group and 0.024 in the MP group) values were still lower after MI compared to the first measurement taken before PL in both groups. This result indicates that a longer time may be needed for some HRV parameters to recover. Besides, the most important finding was that the results were not explicitly affected by the type of MI. No significant difference was found in any of the HRV values obtained from the participants after MP and DW.

Previous research has suggested that mindfulness practices are effective for the autonomic nervous system and should be examined in more detail (Krygier et al., 2013). Since HRV has been accepted as an indicator of the autonomic nervous system that is affected by both physical and mental health (Brown et al., 2021), the present research focused on the changes in HRV measurement after PL and MI and its effects on cognitive tasks. As a kind of mindfulness practice, a 10-day Vipassana meditation was carried out by people with no previous meditation history, and its chronic and acute effects on HRV and some wellbeing and ill-being inventories were investigated (Krygier et al., 2013). According to the results, a 10-day mindfulness intervention, which involved 5 min of rest and 5 min of meditation practice, caused an increase in all the wellbeing parameters and decreased many of the ill-being parameters despite no change in HRV. However, the comparison of the resting baseline and mindfulness phases of all sessions revealed a task effect on HF power, indicating the parasympathetic dominance of HRV. The task effect observed may be due to the fact that the MP in this study was based on breathing exercises, in particular, or the repetition of the sessions. Kirk and Axelsen (2020) conducted a study comparing the acute and chronic effects of mindfulness and music-listening interventions on HRV. The daily time commitment for both interventions was 20 min for the first 5 days and 30 min for the last 5 days. At the end of the 10 days, they found that the mindfulness intervention was more effective in improving HRV, including sleep quality. In terms of the acute comparisons, they

10.3389/fpsyg.2023.1196066

TABLE 3 The results of the RPE and NASA TLX-2 subscales and their mean comparisons.

		Before physical loading	After physical loading	After mental intervention	*P*_	n^2
RPE	DW	6.00 ± 0.00	13.67 ± 2.16^t	7.00 ± 0.89	0.000**	0.995
	MP	6.00 ± 0.63	14.17 ± 3.60^t	6.00 ± 0.42	0.003**	0.985
	*P*_	1.000	0.777	0.051		
Mental demand	DW	19.17 ± 12.01	35.83 ± 24.58	31.67 ± 19.41	0.121	
	MP	15.83 ± 12.81	40.83 ± 30.07	35.83 ± 35.41	0.385	
	*P*_	0.490	0.759	0.806		
Physical demand	DW	5.83 ± 2.04	66.67 ± 20.90^t	5.00 ± 0.00	0.000**	0.912
	MP	6.67 ± 4.08	70.00 ± 30.17^t	6.67 ± 2.59	0.005**	0.883
	*P*_	0.902	0.462	0.138		
Temporal demand	DW	25.83 ± 35.27	54.17 ± 27.10	36.67 ± 35.02	0.118	
	MP	30.00 ± 38.73	55.00 ± 28.64	30.83 ± 29.23	0.327	
	*P*_	0.849	0.686	0.871		
Performance	DW	48.33 ± 47.50	60.83 ± 15.63	43.33 ± 43.55	0.161	
	MP	35.83 ± 34.70	61.67 ± 27.51	34.17 ± 32.93	0.154	
	*P*_	0.806	0.746	0.690		
Effort	DW	9.17 ± 4.92	75.83 ± 17.15^t	12.50 ± 11.73	0.000**	0.896
	MP	12.50 ± 8.22	70.00 ± 33.47^t	16.67 ± 19.15	0.007**	0.849
	*P*_	0.503	0.712	0.858		
Frustration level	DW	13.33 ± 10.33	53.33 ± 16.02^t	28.33 ± 38.43	0.005**	0.787
	MP	25.00 ± 32.25	51.67 ± 29.27^t	15.83 ± 12.01	0.048*	0.714
	*P*_	0.566	0.905	0.464		

RPE, the rating of perceived exertion. *$p < 0.05$, **$p < 0.01$.

***P*_**: The ***P*_** value in the column represents the average comparison of the values obtained at different times in a single group. The ***P*_** value in the row represents the average comparison of two different groups.

^{t}indicates the measurement time at which the difference originates.

stated that both practicing mindfulness and listening to music had similar positive effects on HRV compared to the control group. The results obtained from this study can be considered congruent with those in the current study, which revealed that watching a documentary was as effective as mindfulness in improving HRV. Based on this result, we can conclude that any relaxing activity could have acutely positive effects on HRV. However, this similarity shows that, when mindfulness is practiced for a long time, its acute effects can be more pronounced in addition to its chronic effects. Another study supporting this statement was conducted by Delgado-Pastor et al. (2013). They compared 30-min mindfulness with 30-min random thinking. As a result, they found that experienced Vipassana meditators had better HRV values after MP. Delgado-Pastor et al. (2013) also showed that practicing mindfulness regularly has more pronounced effects. In a study in which mindfulness body scan meditation was used as in the current research, it was stated that respiratory sinus arrhythmia, which is accepted as an indicator of vagal activity, increased significantly after 20 min of intervention in people with no meditation history when compared to progressive muscle relaxation or the control group (Ditto et al., 2006). This increase observed in the mindfulness body scan meditation group was similarly high when measured 1 month later. In the measurement repeated 1 month later, the results of the progressive muscular relaxation group were also high. However, in this first part of the research, they found no significant change in systolic and diastolic blood pressure. In the second part of their study, in which the data were collected from different participants, it was found that the LF and HF power of HRV were higher after 20 min of mindfulness body scan meditation in comparison to 20 min of listening to an audiobook, with no change found in the blood pressure. As a result, they concluded that some of the changes were independent of the type of relaxation activity and that this research revealed similarities and differences between mindfulness body scan meditation and other relaxation activities. However, there are also other studies indicating that there is no interaction between HRV and mindfulness. Brown et al. (2021), in the first comprehensive meta-analysis study in which they analyzed the results of 19 randomized controlled trials, claimed that mindfulness-based interventions were not significantly associated with vagally mediated HRV due to the heterogeneity of the studies.

Since many studies have examined the effects of different mindfulness interventions on HRV, it may be useful to mention the comparisons between HRV biofeedback practice and MP

in the literature. The closest study to the current research was conducted by Paul and Garg (2012). They discovered positive chronic effects of 10 sessions of 20-min HRV biofeedback training on HRV values such as total HRV, LF, HF, and respiration rate, as well as state-trait anxiety and self-efficacy in basketball players that were measured against 10-min motivational video-watching and the control condition. It was demonstrated that HRV biofeedback training performed by breathing at one's own resonant frequency increases parasympathetic activity by increasing the respiratory sinus arrhythmia and that it is an effective way to enhance the activity of the autonomic nervous system. However, different results were found in different studies examining the effects of HRV biofeedback training on stress and, thus, on the autonomic nervous system when compared to MP. In a long-term study comparing the effects of 6-week mindfulness practice, which was based on breathing, thoughts, feelings, and physiological sensations, and HRV biofeedback on stress levels, no significant difference was found in the experimental groups or in the control group (Brinkmann et al., 2020). In another comparison, Van Der Zwan et al. (2015) investigated the effects of a 5-week physical activity, mindfulness meditation, and HRV biofeedback interventions on reducing stress, depression, and anxiety. They concluded that all interventions were significantly effective, with no differences between the interventions. The duration of both interventions was 10 min/day for the first week, 15 min/day for the second week, and 20 min/day for the remaining weeks, and the MP was focused on breathing, body scanning, and mindful walking. There is another study in which the stress level of basketball players was measured. The authors measured salivary cortisol concentration and immunoglobulin-A secretion as a useful method to monitor physical and psychological stress and reach efficient recovery approaches in well-trained basketball players (Macdonald and Minahan, 2018). They indicated that 8 weeks of mindfulness practice was a beneficial and relaxing method, as it resulted in decreased salivary cortisol concentration during the competition period.

Another purpose of the present study was to investigate the potential positive effects of mindfulness practice (MP) on cognitive performance and to determine how cognitive tasks are affected by MP. For this reason, the subjects were asked to perform the Go/No-go test before and after the PL and after the MI, and the duration of the test and the number of errors were recorded. However, no significant difference was found in cognitive task performance of the participants before and after physical loading, and a lack of change in the mental demand subscale of the NASA TLX-2 confirmed this finding. The lack of improvement in the duration of the Go/No-go test and the number of errors after the mental intervention showed that both MP and DW did not have a significant effect on cognitive performance. This finding should be examined from two different perspectives. First, physical fatigue during the first half of a simulated basketball game may not affect cognitive performance. Second, any mental intervention does not improve cognitive task scores. The practice of mindfulness, which was used as a mental relaxation method, was no different from watching documentaries in terms of improving cognitive task performance. In the literature, there are studies examining the effects of brief mindfulness practices on cognitive tasks and mental fatigue. In a study conducted by Zhu et al. (2020a), the effects of acute mindfulness practice on cognitive functions were examined. The study involved having participants perform a 6-min mindfulness practice during the half-time break of a simulated soccer game using the Loughborough Intermittent Shuttle Test to reflect athletic performance as in a soccer game. The results indicated that, while the control group did not show any change in the Stroop Color and Word Test, the Corsi block-tapping test, or the rapid visual information processing task test, both the CHO and CHO + mindfulness groups exhibited improvements in the Corsi block-tapping test and the rapid visual information processing task test. Only the CHO + mindfulness group showed an increase in the Stroop Color test score. In a similar study, researchers evaluated the same 6-min mindfulness practice on the recovery process during a half-time break of a simulated soccer game (Zhu et al., 2020b). The authors concluded that a 6-min brief mindfulness practice applied with CHO consumption increases mindfulness levels and decreases mental fatigue. They also claimed that CHO + mindfulness intervention increased the repeated sprint ability of the athletes compared to the control or only CHO consumption group. Although these studies are structurally similar to the current one, the results obtained were different. Even though MP was applied for 10 min and the score of the state of mindfulness was significantly higher in the present study, it was not effective in improving cognitive function or reducing physical fatigue. The difference between the studies may have occurred due to CHO consumption. Another study compared the acute effects of hatha yoga practice and mindfulness intervention on cognitive functions and mood (Luu and Hall, 2017). The researchers found that both interventions were effective in improving either cognitive task performance or mood levels at the same levelwhen compared to the control group. Both interventions lasted 25 min in the study, and cognitive task performance was evaluated using the Stroop test and mood using the Profile of Mood States-2 Adult Short. There may be several reasons why this research and the current study show different results. First, the participants were selected from people who regularly practice yoga and meditation. Second, the application time was 25 min. Normally, the effect can be expected to increase as the duration increases. Another reason is that, before the mindfulness intervention, the participants did not engage in tasks that required physical and mental efforts, as is the case in this study. The acute effects of brief mindfulness practice were evaluated on free-throw shooting performance during low- and high-pressure phases in young basketball players (Wolch et al., 2021). The researchers stimulated high-pressure conditions by informing the participants that their shots would be recorded. The comparison of a 15-min audio mindfulness intervention with 15-min audio basketball history listening demonstrated no change in free-throw shooting performance. The only significant effect of a brief MP was observed on cognitive-state anxiety. Their somatic anxiety and self-confidence scores did not differ. In a similar study, Shaabani et al. (2020) evaluated the effects of a 15-min audio mindfulness training on free-throw shooting performance in experienced basketball players. They indicated that free-throw performance, which was impaired by ego depletion by applying the Stroop test for 15 min, could be restored to pre-ego depletion levels through MP. However, another study found no positive

effects of a 4-min audio-based mindfulness practice on plank exercise in comparison to 4 min of audiobook listening (Stocker et al., 2019). The participants with no previous mindfulness experience did not show any improvement in cognitive task performance, depending on the MP, after the ego depletion process. It is evident from the results of these studies that the effects of mindfulness practice on sports performance are not certain and need further investigation.

5. Conclusion

In this research, the effects of a brief body scan mindfulness practice on HRV, cognitive task performance, and subjective scales in professional female basketball players were evaluated. The study found consistent results across all physiological, cognitive, and subjective measurement tools, suggesting that the results were consistent. Although the participants returned to their baseline levels after the 10-min MI phase, this was not specifically due to MP. According to the results, it could be concluded that acute MP had no additional positive effect on HRV or on cognitive tasks in athletes with no previous mindfulness experience. According to this result, athletes may not benefit acutely from short-term mindfulness practice. Nevertheless, it has been stated that mindfulness intervention has many positive effects on athletes (Sappington and Longshore, 2015; Bühlmayer et al., 2017; Creswell, 2017). In fact, it has been reported that mindfulness can even be effective in reducing sports injuries by reducing the level of anxiety and increasing awareness and attention in young football players (Naderi et al., 2020). However, these positive effects are more pronounced when mindfulness is applied for a long time. For this reason, it is recommended that the practice of mindfulness be continuously included in the training programs of athletes. Particularly in such high-intensity, intermittent sports branches, athletes should make mindfulness practice a habit. While the acute effect may not be as pronounced in athletes with no previous mindfulness experience, maintaining a long-term practice may lead to more significant benefits. Thus, even in basketball, with a recovery interval as short as 10 min, mindfulness can be utilized. Therefore, in future research, the acute effect can be examined in basketball players who consistently practice mindfulness.

Additionally, the results of studies on the acute effects of mindfulness in the literature are not consistent. Having many different mindfulness interventions, different mindfulness practice durations, different control group practices, different ways of practicing mindfulness (video-based, audio-based, and accompanied by an expert), HRV recording time, and different body positions of the participants during the recording of HRV increase the heterogeneity of mindfulness studies. Therefore, more controlled studies are needed. For example, because the effect of respiratory control on the autonomic nervous system is evident, and this is reflected in the measurement of HRV, respiratory rate, and depth, these can also be controlled during mental practices. Apart from this, comparing the acute and chronic effects of different mindfulness practices in future studies may contribute to the development of a standard method. As another suggestion, future researchers may conduct performance tests and more valid physiological tests that also allow the observation of neural changes to monitor the effects of acute mindfulness practice or fatigue, in addition to the cognitive and perceptual measurement methods used in this research. Thus, more precise results can be obtained. The most important limitation of this study was the small number of participants. Subsequent research may increase the number of participants and attempt this protocol not only on women but also on men. Similarly, research can be applied to different age groups, such as children and young athletes.

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 Ethical approval was obtained from the Ankara University Institutional Ethical Committee (2022-SBB-0443). The patients/participants provided their written informed consent to participate in this study.

Author contributions

DA: conceptualization, methodology, software, validation, formal analysis, investigation, resources, supervision, and project administration. AS, TD, CC, DG, YG, and AU: data curation. DA and AU: writing—original draft preparation and visualization. AU, MG, and MA: writing—review and editing. MA: funding acquisition. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by the Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2023R286), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

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

Alaphilippe, A., Mandigout, S., Ratel, S., Bonis, J., Courteix, D., and Duclos, M. (2012). Longitudinal follow-up of biochemical markers of fatigue throughout a sporting season in young elite rugby players. *J. Strength Cond. Res.* 26, 3376–3384. doi: 10.1519/JSC.0b013e3182474687

Anon (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation* 93, 1043–1065.

Aras, D., Erdogmuş, T.N., Ayvaz, Ö., and BIrol, A. (2022). Kalp Hizi Degişkenligi ve Egzersize Kronik Yanitlari. *SPORMETRE Beden Egitimi ve Spor Bilimleri Dergisi* 20, 1–40. doi: 10.33689/spormetre.1129126

Baker, L. B., Rollo, I., Stein, K. W., and Jeukendrup, A. E. (2015). Acute effects of carbohydrate supplementation on intermittent sports performance. *Nutrients* 7, 5733–5763. doi: 10.3390/nu7075249

Bangsbo, J., Iaia, F. M., and Krustrup, P. (2008). The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med.* 38, 37–51. doi: 10.2165/00007256-200838010-00004

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* 14, 377–381. doi: 10.1249/00005768-198205000-00012

Brinkmann, A. E., Press, S. A., Helmert, E., Hautzinger, M., Khazan, I., and Vagedes, J. (2020). Comparing effectiveness of HRV-biofeedback and mindfulness for workplace stress reduction: a randomized controlled trial. *Appl. Psychophysiol. Biofeedback* 45, 307–322. doi: 10.1007/s10484-020-09477-w

Brown, K. W., and Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological wellbeing. *J. Pers. Soc. Psychol.* 84, 822. doi: 10.1037/0022-3514.84.4.822

Brown, L., Rando, A. A., Eichel, K., Van Dam, N. T., Celano, C. M., Huffman, J. C., et al. (2021). The effects of mindfulness and meditation on vagally mediated heart rate variability: a meta-analysis. *Psychosom. Med.* 83, 631–640. doi: 10.1097/PSY.0000000000000900

Bühlmayer, L., Birrer, D., Röthlin, P., Faude, O., and Donath, L. (2017). Effects of mindfulness practice on performance-relevant parameters and performance outcomes in sports: a meta-analytical review. *Sports Med.* 47, 2309–2321. doi: 10.1007/s40279-017-0752-9

Coutts, A. J., Slattery, K. M., and Wallace, L. K. (2007). Practical tests for monitoring performance, fatigue and recovery in triathletes. *J. Sci. Med. Sport* 10, 372–381. doi: 10.1016/j.jsams.2007.02.007

Creswell, J. D. (2017). Mindfulness interventions. *Annu. Rev. Psychol.* 68, 491–516. doi: 10.1146/annurev-psych-042716-051139

Delgado-Pastor, L. C., Perakakis, P., Subramanya, P., Telles, S., and Vila, J. (2013). Mindfulness (Vipassana) meditation: effects on P3b event-related potential and heart rate variability. *Int. J. Psychophysiol.* 90, 207–214. doi: 10.1016/j.ijpsycho.2013.07.006

Desmond, P. A., and Hancock, P. A. (2001). "Active and passive fatigue states," in *Stress, Workload, and Fatigue* (Mahwah, NJ: Lawrence Erlbaum), 455–465.

Ditto, B., Eclache, M., and Goldman, N. (2006). Short-term autonomic and cardiovascular effects of mindfulness body scan meditation. *Ann. Behav. Med.* 32, 227–234. doi: 10.1207/s15324796abm3203_9

Hafenbrack, A. C., Kinias, Z., and Barsade, S. G. (2014). Debiasing the mind through meditation: mindfulness and the sunk-cost bias. *Psychol. Sci.* 25, 369–376. doi: 10.1177/0956797613503853

Hart, S. G., and Staveland, L. E. (1988). *Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research*. Elsevier EBooks. doi: 10.1016/s0166-4115(08)62386-9

Job, R., and Dalziel, J. (2001). "Defining fatigue as a condition of the organism and distinguishing it from habituation, adaptation, and boredom," in *Stress, Workload, and Fatigue*, ed P. A. Hancock (Lawrence Erlbaum Associates Publishers), 466–478.

Joyce, D., and Lewindon, D. (2014). *High-Performance Training for Sports, 2nd Edition*. Champaign, IL: Hum. Kinet.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: past, present, and future. *Clin. Psychol. Sci. Pract.* 10, 144–156. doi: 10.1093/clipsy.bpg016

Kee, Y. H. (2019). Mindfulness and its relevance for sports coaches adopting nonlinear pedagogy. *Int. J. Sports Sci. Coach.* 14, 419–427. doi: 10.1177/1747954119830819

Kellmann, M. (2010). Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scand. J. Med. Sci. Sports* 20 (Suppl. 2), 95–102. doi: 10.1111/j.1600-0838.2010.01192.x

Kirk, U., and Axelsen, J. L. (2020). Heart rate variability is enhanced during mindfulness practice: a randomized controlled trial involving a 10-day online-based mindfulness intervention. *PLoS ONE* 15, e0243488. doi: 10.1371/journal.pone.0243488

Klusemann, M. J., Pyne, D. B., Hopkins, W. G., and Drinkwater, E. J. (2013). Activity profiles and demands of seasonal and tournament basketball competition. *Int. J. Sports Physiol. Perform.* 8, 623–629. doi: 10.1123/ijspp.8.6.623

Knicker, A. J., Renshaw, I., Oldham, A. R., and Cairns, S. P. (2011). Interactive processes link the multiple symptoms of fatigue in sport competition. *Sports Med.* 41, 307–328. doi: 10.2165/11586070-000000000-00000

Krygier, J. R., Heathers, J. A., Shahrestani, S., Abbott, M., Gross, J. J., and Kemp, A. H. (2013). Mindfulness meditation, wellbeing, and heart rate variability: a preliminary investigation into the impact of intensive Vipassana meditation. *Int. J. Psychophysiol.* 89, 305–313. doi: 10.1016/j.ijpsycho.2013.06.017

Li, C., Zhu, Y., Zhang, M., Gustafsson, H., and Chen, T. (2019). Mindfulness and athlete burnout: a systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* 16, 449. doi: 10.3390/ijerph16030449

Luu, K., and Hall, P. A. (2017). Examining the acute effects of hatha yoga and mindfulness meditation on executive function and mood. *Mindfulness* 8, 873–880. doi: 10.1007/s12671-016-0661-2

Macdonald, L. A., and Minahan, C. L. (2018). Mindfulness training attenuates the increase in salivary cortisol concentration associated with competition in highly trained wheelchair-basketball players. *J. Sports Sci.* 36, 378–383. doi: 10.1080/02640414.2017.1308001

Montgomery, P. G., Pyne, D. B., Hopkins, W. G., Dorman, J. C., Cook, K., and Minahan, C. L. (2008). The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J. Sports Sci.* 26, 1135–1145. doi: 10.1080/02640410802104912

Naderi, A., Shaabani, F., Gharayagh Zandi, H., Calmeiro, L., and Brewer, B. W. (2020). The effects of a mindfulness-based program on the incidence of injuries in young male soccer players. *J. Sport Exerc. Psychol.* 9, 1–11. doi: 10.1123/jsep.2019-0003

Neale, M. I. (2006). Mindfulness meditation: an integration of perspectives from Buddhism, science and clinical psychology. *Diss. Abstr. Int.* 67.

Paul, M., and Garg, K. (2012). The effect of heart rate variability biofeedback on performance psychology of basketball players. *Appl. Psychophysiol. Biofeedback* 37, 131–144. doi: 10.1007/s10484-012-9185-2

Sappington, R., and Longshore, K. (2015). Systematically reviewing the efficacy of mindfulness-based interventions for enhanced athletic performance. *J. Clin. Sport Psychol.* 9, 232–262. doi: 10.1123/jcsp.2014-0017

Shaabani, F., Naderi, A., Borella, E., and Calmeiro, L. (2020). Does a brief mindfulness intervention counteract the detrimental effects of ego depletion in basketball free throw under pressure? *Sport Exerc. Perf. Psychol.* 9, 197. doi: 10.1037/spy0000201

Shaffer, F., Mccraty, R., and Zerr, C. L. (2014). A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability. *Front. Psychol.* 5, 1040. doi: 10.3389/fpsyg.2014.01040

Stocker, E., Englert, C., and Seiler, R. (2019). Self-control strength and mindfulness in physical exercise performance: does a short mindfulness induction compensate for the detrimental ego depletion effect? *J. Appl. Sport Psychol.* 31, 324–339. doi: 10.1080/10413200.2018.1471754

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., and Milanović, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: a systematic review. *Sports Med.* 48, 111–135. doi: 10.1007/s40279-017-0794-z

Van Cutsem, J., Marcora, S., De Pauw, K., Bailey, S., Meeusen, R., and Roelands, B. (2017). The effects of mental fatigue on physical performance: a systematic review. *Sports Med.* 47, 1569–1588. doi: 10.1007/s40279-016-0672-0

Van Der Zwan, J. E., De Vente, W., Huizink, A. C., Bögels, S. M., and De Bruin, E. I. (2015). Physical activity, mindfulness meditation, or heart rate variability biofeedback for stress reduction: a randomized controlled trial. *Appl. Psychophysiol. Biofeedback* 40, 257–268. doi: 10.1007/s10484-015-9293-x

Weinberg, R. S., and Gould, D. (2019). *Foundations of sport and exercise psychology, 7th Edition*. Champaign, IL: Hum. Kinet.

Wolch, N. J., Arthur-Cameselle, J. N., Keeler, L. A., and Suprak, D. N. (2021). The effects of a brief mindfulness intervention on basketball free-throw shooting performance under pressure. *J. Appl. Sport Psychol.* 33, 510–526. doi: 10.1080/10413200.2020.1720044

Zhu, Y., Sun, F., Li, C., and Chow, D. H. K. (2020a). Acute effects of brief mindfulness intervention coupled with carbohydrate ingestion to re-energize soccer players: a randomized crossover trial. *Int. J. Environ. Res. Public Health* 17, 9037. doi: 10.3390/ijerph17239037

Zhu, Y., Sun, F., Li, C., Chow, D. H. K., and Wang, K. (2020b). Acute effect of brief mindfulness-based intervention coupled with fluid intake on athletes' cognitive function. *J. Sports Sci. Med.* 19, 753–760.

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 23 June 2023
DOI 10.3389/fpubh.2023.1199782

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Giulia Cossu,
University of Cagliari, Italy
Jingyi Tan,
Lundquist Institute for Biomedical Innovation, United States

*CORRESPONDENCE
Jin Yan
✉ jin.yan@uon.edu.au

RECEIVED 04 April 2023
ACCEPTED 08 June 2023
PUBLISHED 23 June 2023

CITATION
Liu T, Li D, Yang H, Chi X and Yan J (2023) Associations of sport participation with subjective well-being: a study consisting of a sample of Chinese school-attending students. *Front. Public Health* 11:1199782. doi: 10.3389/fpubh.2023.1199782

Associations of sport participation with subjective well-being: a study consisting of a sample of Chinese school-attending students

Tianzhuo Liu[1], Dong Li[2], Hongying Yang[3], Xinli Chi[4] and Jin Yan[5,6]*

[1]School of Physical Education, Northeast Normal University, Changchun, Ji Lin, China, [2]Department of International Culture Education, Chodang University, Muan, Republic of Korea, [3]Library of Beijing Sport University, Beijing, China, [4]School of Psychology, Shenzhen University, Shenzhen, China, [5]Centre for Active Living and Learning, University of Newcastle, Callaghan, NSW, Australia, [6]College of Human and Social Futures, University of Newcastle, Callaghan, NSW, Australia

Purpose: Past studies have illustrated that the impact of sports participation on school-attending students' well-being plays a significant role in the life course of adolescence, which is a golden period for developing sound psychological qualities. However, the relationship between sports participation and subjective well-being is not clear, particularly in Chinese primary and middle schools. Therefore, the current study was aimed to explore the relationship between sports participation and subjective well-being in elementary and middle schools in China.

Method: All involved children and adolescents were asked to conduct a self-report of their sociodemographic factors (e.g., sex, grade, and age), independence, and outcomes. The survey involved a two-stage sampling design (district school). Besides, in order to examine the relationship between participation in sports and subjective well-being, a self-report questionnaire was used. Logistic regression with 95% confidence interval and odds ratios (ORs), was conducted to investigate the relationship between sports participation and subjective well-being.

Results: A total of 67,281 participants in total provided complete data for the final analysis of the current study. The percentage of boys and girls was 51.9% and 48.1%, namely. The current study found that compared with children who never participate in sports, those children who participated sports in 1–3 times a month, 1–2 times a week, and 3 times a week and above were more likely to enjoy better well-being. Compared with children who never participate in sports, those children who in every grade participated sports in 1–3 times a month, 1–2 times a week, and 3 times a week and above were more likely to achieve better well-being.

Conclusion: Our current study offered the positive effect of sports participation on children and adolescents' subjective well-being. For schools and governments, further studies are needed to focus on sports participation and positive feedback on adolescents' mental health, and the three parties' endeavors should be intervened.

KEYWORDS

sport participation, well-being, school-aged children, adolescents, China

1. Introduction

Sports participation refers to the attitude and behavior of students taking the initiative to participate in sports activities, it is only the overall description of sports goals (1–3). From the perspective of sociology and psychology, sports participation is an important strategy to realize children's socialization, which is essentially a socialization process (3, 4). Sports participation means victory and the investment of mental energy, and different students' energy into activities varies with time and goals (5). This concept covers not only the external indicators of the activity, such as heart rate and mood but also the goals of the exercise. Wicker and Frick's (6) study showed that men and women who exercised more frequently reported better subjective health, but for women, the differences in subjective health were partly due to education, economic deprivation, and work-family burdens. Eime and other scholars (7) point out that regular physical activity helps prevent chronic diseases and reduces the risk of premature death. Similarly, Kantomaa et al. (8) have shown that high levels of physical activity and cardiorespiratory fitness are positively correlated with adolescents' self-rated health, and other studies suggested that exercise can improve a person's self-rated health (9, 10).

Sports participation has a strong relationship with mental health. Regular physical activity has been shown to have a positive impact on various aspects of mental health including reducing symptoms of anxiety and depression, improving mood, and increasing self-esteem (11). Sports participation helps to release endorphins, which are natural mood boosters and also provide an outlet for stress and tension (12). Furthermore, exercise can improve sleep quality, which is crucial for good mental health (13). Additionally, participating in physical activity and being part of a sports team can provide social support, which is important for mental well-being (14–16). Exercise can also serve as a distraction from negative thoughts and feelings and can provide a sense of accomplishment and purpose (7). Therefore Easterlin et al. (17) supposes that sports participation is a crucial aspect of maintaining good mental health and should be incorporated into one's daily routine. It is important to find physical activities that are enjoyable and sustainable in the long term to ensure continued participation and mental health benefits.

Adolescence is a critical stage of the life course, which is a golden period for developing sound psychological qualities (18). However, an increasing rate of mental disorders and self-harm behaviors have been seen among adolescents (19), which greatly burden society. The mental health of young people is a global public-health challenge (20). Although most mental disorders are often detected in adulthood, they always begin during adolescence. Research on adolescents' mental health has been historically dominated by investigating risks and vulnerabilities for mental health problems (21). In the last few decades, a positive perspective on adolescent mental health with a focus on strengths and well-being is gaining increasing popularity. As a concept closely related to positive mental health, psychological resilience has drawn significant attention from researchers in the area of adolescent mental health (22). Psychological resilience is considered a protective factor or dynamic process that stimulates individuals to remain healthy or recover swiftly in the face of adversities (23). Though there is no universal definition of psychological resilience, it was mostly defined as an ability to rise above to overcome adversity or bounce back from adversity with an outcome of adaptation and adjustment, or maintenance of good mental health (24). High levels of resilience could help individuals cope with stressful situations in a positive direction toward better outcomes (25). Previous research showed that adolescents with a high level of resilience had more desirable developmental outcomes, such as healthier dietary patterns, improved sleep quality (26, 27), better academic performance (28) and social competence (29), less depressive and anxiety symptoms (30), and less suicidal ideation (31) and suicidal behaviors (32).

Subjective well-being popularly referred to as happiness or life satisfaction is also a key aspect of positive mental health. In the past decades, the empirical literature on subjective well-being has grown enormously with the remarkable progress in positive psychology (33). Subjective well-being can be defined as being satisfied with life, experiencing long-term happiness, and having fewer negative emotions (34). As such, subjective well-being is a multi-dimensional concept, including the cognitive dimension (general life satisfaction) and the affective dimension (presence of pleasant affect and absence of unpleasant affect) (35). Many researchers hold that the subjective well-being of adolescents summarizes all aspects of their well-being, by not only serving as an indicator of their mental health but also playing a role in their physical health (36). Benefits brought by subjective well-being include good physical health, longer longevity, greater self-esteem, more satisfactory social relationship, and better creativity and cognitive performance (9, 33). Considering the importance of promoting psychological resilience and subjective well-being among adolescents, more research on this topic is needed for a better understanding of positive development in adolescence (37). One primary focus is to find out modifiable factors related to psychological resilience or subjective well-being for targeted interventions.

Since the teenage years are a crucial period to develop our relationships with others and views on the outside world, scientific research has suggested that our lifestyle and even habits can have a significant impact on the drastic changes in our psychosocial and cognitive functions (38). An abundance of research evidence has proved a strong correlation between sport participation and the overall well-being of adolescents (39). Recent research has been conducted in various countries and social contexts, delving into the specific aspects of exercise and its impact on young adults' minds and bodies. For instance, Costigan et al. (40) intended to find the intensity of physical exercise and its influence on the mental well-being of adolescents. Their research results discovered that intense physical workout is positively related to enhanced self-reported well-being among young adults, in compliance with the contemporary physical exercise guidelines advocating for more appropriate and necessary active workouts at least three times per week. Martínez-López et al. (41), from another perspective, discovered that physical activities not only have a favorable impact on teenagers' general well-being but also facilitate their coping mechanisms when experiencing stress and pain in puberty. Moreover, in hopes of promoting mental health and targeting useful strategies to help young adults thrive in adolescence, Pigaiani et al. (42) conducted a thorough meta-analysis among Italian adolescents, concluding that participation in physical activities can remarkably contribute to adolescents' subjective well-being, along with other crucial factors such as gaining social and familial support. However, it is noteworthy that all of these results showed a subtle deviation based on gender differences, pointing to the need for further relevant research done in the future. Such gender-based variations were displayed in the likelihood of reporting mental state changes, etc.

In a word, physical activities are key to fulfilling the psychosocial development of all adolescents.

2. Methods

2.1. Procedure and participants

In March 2021, we conducted a large-scale survey in Shenzhen, a relatively developed city in China. The targeted participants were students from local public primary and secondary schools. The survey adopted a two-stage sampling design (district school), a balanced representation of geography, economic development, and rural–urban diversity was achieved. Public schools in 11 districts in Shenzhen of China were recruited. The sampling procedure involved sampling towns, and local community districts that represented a mix of rural and urban areas. China's education system is a 6-3-3 system, including 6 years of primary school, 3 years of junior middle school, and 3 years of senior high school. The study included all students in grades 5–6 of primary school, grades 1–2 of junior middle school, and grades 1 and 2 of senior high school in the selected schools. The survey included adolescents in Grade 5 and above (≥ 10 years old) to ensure that they were cognitively able to complete the self-report questionnaire. In addition, the survey did not include students in the third grade of junior middle school and the third grade of senior high school, because they were preparing for the high school and university entrance examinations, and the curriculum was relatively compact, which might not be able to coordinate the time to participate in such a large-scale survey collectively.

Before the investigation, all participants and their guardians were informed of the purpose and overview of the investigation. We highlighted that participation was voluntary and data would be collected and analyzed anonymously. The students who agreed to participate completed the online questionnaire (about 20 min) independently in the school computer room under the leadership of the class teacher. The questionnaire was completed on the Wenjuanxing platform, a Chinese online questionnaire platform. Before entering the formal answer page, the page of electronic informed consent was displayed first. Only students who clicked the button for consent to participate in the survey button could enter the formal answer page. The survey was approved by the Research Committee of Shenzhen University (No. 2020005) and the participating schools.The approval date was May 21, 2020.

Finally, a total of 78,428 people submitted questionnaires. After completing the preliminary data cleaning (such as deleting the data of participants whose answer time was less than 300 s), 73,323 samples from 135 schools were retained, forming the preliminary database of the survey. According to the availability of the variables required for the current study in the database, a total of 67,281 students formed the analysis sample of the current study.

2.2. Measurements

2.2.1. Independent variable (sports participation)

The item was used to measure the frequency of sports participation: "How often have you participated in sports teams or sports clubs in the past year?" Participants reported the frequency by selecting one of the following options: never, 1–3 times per month, 1–2 times per week, and 3 or more times per week. The frequency corresponding to the option increased in turn.

2.2.2. Dependent variable (subjective well-being)

Subjective well-being was measured by the Chinese version of the World Health Organization Five-Item Well-being Index (WHO-5) (43). The WHO-5 consists of 5 questions, which are answered on a 6-point scale (5 = All of the time, 4 = most of the time, 3 = more than half of the time, 2 = less half the time, 1 = sometimes, 0 = never). Item scores are summed and converted to obtain a total score ranging from 0–25, where 25 presents the best possible level of well-being. Psychometric properties of the Chinese version of WHO-5 have been validated among the Chinese population (43). In the study, the Cronbach α coefficient for WHO-5 was 0.94.

2.3. Covariates

The data about age, BMI, grade, gender, subjective family socioeconomic status [a measure for evaluating the ethnic of participants, and the MacArthur Scale of Subjective Social Status's adapted version was adopted to assess it (44)], educational level of parents (i.e., master's degree or above; bachelor's degree; senor high school; secondary school or below), and siblings (only kid or not) were collected. In further analysis, these factors were regarded as covariates.

2.4. Data analyses

Some questionnaires' data were eliminated due to unreasonable or missing values. Apart from that, 67,281 participants in total provided complete data for the final analysis of the study. In addition, the statistical analysis was conducted using STATA BE 17.0 (College Station, Texas, United States). Prior to formal analysis, the complete cases were used to address missing data. Based on the descriptive statistics, the sample characteristics were described by denoting mean (M) with standard deviations (SD) for continuous variables or frequency (n) with percentage (%) for categorical variables. Eventually, an ordered logistic regression was conducted to explore the relationship between the sports team's participation and subjective well-being after control of the covariates (i.e., gender, BMI, age, grade, siblings, parents' education background, and ethnicity). What's more, results were described as odds ratios (OR), with the confidence interval (CI) being 95%. Besides, statistical significance was determined by using a prior value of p below 0.05.

3. Results

The demographic characteristics of the total sample have been displayed in Table 1. A total of 67,281 children (M age = 13.0 years, SD = 1.80) were involved in the final analysis (Figure 1). The percentage of boys and girls was 51.9% and 48.1%, namely. In terms of BMI, the rate of "normal" accounted for 68.1%, which was the most population, followed by the "overweight" (13.5%), and "obese" (18.4%), respectively. Regarding sport participation, around half the

TABLE 1 Demographic characteristics of the participants.

		n/mean	%/sd
Age		13.0	1.8
Sex			
	Boy	34,909	51.9
	Girl	32,372	48.1
BMI			
	normal	45,817	68.1
	overweight	9,051	13.5
	obese	12,413	18.4
Grade			
	Primary school	27,954	41.5
	Middle school	27,124	40.3
	High school	12,203	18.1
Father's education level			
	Middle school and below	14,619	21.7
	High school/secondary school/vocational high school/technical school	18,159	27.0
	University/College/Higher Vocational	26,030	38.7
	Master's/PhD	2,796	4.2
	Not clear	5,677	8.4
Mother's education level			
	Middle school and below (including middle school)	17,617	26.2
	High school/secondary school/vocational high school/technical school	18,706	27.8
	University/College/Higher Vocational	23,922	35.6
	Master's/PhD	1,635	2.4
	Not clear	5,401	8.0
Live with parents			
	Yes	62,836	93.4
	No	4,445	6.6
Ethnic			
	Han	65,027	96.6
	Other	2,254	3.4
Sport participation			
	Never	31,721	47.1
	1–3 times/month	15,050	22.4
	1–2 times/week	11,789	17.5
	3 times/week and above	8,721	13.0
Affluence		5.0	1.7
Subjective well-being		20.2	6.7

sample reported "Never," and one-fifth of children reported "1–3 times/month." More details can be found the Table 1.

Overall, A positive association was found between sports participation and better well-being among Chinese children. Based on Table 2, compared with children who never engage in sports, those children who participated sports in 1–3 times a month, 1–2 times a week, and 3 times a week and above were more likely to enjoy better well-being (OR = 1.26, 95% CI: 1.22–1.30), (OR = 1.41, 95% CI: 1.36–1.46), and (OR = 1.66, 95% CI: 1.59–1.73), respectively. A similar trend has also been displayed in the boys, compared with boys who never engage in sports, those boys who participated sports in 1–3 times a month, 1–2 times a week, and 3 times a week and above were more likely to have better well-being (OR = 1.27, 95% CI: 1.21–1.33), (OR = 1.38, 95% CI: 1.31–1.46), and (OR = 1.74, 95% CI: 1.65–1.85). In terms of girls, compared with students who never engage in sports, those students who participated sports in 1–3 times a month, 1–2

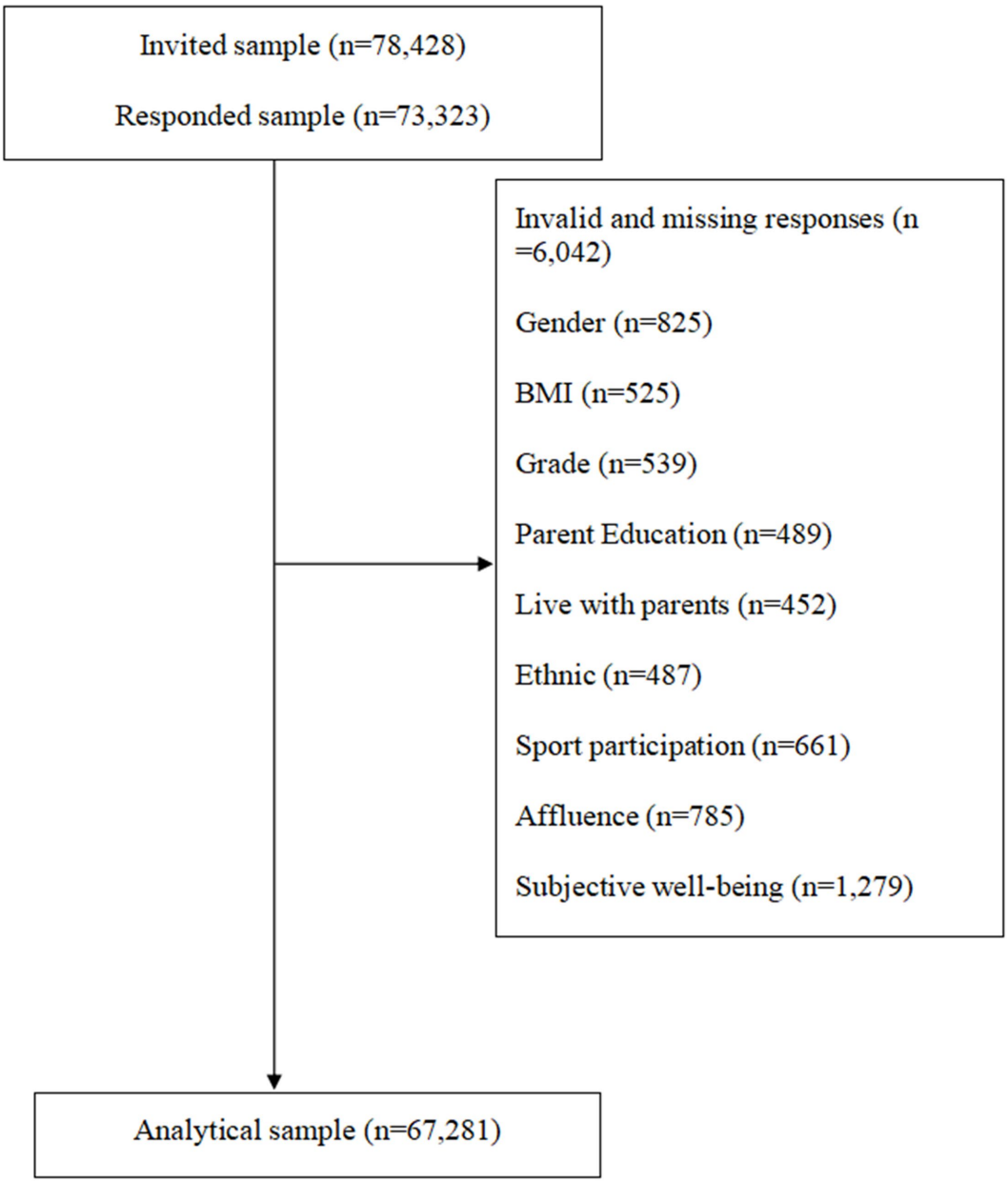


FIGURE 1
The procedure used for cleaning invalid and missing data in this study.

times a week, and 3 times a week and above were more likely to have better well-being (OR = 1.25, 95% CI: 1.19–1.31), (OR = 1.45, 95% CI: 1.37–1.53), and (OR = 1.55, 95% CI: 1.45–1.66).

The associations between sport participation and grade were demonstrated in Table 3. It can be observed the similar trend in all groups of elementary, middle, and high school. For example, in terms of elementary, compared with children who never engage in sports, those children who in every grade engage sports in 1–3 times a month, 1–2 times a week, and 3 times a week and above were more likely to have better well-being (OR = 1.19, 95% CI: 1.31–1.26), (OR = 1.35, 95% CI: 1.27–1.42), and (OR = 1.62, 95% CI: 1.52–1.72). Detailed information can be found in Table 3.

4. Discussion

The purpose of our study was to explore the relationship between sports participation and subjective well-being. Through analysis, we can know that exercise has a very high significance in improving happiness and is also the most obvious compared with other variables. Physical exercise can improve people's psychological emotions, self-confidence, and overall happiness, so it is beneficial to participate in physical exercise more (45). The results show similarity with the research results of western countries. Ruseski et al. (46) conducted a study on the population living in Rheinberg, Germany in 2009, and the results indicate that people who participated in sports had higher

TABLE 2 Odds ratio and 95% CI for subjective well-being concerning the sex.

Overall					Boys					Girls				
Subjective well-being	OR	95% CI		Sig	Subjective well-being	OR	95% CI		Sig	Subjective well-being	OR	95% CI		Sig
Frequencies														
1–3 times a month	1.26	1.22	1.30	***p* < 0.001**	1–3 times a month	1.27	1.21	1.33	***p* < 0.001**	1–3 times a month	1.25	1.19	1.31	***p* < 0.001**
1–2 times a week	1.41	1.36	1.46	***p* < 0.001**	1–2 times a week	1.38	1.31	1.46	***p* < 0.001**	1–2 times a week	1.45	1.37	1.53	***p* < 0.001**
3 times a week and above	1.66	1.59	1.73	***p* < 0.001**	3 times a week and above	1.74	1.65	1.85	***p* < 0.001**	3 times a week and above	1.55	1.45	1.66	***p* < 0.001**

Reference group: never participate in sports. All models controlled for sex, age, BMI, grade, subjective family socioeconomic status, parents' educational background, and ethnic; statistically significant at $p < 0.05$.

TABLE 3 Odds ratio and 95% CI for subjective well-being concerning the grade.

Elementary school					Middle school					High school				
Subjective well-being	OR	95% CI		Sig	Subjective well-being	OR	95% CI		Sig	Subjective well-being	OR	95% CI		Sig
Frequencies														
1–3 times a month	1.19	1.13	1.26	***p* < 0.001**	1–3 times a month	1.30	1.24	1.37	***p* < 0.001**	1–3 times a month	1.32	1.22	1.42	***p* < 0.001**
1–2 times a week	1.35	1.27	1.42	***p* < 0.001**	1–2 times a week	1.43	1.35	1.52	***p* < 0.001**	1–2 times a week	1.54	1.41	1.68	***p* < 0.001**
3 times a week and above	1.62	1.52	1.72	***p* < 0.001**	3 times a week and above	1.66	1.55	1.77	***p* < 0.001**	3 times a week and above	1.81	1.60	2.04	***p* < 0.001**

Reference group: never participate in sports. All models controlled for sex, age, BMI, grade, subjective family socioeconomic status, parents' educational background, and ethnic; statistically significant at $p < 0.05$.

subjective well-being. The report also shows that men are happier than women generally. Mansfield and his colleagues (47) have systematically reviewed 6,587 published articles and further distinguished the influence of different sports based on functionality. Research shows that group activities and collective sports involving partners, including dance, significantly improve subjective well-being compared to meditative exercises and sports therapy (47). However, negative emotions exist in competitive sports activities, which may affect subjective well-being to a certain extent. The possible explanation is that competitive sports require participants to reach the limits of their functions, thus causing discomfort and exclusion feelings (48).

The current results displayed a positive correlation between the frequency of physical exercise and subjective well-being. Moreover, with the increase of age, the effect of exercise on well-being is more obvious, results showed that old people (51–75 years) and middle-aged people (31–50 years) were more likely to report physical benefits than young people (18–30 years) ($p < 0.05$), respectively. (49). It can be said that sports participation brings more benefits to older students, which is consistent our finding. Some studies have shown that sports can improve students' cognition, especially those with higher requirements for physical coordination (50, 51). From the perspective of neuroscience, the development of the brain has a positive relationship with the size of cognitive ability (52, 53). It can also be considered that the more nerve fibers, dendrites, and synapses in the human brain, the stronger the cognitive ability (54). In the process of children's growth, sports can significantly increase the number of nerve fibers, dendrites, and synapses in the brain, promoting the development of the brain and improving children's cognitive ability (55). In terms of gender differences, the current study shows that boys generally enjoy a stronger sense of well-being than women as the frequency of sports participation goes higher ($p < 0.01$), which is consistent with previous studies (7, 46). The potential explanation lies in the sports preference difference between men and women. Men generally choose high-intensity activities like basketball, volleyball, football, and other sports which require collective participation (56). However, women tend to choose dancing, yoga, aerobic exercise, and jogging, which can be performed individually with less collective effort (57). The sports suitable for men require more parts of the brain activities with higher emotional needs and interpersonal relations.

In terms of the influence on different sports, the research shows that all exercise interventions have increased the total score of subjective well-being (58). However, the intervention effect of sports such as aerobics and yoga is better than that of antagonistic sports, which is consistent with previous research results (59, 60). Through experimental research, Kim et al. (61) found that the total score of subjective well-being of college students performing aerobics was significantly higher than that of the basketball group ($F = 93.34$, $p < 0.001$). The reason may be that students need a lot of communication and cooperation in the process of aerobics, for example, frequent communication of body language and facial expressions is easier to create harmonious interpersonal relationships (62). This harmonious learning and sports environment enables students to correctly handle interpersonal relationships, thus improving their

social adaptability, and then express themselves more confidently in daily life, making it easier to obtain positive emotions, thus having a strong sense of subjective well-being. In contrast, basketball is a skill-oriented game in the play-field. It does only require students to have high technical and tactical abilities, but also requires high cooperation between team members (63, 64). In practice or competition, physical contact between students is easy to occur, and collision is inevitable. For junior high school students with unstable emotions, it is easy to have impulses, anger, and other emotions, which require higher emotional management ability to restrain themselves and suppress their bad temper. Therefore, compared with aerobics students, who participate in basketball have less subjective well-being (65). Existing research has demonstrated a dose–response relationship between cardio exercises and depression, indicating that involvement in intensive exercises would generate desirable fitness outcomes that are more inducive to psychological health ($\beta = -0.266$, $p < 0.001$) (66). Hamer et al. conducted self-reported surveys trying to discover the optimal amount of sports participation and different types to achieve improved psychological conditions (OR 0.67, 95% CI 0.61–0.75) (67). The results exhibit a dose–response relationship, with a temperate decline in mental issues with less frequent activities.

Taking China as a research background, many studies have been conducted to explore the relationship between physical activity and mental health issues. In Hong Kong, it is found that the self-efficacy and resilience shown by teenagers when performing sports activities can have a profound impact on their psychological well-being (68). Another study revealed that adolescents with low BMI scores and high levels of lung capacity, muscle strength and flexibility report better well-being, motivation and enjoyment in Chinese background (15). Sports can not only make muscles more developed but also stimulate the brain stem and provide energy, enthusiasm, and motivation for athletes (16). Intending to reveal the relationship between physical activity and subjective well-being, for example, a study conducted a questionnaire among 723 college students in China finding that a positive relationship between life satisfaction and vigorous physical activities, indicating the significant roles of regular exercise for students (69), which is in line with western studies (70, 71).

In future research, it is essential to probe into the strategy that optimizes the sport's effect on kids' mental health. There is a need to explore more high-quality game-based approach longitudinal and intervention studies to improve children's physical self-perception, intrinsic motivation, well-being, physiological and underlying psychological outcomes (72). It is noteworthy that the SAAFE (supportive, active, autonomous, fair, and enjoyable) principle offers a framework for designing and delivering exercise sessions (73). Under the guidance of self-determination theory, these kinds of principles are successfully applied to two high-intensity interval training (HIIT) studies (74, 75). Despite the aversive nature of HIIT, it is considered that vigorous physical activities may be more enjoyable to kids if their design can meet the fundamental psychological demands (i.e., relatedness, competence, and autonomy) (76). For instance, autonomy may be satisfied by offering participants selections of exercises and rest interval durations. Apart from that, participants' competence perceptions may be enhanced by giving positive feedback. At the same time, it can be more enjoyable to perform vigorous physical activities in groups, which will meet the relatedness perception.

Admittedly, the self-report of subjective well-being has some limitations, given that it may lead to bias and social desirability. What's more, the cross-sectional design may not be able to explain the causal relationships satisfactorily. Furthermore, one of the most important limitations of this study is undoubted that no distinction was made by a type of movement other than by type of frequency, and no data regarding the differentiating different types of sports was supported in the current study. To better understand the causal relationship between sports participation in Chinese school and subjective well-being, and improve the success rate of intervention, it is essential to make a prospective research design. Besides, there are some biases in the use of a questionnaire for collecting data. Lastly, convenience sampling has an obvious disadvantage. Specifically, it may be biased, as it is likely to be not representative of the population. Given the limitations, future research needs to be carried out to solve problems and get stronger shreds of evidence.

4.1. Practical implications

At the same time, this study's findings have practical implications for future research. First of all, the families, schools, and government should focus on the sports participation's positive feedback on the adolescents' mental health, and the three parties' endeavors should be intervened. In addition, the government needs to tackle with disadvantages of irrational educational structures and unbalanced sports equipment, to offer teenagers perfect conditions and hardware. Second, schools should draw up sports plans and try to stimulate students' enthusiasm, in order to make them feel positive feedback from sports participation. For example, providing participants with choices of exercises may help to satisfy autonomy. At the same time, the participants' competence awareness can be strengthened by offering positive feedback and encouragement. Carrying out activities in groups is conducive to meeting the perception of relatedness. Beyond that, strategies, such as making use of music, can optimize the cognitive health benefits. Lastly, parents should give active guidance and capture teenagers' interests timely, so as to maximize the physical needs of kids. All in all, sports education targeted at youth is a long-term objective, which requires high-quality macro conditions. Meanwhile, it is essential to consider the student's individual needs to promote their participation in sports.

5. Conclusion

The current study has confirmed evidence for the positive relationship between sports participation in children and adolescents' subjective well-being. In future studies, it is essential to probe into the strategy that optimizes the sport's effect on kids' mental health. Beyond that, the size of the effect is likely to be optimized by paying attention to the neurobiological, behavioral, and psychosocial mechanisms. Secondly, the families, schools, and government should focus on the sports participation's positive feedback on the adolescents' mental health, and the three parties' endeavors should be intervened. In addition, the government should tackle the disadvantages of irrational educational structures and unbalanced sports equipment, to offer teenagers perfect conditions and hardware. All in all, sports education targeted at youth is a long-term objective, which requires high-quality macro conditions. Meanwhile, it is essential to consider the student's needs to promote their participation in sports.

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.

Ethics statement

The studies involving human participants were reviewed and approved by this study was conducted based on approval from the Research Committee of Shenzhen University (No. 2020005) and schools that participated in the survey. The approval date was May 21, 2020. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

TL and DL: conceptualization and methodology. TL: software and validation. HY and JY: formal analysis. TL and JY: investigation and data curation. HY and DL: resources. XC: writing—original draft preparation, visualization, and project administration. JY: writing—review and editing and supervision. All authors contributed to the article and approved the submitted version.

Funding

Research on the Reform of School Physical Education under the background of modern information technology (Jilin Province education science "13th Five-Year Plan" subject; No.GH19428). Natural Science Foundation of Guangdong Province [grant number 2021A1515011330]; Shenzhen Education Science Planning Project [grant number cgpy21001]. Shenzhen University-Lingnan University Joint Research Programme [grant number 202202001].

Acknowledgments

The authors would like to appreciate the children who actively participate in the study.

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. Borgers J, Pilgaard M, Vanreusel B, Scheerder J. Can we consider changes in sports participation as institutional change? A conceptual framework. *Int Rev Sociol Sport*. (2018) 53:84–100. doi: 10.1177/1012690216639598

2. Chen S, Li X, Yan J, Ren Z. To be a sportsman? Sport participation is associated with optimal academic achievement in a nationally representative sample of high school students. *Front Public Health*. (2021) 9:730497. doi: 10.3389/fpubh.2021.730497

3. Ren T, Yan J, Sun Q. Sociodemographic correlates of organized sports participation in a sample of middle school students in China. *Front Public Health*. (2021) 9:730555. doi: 10.3389/fpubh.2021.730555

4. Kraaykamp G, Oldenkamp M, Breedveld K. Starting a sport in the Netherlands: a life-course analysis of the effects of individual, parental and partner characteristics. *Int Rev Sociol Sport*. (2013) 48:153–70. doi: 10.1177/1012690211432212

5. Farias C, Hastie PA, Mesquita I. Towards a more equitable and inclusive learning environment in sport education: results of an action research-based intervention. *Sport Educ Soc*. (2017) 22:460–76. doi: 10.1080/13573322.2015.1040752

6. Wicker P, Frick B. The relationship between intensity and duration of physical activity and subjective well-being. *Eur J Public Health*. (2015) 25:868–72. doi: 10.1093/eurpub/ckv131

7. Eime RM, Young JA, Harvey JT, Charity MJ, Payne WR. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int J Behav Nutr Phys Act*. (2013) 10:98–21. doi: 10.1186/1479-5868-10-98

8. Kantomaa MT, Tammelin T, Ebeling H, Stamatakis E, Taanila A. High levels of physical activity and cardiorespiratory fitness are associated with good self-rated health in adolescents. *J Phys Act Health*. (2015) 12:266–72. doi: 10.1123/jpah.2013-0062

9. Shi C, Yan J, Wang L, Shen H. Exploring the self-reported physical fitness and self-rated health, mental health disorders, and body satisfaction among Chinese adolescents: a cross-sectional study. *Front Psychol*. (2022) 13:1003231. doi: 10.3389/fpsyg.2022.1003231

10. Chen Z, Chi G, Wang L, Chen S, Yan J, Li S. The combinations of physical activity, screen time, and sleep, and their associations with self-reported physical fitness in children and adolescents. *Int J Environ Res Public Health*. (2022) 19:5783. doi: 10.3390/ijerph19105783

11. Appelqvist-Schmidlechner K, Vaara J, Häkkinen A, Vasankari T, Mäkinen J, Mäntysaari M, et al. Relationships between youth sports participation and mental health in young adulthood among Finnish males. *Am J Health Promot*. (2018) 32:1502–9. doi: 10.1177/0890117117746336

12. Parker A, Meek R, Lewis G. Sport in a youth prison: male young offenders' experiences of a sporting intervention. *J Youth Stud*. (2014) 17:381–96. doi: 10.1080/13676261.2013.830699

13. Wickham S-R, Amarasekara NA, Bartonicek A, Conner TS. The big three health behaviors and mental health and well-being among young adults: a cross-sectional investigation of sleep, exercise, and diet. *Front Psychol*. (2020) 11:579205. doi: 10.3389/fpsyg.2020.579205

14. Laird Y, Fawkner S, Niven A. A grounded theory of how social support influences physical activity in adolescent girls. *Int J Qual Stud Health Well Being*. (2018) 13:1435099. doi: 10.1080/17482631.2018.1435099

15. Zheng W, Shen H, Belhaidas MB, Zhao Y, Wang L, Yan J. The relationship between physical fitness and perceived well-being, motivation, and enjoyment in Chinese adolescents during physical education: a preliminary cross-sectional study. *Children*. (2023) 10:111. doi: 10.3390/children10010111

16. Lin Y, Yan J. Muscle-strengthening activities and sociodemographic correlates among adults: findings from samples in mainland China. *Int J Environ Res Public Health*. (2020) 17:2266. doi: 10.3390/ijerph17072266

17. Easterlin MC, Chung PJ, Leng M, Dudovitz R. Association of team sports participation with long-term mental health outcomes among individuals exposed to adverse childhood experiences. *JAMA Pediatr*. (2019) 173:681–8. doi: 10.1001/jamapediatrics.2019.1212

18. Gove WR. The effect of age and gender on deviant behavior: a biopsychosocial perspective In: *Gender and the life course*: Routledge (2018). 115–44.

19. Hawton K, Saunders KE, O'Connor RCJTL. Self-harm and suicide in adolescents. *Lancet*. (2012) 379:2373–82. doi: 10.1016/S0140-6736(12)60322-5

20. Aadland KN, Moe VF, Resaland GK, Skrede T, Stavnsbo M, Aadland E, et al. Effects of the active smarter kids (ASK) physical activity school-based intervention on executive functions: a cluster-randomized controlled trial. *Scand J Educ Res*. (2019) 63:214–28. doi: 10.1080/00313831.2017.1336477

21. Rutten BP, Hammels C, Geschwind N, Menne-Lothmann C, Pishva E, Schruers K, et al. Resilience in mental health: linking psychological and neurobiological perspectives. *Acta Psychiatr Scand*. (2013) 128:3–20. doi: 10.1111/acps.12095

22. Davydov DM, Stewart R, Ritchie K, Chaudieu I. Resilience and mental health. *Clin Psychol Rev*. (2010) 30:479–95. doi: 10.1016/j.cpr.2010.03.003

23. Sisto A, Vicinanza F, Campanozzi LL, Ricci G, Tartaglini D, Tambone V. Towards a transversal definition of psychological resilience: a literature review. *Medicina*. (2019) 55:745. doi: 10.3390/medicina55110745

24. Aburn G, Gott M, Hoare K. What is resilience? An integrative review of the empirical literature. *J Adv Nurs*. (2016) 72:980–1000. doi: 10.1111/jan.12888

25. Ye Z, Yang X, Zeng C, Wang Y, Shen Z, Li X, et al. Resilience, social support, and coping as mediators between COVID-19-related stressful experiences and acute stress disorder among college students in China. *App Psychol Health Well-Being*. (2020) 12:1074–94. doi: 10.1111/aphw.12211

26. Guazzelli Williamson V, Lee AM, Miller D, Huo T, Maner JK, Cardel M. Psychological resilience, experimentally manipulated social status, and dietary intake among adolescents. *Nutrients*. (2021) 13:806. doi: 10.3390/nu13030806

27. Wang J, Zhang X, Simons SR, Sun J, Shao D, Cao F. Exploring the bi-directional relationship between sleep and resilience in adolescence. *Sleep Med*. (2020) 73:63–9. doi: 10.1016/j.sleep.2020.04.018

28. Ayyash-Abdo H, Sanchez-Ruiz M-J, Barbari ML. Resiliency predicts academic performance of Lebanese adolescents over demographic variables and hope. *Learn Individ Differ*. (2016) 48:9–16. doi: 10.1016/j.lindif.2016.04.005

29. Bottolfs M, Støa EM, Reinboth MS, Svendsen MV, Schmidt SK, Oellingrath IM, et al. Resilience and lifestyle-related factors as predictors for health-related quality of life among early adolescents: a cross sectional study. *J Int Med Res*. (2020) 48:0300060520903656.

30. Dray J, Bowman J, Campbell E, Freund M, Wolfenden L, Hodder RK, et al. Systematic review of universal resilience-focused interventions targeting child and adolescent mental health in the school setting. *J Am Acad Child Adolesc Psychiatry*. (2017) 56:813–24. doi: 10.1016/j.jaac.2017.07.780

31. Hirschtritt ME, Ordóñez AE, Rico YC, LeWinn KZ. Internal resilience, peer victimization, and suicidal ideation among adolescents. *Int J Adolesc Med Health*. (2015) 27:415–23. doi: 10.1515/ijamh-2014-0060

32. Chen Y-L, Kuo P-H. Effects of perceived stress and resilience on suicidal behaviors in early adolescents. *Eur Child Adolesc Psychiatry*. (2020) 29:861–70. doi: 10.1007/s00787-019-01401-w

33. Diener E, Oishi S, Tay L. Advances in subjective well-being research. *Nat Hum Behav*. (2018) 2:253–60. doi: 10.1038/s41562-018-0307-6

34. Diener E, Chan MY. Happy people live longer: subjective well-being contributes to health and longevity. *Appl Psychol Health Well Being*. (2011) 3:1–43. doi: 10.1111/j.1758-0854.2010.01045.x

35. Nartova-Bochaver S, Donat M, Rüprich C. Subjective well-being from a just-world perspective: a multi-dimensional approach in a student sample. *Front Psychol*. (2019) 10:1739. doi: 10.3389/fpsyg.2019.01739

36. Shaffer-Hudkins E, Suldo S, Loker T, March A. How adolescents' mental health predicts their physical health: unique contributions of indicators of subjective well-being and psychopathology. *Appl Res Qual Life*. (2010) 5:203–17. doi: 10.1007/s11482-010-9105-7

37. Víllora B, Larrañaga E, Yubero S, Alfaro A, Navarro R. Relations among poly-bullying victimization, subjective well-being and resilience in a sample of late adolescents. *Int J Environ Res Public Health*. (2020) 17:590. doi: 10.3390/ijerph17020590

38. Schraml K, Perski A, Grossi G, Simonsson-Sarnecki M. Stress symptoms among adolescents: the role of subjective psychosocial conditions, lifestyle, and self-esteem. *J Adolesc*. (2011) 34:987–96. doi: 10.1016/j.adolescence.2010.11.010

39. Khan Y, Taghdisi MH, Nourijelyani K. Psychological well-being (PWB) of school adolescents aged 12–18 yr, its correlation with general levels of physical activity (PA) and socio-demographic factors in Gilgit, Pakistan. *Iran J Public Health*. (2015) 44:804–13.

40. Costigan SA, Lubans DR, Lonsdale C, Sanders T, del Pozo Cruz B. Associations between physical activity intensity and well-being in adolescents. *Prev Med*. (2019) 125:55–61. doi: 10.1016/j.ypmed.2019.05.009

41. Martínez-López E, Hita-Contreras F, Moral-García J, Grao-Cruces A, Ruiz J, Redecillas-Peiró M, et al. Association of low weekly physical activity and sedentary lifestyle with self-perceived health, pain, and well-being in a Spanish teenage population. *Sci Sports*. (2015) 30:342–51. doi: 10.1016/j.scispo.2015.04.007

42. Pigaiani Y, Zoccante L, Zocca A, Arzenton A, Menegolli M, Fadel S, et al. Adolescent lifestyle behaviors, coping strategies and subjective wellbeing during the COVID-19 pandemic: an online student survey. *Healthcare (Basel)*. (2020) 8:472. doi: 10.3390/healthcare8040472

43. Volinn E, Yang B, He J, Sheng X, Ying J, Volinn W, et al. West China hospital set of measures in Chinese to evaluate back pain treatment. *Pain Med*. (2010) 11:637–47. doi: 10.1111/j.1526-4637.2010.00846.x

44. Cundiff JM, Smith TW, Uchino BN, Berg CA. Subjective social status: construct validity and associations with psychosocial vulnerability and self-rated health. *Int J Behav Med*. (2013) 20:148–58. doi: 10.1007/s12529-011-9206-1

45. Lakes KD, Marvin S, Rowley J, San Nicolas M, Arastoo S, Viray L, et al. Dancer perceptions of the cognitive, social, emotional, and physical benefits of modern styles of partnered dancing. *Complement Ther Med*. (2016) 26:117–22. doi: 10.1016/j.ctim.2016.03.007

46. Ruseski JE, Humphreys BR, Hallman K, Wicker P, Breuer C. Sport participation and subjective well-being: instrumental variable results from German survey data. *J Phys Act Health*. (2014) 11:396–403. doi: 10.1123/jpah.2012-0001

47. Mansfield L, Kay T, Meads C, Grigsby-Duffy L, Lane J, John A, et al. Sport and dance interventions for healthy young people (15–24 years) to promote subjective well-being: a systematic review. *BMJ Open*. (2018) 8:e020959. doi: 10.1136/bmjopen-2017-020959

48. Leahy AA, Mavilidi MF, Smith JJ, Hillman CH, Eather N, Barker D, et al. Review of high-intensity interval training for cognitive and mental health in youth. *Med Sci Sports Exerc*. (2020) 52:2224–34. doi: 10.1249/MSS.0000000000002359

49. Quiroga Murcia C, Kreutz G, Clift S, Bongard S. Shall we dance? An exploration of the perceived benefits of dancing on well-being. *Arts Health*. (2010) 2:149–63. doi: 10.1080/17533010903488582

50. Biddle SJ, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med*. (2011) 45:886–95. doi: 10.1136/bjsports-2011-090185

51. Voss MW, Kramer AF, Basak C, Prakash RS, Roberts B. Are expert athletes "expert" in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Appl Cogn Psychol*. (2010) 24:812–26. doi: 10.1002/acp.1588

52. Deary IJ, Penke L, Johnson W. The neuroscience of human intelligence differences. *Nat Rev Neurosci*. (2010) 11:201–11. doi: 10.1038/nrn2793

53. Zhang Y, Yan J, Jin X, Yang H, Zhang Y, Ma H, et al. Sports participation and academic performance in primary school: a cross-sectional study in Chinese children. *Int J Environ Res Public Health*. (2023) 20:3678. doi: 10.3390/ijerph20043678

54. May A. Experience-dependent structural plasticity in the adult human brain. *Trends Cogn Sci*. (2011) 15:475–82. doi: 10.1016/j.tics.2011.08.002

55. Lippi G, Mattiuzzi C, Sanchis-Gomar F. Updated overview on interplay between physical exercise, neurotrophins, and cognitive function in humans. *J Sport Health Sci*. (2020) 9:74–81. doi: 10.1016/j.jshs.2019.07.012

56. Alentorn-Geli E, Myer GD, Silvers HJ, Samitier G, Romero D, Lázaro-Haro C, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: mechanisms of injury and underlying risk factors. *Knee Surg Sports Traumatol Arthrosc*. (2009) 17:705–29. doi: 10.1007/s00167-009-0813-1

57. Boyle J, Mattern CO, Lassiter JW, Ritzler JA. Peer 2 peer: efficacy of a course-based peer education intervention to increase physical activity among college students. *J Am Coll Heal*. (2011) 59:519–29. doi: 10.1080/07448481.2010.523854

58. Estévez-López F, Gray CM, Segura-Jiménez V, Soriano-Maldonado A, Álvarez-Gallardo IC, Arrayás-Grajera MJ, et al. Independent and combined association of overall physical fitness and subjective well-being with fibromyalgia severity: the al-Ándalus project. *Qual Life Res*. (2015) 24:1865–73. doi: 10.1007/s11136-015-0917-7

59. Wang D, Wang Y, Wang Y, Li R, Zhou C. Impact of physical exercise on substance use disorders: a meta-analysis. *PLoS One*. (2014) 9:e110728. doi: 10.1371/journal.pone.0110728

60. Mikkelsen K, Stojanovska L, Polenakovic M, Bosevski M, Apostolopoulos V. Exercise and mental health. *Maturitas*. (2017) 106:48–56. doi: 10.1016/j.maturitas.2017.09.003

61. Kim S, Kim G, Ki J. Effects of group art therapy combined with breath meditation on the subjective well-being of depressed and anxious adolescents. *Arts Psychother*. (2014) 41:519–26. doi: 10.1016/j.aip.2014.10.002

62. Tao J., Tan T. (2005). Affective computing: a review. in Affective Computing and Intelligent Interaction: First International Conference, ACII 2005, Beijing, China, October 22–24, 2005. Proceedings 1. Springer

63. Wang L, Ha AS. Factors influencing pre-service teachers' perception of teaching games for understanding: a constructivist perspective. *Sport Educ Soc*. (2012) 17:261–80. doi: 10.1080/13573322.2011.607954

64. Casey A, Goodyear VA. Can cooperative learning achieve the four learning outcomes of physical education? A review of literature. *Quest* (2015) 67:56–72. doi: 10.1080/00336297.2014.984733

65. Lee D-J, Sirgy MJ, Yu GB, Chalamon I. The well-being effects of self-expressiveness and hedonic enjoyment associated with physical exercise. *Appl Res Qual Life*. (2015) 10:141–59. doi: 10.1007/s11482-014-9305-7

66. Yang G, Li Y, Liu S, Liu C, Jia C, Wang S. Physical activity influences the mobile phone addiction among Chinese undergraduates: the moderating effect of exercise type. *J Behav Addict*. (2021) 10:799–810. doi: 10.1556/2006.2021.00059

67. Hamer M, Stamatakis E, Steptoe A. Dose-response relationship between physical activity and mental health: the Scottish health survey. *Br J Sports Med*. (2009) 43:1111–4. doi: 10.1136/bjsm.2008.046243

68. Ho FKW, Louie LHT, Chow CB, Wong WHS, Ip P. Physical activity improves mental health through resilience in Hong Kong Chinese adolescents. *BMC Pediatr*. (2015) 15:1–9. doi: 10.1186/s12887-015-0365-0

69. Zuo Z, Li S, Liu S, Wang Q. Life satisfaction and parental support among secondary school students in Urumqi: the mediation of physical activity. *PeerJ*. (2022) 10:e14122. doi: 10.7717/peerj.14122

70. Randall K, Ford TG, Kwon K-A, Sisson SS, Bice MR, Dinkel D, et al. Physical activity, physical well-being, and psychological well-being: associations with life satisfaction during the COVID-19 pandemic among early childhood educators. *Int J Environ Res Public Health*. (2021) 18:9430. doi: 10.3390/ijerph18189430

71. Pedišić Ž, Greblo Z, Phongsavan P, Milton K, Bauman AE. Are total, intensity- and domain-specific physical activity levels associated with life satisfaction among university students? *PLoS One*. (2015) 10:e0118137. doi: 10.1371/journal.pone.0118137

72. Yan J, Jones B, Smith JJ, Morgan P, Eather N. A systematic review investigating the effects of implementing game-based approaches in school-based physical education among primary school children. *J Teach Phys Educ*. (2022) 1:1–14. doi: 10.1123/jtpe.2021-0279

73. Lubans DR, Lonsdale C, Cohen K, Eather N, Beauchamp MR, Morgan PJ, et al. Framework for the design and delivery of organized physical activity sessions for children and adolescents: rationale and description of the 'SAAFE'teaching principles. *Int J Behav Nutr Phys Act*. (2017) 14:1–11. doi: 10.1186/s12966-017-0479-x

74. Costigan SA, Eather N, Plotnikoff RC, Hillman CH, Lubans DR. High-intensity interval training for cognitive and mental health in adolescents. *Med Sci Sports Exerc*. (2016) 48:1985–93. doi: 10.1249/MSS.0000000000000993

75. Leahy A, Hillman C, Shigeta T, Smith J, Eather N, Morgan P, et al. Teacher facilitated high-intensity interval training intervention for older adolescents: the 'burn 2 Learn'pilot randomised controlled trial. *J Sci Med Sport*. (2018) 21:S72. doi: 10.1016/j.jsams.2018.09.163

76. Leahy AA, Eather N, Smith JJ, Hillman CH, Morgan PJ, Plotnikoff RC, et al. Feasibility and preliminary efficacy of a teacher-facilitated high-intensity interval training intervention for older adolescents. *Pediatr Exerc Sci*. (2019) 31:107–17. doi: 10.1123/pes.2018-0039

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 July 2023
DOI 10.3389/fpsyg.2023.1226007

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Khadijeh Irandoust,
Imam Khomeini International University, Iran
Liancheng Zhang,
Tianjin University of Sport, China

*CORRESPONDENCE
Xiaotian Li
✉ lixiaotian@cupes.edu.cn

RECEIVED 20 May 2023
ACCEPTED 16 June 2023
PUBLISHED 13 July 2023

CITATION
Liu G, Li W and Li X (2023) Striking a balance: how long physical activity is ideal for academic success? Based on cognitive and physical fitness mediation analysis.
Front. Psychol. 14:1226007.
doi: 10.3389/fpsyg.2023.1226007

Striking a balance: how long physical activity is ideal for academic success? Based on cognitive and physical fitness mediation analysis

Guoqing Liu[1], Wenjie Li[2] and Xiaotian Li[2]*

[1]Institute of Physical Education and Training, Capital University of Physical Education and Sports, Beijing, China, [2]School of Recreation and Community Sport, Capital University of Physical Education and Sports, Beijing, China

Balancing physical activity and studying is an important issue facing Chinese teenagers. Therefore, numerous studies have found that engaging in physical activity can promote academic performance among students. However, what is the optimal duration of physical activity? This study used data from the China Education Panel Survey, with a sample size of 18,009 valid respondents. General linear regression analysis was conducted using Stata 17 software to evaluate the effects of different durations of physical activity, cognitive ability, and physical Fitness on academic performance among adolescents. Furthermore, the "Bootstrap Mediation" method and the "Maximum Likelihood Estimation" method were used to analyze whether physical health and cognitive ability have significant mediating effects. The present study reveals the following findings: (1) There exists a non-linear relationship between students' academic performance and the duration of physical exercise. The greatest improvement in academic performance is observed when the exercise duration reaches 2 hours. (2) Physical exercise can enhance students' academic performance by promoting physical health and cognitive abilities. (3) Gender heterogeneity is observed, with the optimal exercise duration for male students being 2 hours, while female students exhibit the highest academic performance when exercising for one hour. This study provides theoretical guidance for research on adolescents' participation in physical Activity and improving academic performance, enabling adolescents to engage in physical Activity more scientifically and rationally.

KEYWORDS

structural equation modeling, physical activity, academic achievement, cognitive ability, physical fitness, mediation analysis

1. Introduction

In 2022, the World Health Organization (WHO) recommended that adolescents engage in at least 60 min of moderate to vigorous physical activity (PA) per day, every day of the week (World Health Organization, 2022). However, according to the "Guidelines on Physical Activity and Sedentary Behavior" released by the WHO, approximately 81% of adolescents worldwide do not meet the recommended level of physical activity (Guthold et al., 2020). In China, only 23.8% of students have achieved the standard for health and fitness (News, 2021). On the one

hand, academic performance is undeniably one of the most valued aspects within the educational system, driven by the prevailing exam-oriented ideology. However, physical exercise is often overlooked and placed at the bottom of the educational agenda, resulting in significant academic pressure faced by adolescents (Wunsch et al., 2017), adolescents lack time to exercise. On the other hand, there is a widespread belief in contemporary society that academic achievement and physical exercise are contradictory, leading to social biases against student participation in physical activities (Hao and Yi, 2022), which holds that physical exercise takes up study time and consumes energy that is detrimental to learning. In addition, many parents arrange various types of cultural classes for their children on the weekend, depriving them of time for physical exercise (Pei and Gao, 2013). This misconception and neglect of physical exercise have led to the increasing prominence of sub-health issues among adolescents. However, is this perception accurate? What is the actual relationship between physical exercise and academic achievement? And through what mechanisms does physical exercise influence academic performance? These questions have been the subject of extensive discussions and research in fields such as education and psychology, attracting widespread attention and concern from various sectors of society.

Currently, there is limited research on the correlation between Physical activity duration, cognitive ability, Physical fitness, and academic achievement. However, many studies have explored the relationship between Physical activity and academic achievement. For example, a data analysis of a sample size of 10,205 showed that physical activity can improve classroom behavior and benefit academic achievement (Álvarez-Bueno et al., 2017). A randomized controlled trial from Spain found that moderate to high-intensity physical activity can improve academic achievement (Visier-Alfonso et al., 2021). In a 14-week randomized controlled trial in Australia involving 500 students, adding 1.25 h of endurance training per day did not negatively affect academic achievement (Dwyer et al., 1983), and subsequent follow-up data showed an upward trend in academic achievement (Maynard et al., 1987). Therefore, the viewpoint that Physical activity can improve academic achievement has been widely supported (Bangsbo et al., 2016; Reed, 2016; McPherson et al., 2018). In addition, a longitudinal study with a sample size of 5,316 found that longer Physical activity sessions per week had a greater impact on academic achievement for female students, but had no effect on male students (Carlson et al., 2008). Research has found that academic and cognitive performance are important factors that influence the health of students (Masoomi et al., 2020). An American cross-sectional study conducted over two semesters found no correlation between attending physical education class and academic achievement, but subsequent analyses found that self-initiated intense physical activity outside of class significantly improved students' academic achievement (Coe et al., 2006). These two studies suggest that there may be heterogeneity between male and female students, and that Physical activity outside of physical education classes can impact academic achievement.

In contrast, a study of 708 Hong Kong teenagers found that 22.54% of participants met the daily 60-min exercise requirement, but their academic achievement did not improve (Chan and Hui, 2016). In another study in China involving 333 Hong Kong students, academic achievement was measured by their exam results, and the results showed that the level of physical activity was unrelated to academic achievement (Yu et al., 2006). Singh's review of 11 high-quality intervention studies found no correlation between physical activity and academic achievement improvement (Singh et al., 2019). A Canadian cross-sectional study with a sample size of 6,923 found a positive correlation between physical activity and self-esteem, but a small negative correlation with academic achievement (Tremblay et al., 2000). Based on these studies, it can be concluded that there are conflicting views in existing literature on whether Physical activity affects academic achievement, This may be primarily because researchers have overlooked that different durations of Physical activity may have different effects on students' academic achievement. Physical activity duration may have an optimal value, and when this time is exceeded, Physical activity may have a negative impact on students' academic achievement. In addition, the arousal theory suggests that appropriate duration of physical exercise can awaken the functional levels of the body and mind in adolescents (Hillman et al., 2008). Therefore, based on the above research and common sense, this article proposes the hypothesis that different durations of Physical activity have different effects on students' academic achievement.

However, how does Physical activity affect academic achievement? Some studies suggest that Physical activity can improve academic achievement (Reed, 2016; Tomporowski and Pesce, 2019) by improving Physical fitness level and enhancing cognitive ability. Since physical exercise can enhance cognitive abilities and improve academic performance, can it also improve academic performance by enhancing physical fitness levels? Therefore, based on the above findings and hypotheses, this article explores the effects of different durations of Physical activity on students' academic achievement, examines the mediating effect of cognitive ability and Physical fitness on the relationship between Physical activity and academic achievement. This study provides theoretical guidance for research on adolescent participation in Physical activity and academic achievement, guides adolescents to participate in Physical activity scientifically, and improves society's understanding of Physical activity, breaking down their misconceptions about how Physical activity affects academic achievement.

2. Materials and methods

2.1. Data sources

This study utilized data from the China Education Panel Study (CEPS), which was conducted by the National Survey Research Center (NSRC) at Renmin University of China. The baseline survey focused on students in the seventh and ninth grades. The sampling design for CEPS employed a multi-stage probability proportionate to size (PPS) method. The sampling process involved four stages: In the first stage (PSU), 28 counties (districts) were selected from county-level administrative units nationwide. In the second stage (SSU), within each selected county (district), four schools offering seventh and ninth grades were chosen within their respective geographic areas. In the third stage (TSU), four classes were selected from each sampled school, including two classes from the seventh grade and two classes from the ninth grade. Finally, in the fourth stage, all students, parents, homeroom teachers, subject teachers (Chinese, math, and English), and school administrators from the selected classes constituted the final survey sample. The data collection process involved randomly

selecting 438 classes from 112 schools located in 28 county-level units (counties, districts, and cities) across China, ensuring good national representativeness. The CEPS dataset not only collected basic information such as students' height, weight, cognitive ability, and academic achievement but also included rich family and school-related information. A total of 19,487 students were surveyed at baseline, and after excluding samples with missing values, 18,009 valid samples remained (see Table 1).

2.2. Research methods

This article mainly uses two statistical methods. Firstly, a general linear regression model is used to evaluate the effects of cognitive ability and Physical fitness on academic achievement of adolescents under different durations of Physical activity. The linear regression model is used to analyze whether there are significant differences in the effects of cognitive ability and Physical fitness level on academic achievement of adolescents under different exercise duration conditions. Secondly, the "Bootstrap mediation" method and maximum likelihood estimation (ML) method are used to determine whether Physical fitness and cognitive ability have significant mediating effects. Bootstrap is the most widely used coefficient testing method (Chen et al., 2013; Jiang and Li, 2015), which is also a resampling method (Preacher and Hayes, 2008) and a good method for testing multiple mediation effects (Fritz et al., 2012; Hayes and Scharkow, 2013; Wen and Ye, 2014). ML is used for confirmatory factor analysis and structural equation modeling (Legg and Gray, 2000). This model can analyze to what extent different mediator variables positively or negatively affect the relationship between independent and dependent variables, that is, to analyze the significance and direction of the effects of different mediator variables.

Therefore, this article uses the "Bootstrap mediation" method and ML estimation method to analyze the mechanism of how different exercise durations affect the academic achievement of adolescents. Physical fitness and cognitive ability are used as mediator variables to analyze whether Physical fitness and cognitive ability have mediating effects on the academic achievement of adolescents under different exercise duration conditions. At the same time, the significance and direction of the direct and indirect effects produced by the two mediator variables are compared.

2.3. Variables and operational definitions

The dependent variable is academic achievement, mainly referring to students' objective scores. The objective score is the exam score for subjects like Chinese, Math and English. Sun Zhijun et al. (Sun et al., 2009; Lei and Li, 2021) argued that since school papers vary, absolute scores cannot be compared, and standardized scores can ensure objectivity in quantifying scores. Therefore, the standardized score will be used as the indicator of the objective score. After standardization, the average standardized score for the three subjects is 70, and the standard deviation of the standardized score is 10.

The core independent variable is Physical activity duration. The CEPS survey investigated the time arrangement (hours) for physical activity participation on weekends among students. Based on the original answer options, if there was no Physical activity on weekends, it would be recorded as 0; if they exercised for one hour, it would be recorded as 1; if they exercised for two hours, it would be recorded as 2; if they exercised for three or more hours, it would be recorded as 3. The selection of weekend Physical activity time is based primarily on the following points: (1) The Education Department requires students to exercise for one hour every day. During school days, due

TABLE 1 Descriptive statistical analysis of variables.

Var Name	Variable definition	Obs	Mean	SD	Min	Max
new_var	Continuous variable, final grade: translated into a standard score with a mean of 70	18,009	210.050	26.505	27.16	293.93
mz	Category variable, ethnicity; 0 = other ethnicity, 1 = Han ethnicity	18,009	1.910	0.280	1	2
jiaoyu	Categorical variable, education level among parents: education level of the highest parent; 1 = none, 2 = elementary school, 3 = junior high school, 4 = high school, 5 = college and above	18,009	3.570	0.906	1	5
pla23	Category variable, type of area where the school is located; 1 = central urban area of the city/county, 2 = fringe urban area of the city/county, 3 = rural/urban area of the city/county, 4 = town outside the city/county area, 5 = rural	18,009	2.640	1.565	1	5
grade9	Category variable, grade level; 0 = 7th grade, 1 = 9th grade	18,009	0.470	0.499	0	1
sthktype	Category variable, student's current hukou type; 0 = non-agricultural hukou, 1 = agricultural hukou	18,009	0.540	0.498	0	1
nl	Continuous variable, age	18,009	14.510	1.240	12	18
steco_3c	Category variable, student's family economic status; 1 = difficult, 2 = moderate, 3 = rich	18,009	1.850	0.496	1	3
b01	Whether the child is an only child, 0 = non-only child, 1 = only child	18,009	0.440	0.496	0	1
a01	Gender, 0 = female, 1 = male	18,009	0.510	0.500	0	1
zmdl4	Category variable, weekend exercise time; 0 = no exercise, 1 = 1 h, 2 = 2 h, 3 = 3 h	18,009	0.770	1.006	0	3
bmi2	Physical fitness, 0 = unhealthy, 1 = healthy	18,009	0.630	0.484	0	1
cog3pl	Continuous variable, standardized scores on cognitive ability tests (using 3PL model)	18,009	0.020	0.857	−2.03	2.71

to requirements such as sports classes, students may have ensured Physical activity time in school, resulting in small differences between student groups. However, students may lack exercise time on weekends, thus affecting their academic achievement. (2) Compared with previous studies on the relationship between academic achievement and Physical activity, some results showed that Physical activity had no correlation with academic achievement, possibly due to different effects on academic achievement from varying exercise durations. Therefore, this article chooses weekend Physical activity duration as the independent variable.

This study controlled for different variables based on the experience of scholars Asigbee et al. (2018) and Martin et al. (2018), as well as studies conducted by Wen (2015) and fully utilized the information contained in the survey data to control for various characteristics. Individual variables included age, gender, and ethnicity; family variables included household registration type, which primarily involved urban or rural household registration with agricultural households being 1 and urban households being 0; whether or not the participant was an only child, with 1 indicating being an only child and 0 indicating otherwise; parental education level, mainly defined according to the highest education level of either parent, with 0 indicating no education, 1 indicating elementary school, 2 indicating junior high school, 3 indicating high school, and 4 indicating university; family economic situation was divided into three categories: 0 for difficult, 1 for moderate, and 2 for wealthy; school characteristics included school location, which could be divided into main urban areas, secondary urban areas, urban–rural areas, townships, and rural areas depending on the school's location; and grade, including data from seventh and ninth grades.

Mediating variables included cognitive ability and Physical fitness, where the CEPS questionnaire was used to test students' logical thinking and problem-solving ability to reflect their cognitive level. Physical fitness was primarily assessed using height and weight data to calculate BMI scores, and based on the BMI formula and BMI classification standard, participants within the normal BMI range were assigned a score of 1, and others were assigned a score of 0 (Shen and Ma, 2022; Zhang et al., 2022). This was mainly because higher BMI scores are strongly associated with mortality (Xiang et al., 2022), and BMI scores can be used to evaluate student Physical fitness status and serve as a convenient method for measuring student Physical fitness (Han et al., 2022; Liu et al., 2023).

3. Results

3.1. Results of regression analysis of factors influencing adolescents' academic achievement

According to Table 2, compared to students of other ethnicities, Han students had significantly lower academic achievement, especially after accounting for the mediating variable of cognitive ability. The education level of parents had a significant impact on students' academic achievement, with higher parental education levels being associated with better academic achievement. School location also had a significant impact on academic achievement, with rural students outperforming urban students. Grade level was also a significant factor, with ninth-grade students performing better than seventh-grade students. Household registration type also had a significant effect on academic achievement, with agricultural household students performing better than non-agricultural household students. As for age, academic achievement significantly decreased as age increased. Family economic situation did not have a significant impact on academic achievement, but after adding the cognitive ability variable in Model 4, it was found that students from wealthy families had lower academic achievement than those from difficult families. Female students had significantly better academic achievement than male students. After adding Physical activity duration in Model 2, it was found that Physical activity duration had a significant impact on academic achievement, and different exercise durations had different effects on academic achievement. Adding the Physical fitness indicator in Model 3 showed that healthy students performed significantly better than unhealthy students. After adding academic achievement in Model 4, it was found that cognitive ability had a significant impact on academic achievement, with academic achievement improving with increasing cognitive ability. Adding both Physical fitness and cognitive ability variables in Models 3 and 4 resulted in large changes in the coefficient of the effect of Physical activity duration on academic achievement, especially after adding the cognitive ability variable, indicating that these two variables partially mediated the effect, leading to subsequent analysis using an intermediary model based on this model.

The regression model results showed that Physical activity duration can directly affect students' academic achievement and may also affect students' academic achievement through mediating variables. To further verify whether Physical activity affects adolescent students' academic achievement through mediating variables (Physical fitness and cognitive ability), this study used the "Bootstrap method" to analyze the mediating effect.

3.2. Differences between different durations of sports exercise

The effects of different Physical activity durations on adolescent students' academic achievement vary. Compared to students who do not engage in Physical activity, students who exercise for one hour on weekends showed a significant improvement in academic achievement, with an increase of 3.031 standard deviations. Students who exercised for 2 hours on weekends also showed a significant improvement in academic achievement, with an increase of 3.249 standard deviations. However, when the exercise duration reached three or more hours, students' academic achievement decreased by 1.837 standard deviations. Therefore, Physical activity duration has a significant impact on students' academic achievement, and the effect varies depending on the duration of Physical activity. It can be observed that when the exercise duration is within 2 hours, students' academic achievement improves as the duration of exercise increases. However, once this range is exceeded, academic achievement begins to decline (See Tables 3, 4; Figure 1).

3.3. Differences between intermediary paths

Compared to students who do not engage in Physical activity, different exercise durations have a significant effect on Physical fitness ($p < 0.001$). Participating in 1 h and 2 h of Physical activity can increase

TABLE 2 Regression analysis of factors influencing adolescents' academic achievement.

Variables (Compare)	Model I	Model 2	Model 3	Model 4
Han (Other)	−2.602*** (−3.68)	−2.654*** (−3.76)	−2.479*** (−3.49)	−4.320*** (−6.53)
Elementary school (none)	9.306** (2.67)	9.078** (2.61)	8.736* (2.52)	6.517* (2.02)
Junior high school (none)	11.200** (3.25)	10.940** (3.18)	10.440** (3.04)	7.066* (2.21)
High School (none)	13.280*** (3.84)	12.950*** (3.75)	12.440*** (3.61)	8.047* (2.51)
University (none)	18.670*** (5.37)	18.250*** (5.25)	17.610*** (5.08)	11.280*** (3.49)
Border City (Main City)	2.765*** (4.32)	2.689*** (4.21)	2.815*** (4.38)	3.689*** (6.17)
Urban and Rural (Main City)	2.209*** (3.47)	2.214*** (3.49)	2.206*** (3.45)	4.513*** (7.57)
Township (main city)	3.240*** (5.52)	3.237*** (5.52)	3.215*** (5.45)	6.031*** (10.93)
Rural (main city)	3.251*** (5.40)	3.388*** (5.64)	3.599*** (5.94)	6.878*** (12.13)
Ninth Grade (VII)	6.171*** (9.31)	5.997*** (9.06)	5.866*** (8.80)	1.828** (2.93)
Agricultural household (non-farm)	1.976*** (4.37)	1.929*** (4.28)	1.891*** (4.16)	1.822*** (4.30)
Age	−3.390*** (−12.41)	−3.338*** (−12.24)	−3.477*** (−12.65)	−1.405*** (−5.43)
Moderate (difficult)	0.677 (1.39)	0.588 (1.21)	0.545 (1.11)	−0.594 (−1.30)
Affluent (difficult)	−1.528 (−1.71)	−1.722 (−1.93)	−1.750 (−1.95)	−3.670*** (−4.38)
Non Only child (Yes)	0.016 (0.04)	0.035 (0.08)	−0.069 (−0.16)	1.458*** (3.55)
Female (Male)	12.570*** (33.14)	12.490*** (32.60)	12.30*** (31.84)	12.340*** (34.32)
Exercise for 1 h (no participation)		2.901*** (6.24)	2.848*** (6.08)	1.495*** (3.43)
Exercise for 2 h (no)		3.141*** (5.28)	3.067*** (5.12)	1.672** (2.99)
Exercise for 3 h (no)		−1.879** (−2.86)	−2.032** (−3.07)	−1.791** (−2.91)
Body shape (non-standard)			4.317*** (11.00)	3.013*** (8.23)
Cognitive ability				11.650*** (52.75)
_cons	236.3*** (44.56)	235.2*** (44.41)	235.1*** (44.27)	212.4*** (42.81)
N	18,337	18,337	18,009	18,009

Elementary school etc. is the education level of parents; t statistics in parentheses $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$. Standard errors are indicated in parentheses.

Physical fitness by 0.46 standard deviations, while a duration of three or more hours increases Physical fitness by 0.056 standard deviations. Results show that different exercise durations can improve students' Physical fitness. The effect of different exercise durations on cognitive ability is also different. When the exercise duration is one or two hours, students' cognitive ability significantly improves ($p<0.001$), increasing by 0.121 and 0.125 standard deviations, respectively. When the exercise duration reaches three or more hours, cognitive ability decreases by 0.014 standard deviations, but the result is not statistically significant. Path results show that the effects of Physical fitness and cognitive ability on academic achievement are both significant ($p<0.001$) and positive. Every one-unit increase in cognitive ability leads to an increase in academic achievement by 11.662 standard deviations, while Physical fitness can increase academic achievement by 3.003 standard deviations. These results indicate that Physical fitness and cognitive ability play a partial mediating role, and the mediating effect also changes with different exercise durations (See Table 3; Figure 1).

Different exercise durations have different effects on students' Physical fitness and cognitive ability, and compared to students who do not engage in Physical activity, when the exercise duration reaches one hour, both cognitive ability and Physical fitness improve, leading to an improvement in academic achievement. The comparison of two mediating effects revealed that cognitive ability accounts for 91% of the total mediating effect, and although the proportion of Physical fitness's mediating effect is relatively small, it still significantly improves students' academic achievement.

When the exercise duration is two hours, academic achievement is improved by 1.461 standard deviations through the mediating effect of cognitive ability, indicating that cognitive ability has the best effect on academic achievement at this point. When the exercise duration reaches three or more hours, the mediating effect of cognitive ability changes, and cognitive ability does not continue to improve with increasing exercise duration. Instead, there is a slight but not statistically significant decrease in academic achievement by 0.16 standard deviations.

The effects of different exercise durations on students' academic achievement through the mediating variables of Physical fitness are positive and significantly different ($p<0.001$). Pathway results also show that as the exercise duration increases, the effect of Physical fitness on academic achievement continues to improve (See Table 4; Figure 1).

3.4. Analysis of heterogeneity among different genders

As shown in the table, different exercise durations have varying effects on aca-demic achievement for male and female students compared to those who do not participate in Physical activity. From

10.3389/fpsyg.2023.1226007

the overall perspective, different exercise durations have a positive impact on the academic achievement of male students. The relationship between exercise duration and academic achievement presents an inverted U-shaped curve, with the best effect achieved at 2 h of exercise duration, resulting in academic achievement improvement of 6.29 standard deviations. In contrast to male students, female students achieve the best results when exercising for one hour, with an increase in academic achievement of 2.193 standard deviations. However, when the exercise duration reaches three hours, Physical activity significantly reduces female students' academic achievement.

TABLE 3 Bootstrap intermediary model path coefficients.

Variable	*b*	Ses	*t*	LLCI	ULCI
BMI2 ON					
PL2 (no)	0.046***	0.009	5.203	0.029	0.063
PL3 (no)	0.046***	0.012	3.961	0.024	0.068
PL4 (no)	0.056***	0.012	4.593	0.03	0.079
COG3PL ON					
PL2 (no)	0.121***	0.014	8.467	0.095	0.151
PL3 (no)	0.125***	0.019	6.596	0.089	0.164
PL4 (no)	−0.014	0.021	−0.646	−0.054	0.027
NEW_VAR ON					
PL2 (no)	1.478***	0.423	3.494	0.699	2.29
PL3 (no)	1.649**	0.533	3.097	0.485	2.64
PL4 (no)	−1.837**	0.686	−2.677	−3.131	−0.502
COG3PL	11.662***	0.231	50.581	11.19	12.087
Health (no)	3.003***	0.373	8.044	2.273	3.785

pl1 is 1 h of physical activity time, pl2 is 2 h of physical activity time, pl3 is 3 h of physical activity time, LLCI and ULCI = 95%. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The direct effect results show that male students' academic achievement increases with increasing exercise duration, as long as the exercise duration does not exceed two hours. However, when the exercise duration reaches three hours, Physical activity will reduce students' academic achievement. Female students' academic achievement im-proves when they exercise for an hour but significantly decreases with extended exercise durations. The indirect effect results show that exercise has a significant positive impact on male students' academic achievement through cognitive abilities and Physical fitness levels. Female students mainly improve their cognitive abilities through Physical activity to enhance their academic achievement, and only one hour of exercise can promote improvement in Physical fitness and academic achievement (See Table 5).

In summary, different exercise durations have different effects on students' aca-demic achievement. When the exercise duration is within two hours, academic achievement improves as the exercise duration increases, and cognitive ability and Physical fitness play a partial mediating role. However, when the exercise duration reaches three or more hours, academic achievement decreases instead. At this point, the direct effect of Physical activity on academic achievement becomes negative, reducing students' academic achievement. Although exercise duration can improve Physical fit-ness and cognitive ability, the mediating effect value is much lower than the direct effect value, so it cannot improve academic achievement but only mitigates the negative im-pact of exercise duration on academic achievement. Heterogeneity analysis results show that boys are more affected by exercise duration than girls, with boys having a higher improvement in academic achievement when exercising for two hours, while girls have a better academic achievement improvement when exercising for one hour.

TABLE 4 Pathway analysis of the effect of physical fitness and cognitive ability on academic achievement.

Effect types	Effect	Boot SE	Boot LLCI	Boot ULCI	R1	R2
pl2 total effect	3.031*** (6.706)	0.452	2.2	3.924		
Direct effect	1.478*** (3.491)	0.423	0.699	2.29	48.76%	
total indirect effect	1.553*** (8.943)	0.174	1.239	1.915	51.24%	
pl2 → bmi2 → NEW_VAR	0.137*** (4.285)	0.032	0.083	0.208		8.82%
pl2 → COG3PL → NEW_VAR	1.416*** (8.338)	0.17	1.114	1.769		91.18%
pl3 total effect	3.249*** (5.601)	0.58	2.028	4.277		
Direct effect	1.649** (3.093)	0.533	0.485	2.64	50.75%	
total indirect effect	1.599*** (7.008)	0.228	1.171	2.048	49.22%	
pl3 → bmi2 → NEW_VAR	0.139*** (3.527)	0.039	0.071	0.22		8.69%
pl3 → COG3PL → NEW_VAR	1.461*** (6.537)	0.223	1.03	1.916		91.37%
pl4 total effect	−1.829* (−2.447)	0.748	−3.275	−0.404		
Direct effect	−1.837** (−2.677)	0.686	−3.131	−0.502	99.57%	
total indirect effect	0.008 (0.031)	0.254	−0.484	0.471	0.43%	
pl4 → bmi2 → NEW_VAR	0.168*** (3.905)	0.043	0.088	0.257		51.22%
pl4 → COG3PL → NEW_VAR	−0.16 (−0.645)	0.248	−0.62	0.313		48.78%

t statistics in parentheses *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Standard errors are indicated in parentheses; R1: Ratio of indirect and direct to total effect; R2: Ratio of part indirect to total effect to total indirect.

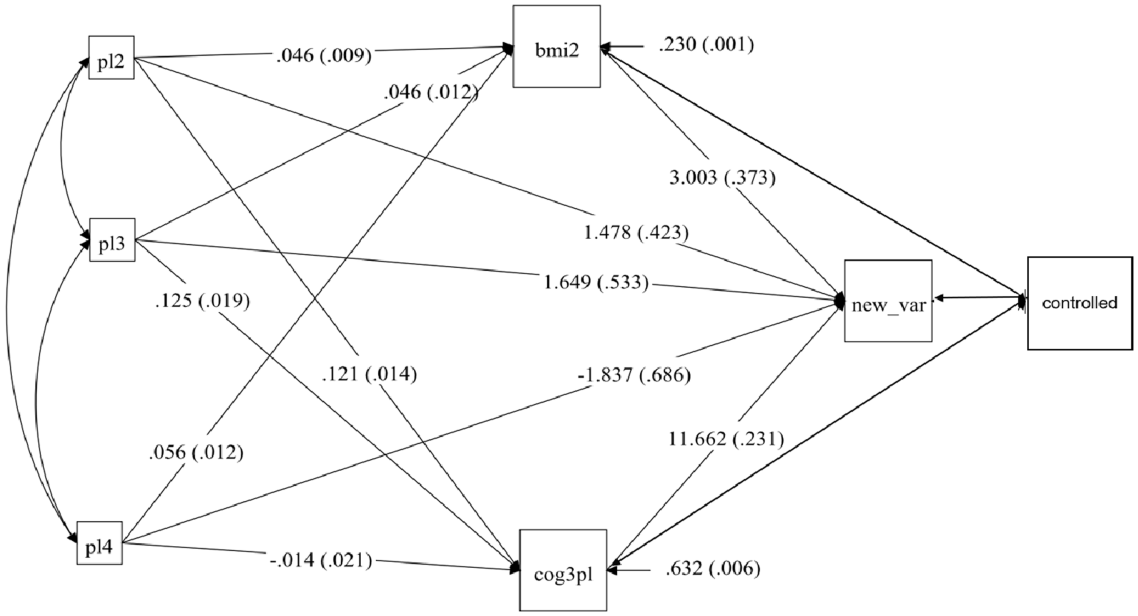


FIGURE 1
Path coefficients of the intermediary model. Model fit index RMSEA: 0.023; CFI: 0.987; TLI: 0.902; SRMR: 0.009; pl1 is 1 h of physical activity time, pl2 is 2 h of physical activity time, pl3 is 3 h of physical activity time; bmi2 = Physical fitness; cog3pl = cognitive ability; new_var = Academic achievement.

3.5. Robustness test

Breen et al. (2013) proposed the KHB method, which not only decomposes the effects of continuous and categorical independent variables but also determines the existence of the mediating effect while measuring the contribution rate of the mediating effect. Therefore, this method is used here to conduct a robustness test on the previous content. The results show consistency with the previous content, that different exercise durations have varying effects on academic achievement, and the best exercise duration is 2 h. The results show passing the robustness test (Table 6).

4. Discussion

4.1. The direct impact of different durations of exercise on academic achievement

The study results indicate that different exercise durations have different effects on students' academic achievement compared to students who do not engage in Physical activity. When the exercise duration is within two hours, it has the best effect on improving academic achievement. A certain amount of Physical activity can help students relax and improve studying efficiency. Scholars believe that Physical activity can affect academic achievement through various direct and indirect physiological, cognitive, emotional, and learning mechanisms (Fang, 2020). Extra-curricular physical activities can improve students' classroom behavior and academic achievement (Álvarez-Bueno et al., 2017). However, when the exercise duration reaches three or more hours, Physical activity will hinder the improvement of students' academic achievement. Studies have shown that performing 50 min of exercise every day improves academic achievement (Bai et al., 2020), while exercising for more than 75 min shows no improvement (Dwyer et al., 1983). Other studies have found that exercising for more than 120 min has a negative impact on academic achievement (Dong and Zhu, 2020). Therefore, although longer exercise may lead to better classroom performance and increased neural activity, excessive exercise time occupies too much of students' study time, leading to a significant decrease in academic achievement when the exercise duration exceeds three hours.

In addition, the commonly used theory applied in research on the relationship between Physical activity and academic achievement is Activation Theory, which suggests an inverted-U relationship between task performance and activation level. Excessive activation levels may result in poor task performance (Wen, 2015). Therefore, appropriate Physical activity can improve adolescent students' academic achievement.

4.2. Effect of physical fitness and cognitive ability on academic achievement

This study found that Physical fitness has a significant impact on students' academic achievement. Different exercise durations can improve students' physical fitness. Compared with non-healthy students who are either overweight or underweight, students who maintain a normal body shape have better academic achievement. However, the relationship between adolescent Physical fitness and academic achievement is complex. Some scholars believe that Physical fitness is the key indicator that affects academic achievement (Liang and Zhang, 2016; Asigbee et al., 2018). Although this study found that Physical fitness can affect students' academic achievement, factors that truly affect academic achievement may not be Physical fitness. Individuals with obesity or underweight features are more likely to

TABLE 5 Heterogeneous path analysis.

Effect types	Boys			Girls		
	Effect	E.S.	Est./S.E.	Effect	E.S.	Est./S.E.
pl2 total effect	5.234***	0.721	7.257	2.193***	0.594	3.690
pl3 total effect	6.290***	0.830	7.578	1.294	0.803	1.612
pl4 total effect	0.334	0.913	0.365	−4.311***	1.223	−3.526
pl2 Direct effect	2.498***	0.664	3.762	0.512*	0.550	0.931
pl3 Direct effect	2.888***	0.794	3.636	0.063	0.736	0.085
pl4 Direct effect	−0.668	0.842	−0.794	−3.89**	1.120	−3.474
pl2 indirect effect	2.736***	0.307	8.903	1.681***	0.237	7.081
pl3 indirect effect	3.402***	0.348	9.785	1.231***	0.315	3.905
pl4 indirect effect	1.002**	0.359	2.790	−0.421	0.432	−0.975
pl2 → bmi2 → NEW_VAR	0.210***	0.056	3.726	0.074*	0.036	2.027
pl2 → COG3PL → NEW_VAR	2.526***	0.300	8.411	1.608***	0.232	6.942
pl3 → bmi2 → NEW_VAR	0.294***	0.073	4.033	−0.027	0.046	−0.599
pl23 → COG3PL → NEW_VAR	3.108***	0.343	9.070	1.259***	0.308	4.093
pl4 → bmi2 → NEW_VAR	0.264***	0.068	3.885	−0.015	0.065	−0.224
pl4 → COG3PL → NEW_VAR	0.738*	0.354	2.087	−0.406	0.423	−0.959

pl2 = 1 h of exercise, pl3 = 2 h of exercise, pl4 = 3 h of exercise; *$p < 0.05$,**$p < 0.01$,***$p < 0.001$.

TABLE 6 KHB mediated effect test of exercise duration on academic achievement: robustness test.

Independent variable	Total effect	Direct effect	Intermediate variables	Indirect effects	Indirect effects as a percentage
1 h	3.040***	1.524***	Physical Health	0.133*	4.37%
			Cognitive ability	1.384***	45.51%
2 h	3.275***	1.691**	Physical Health	0.137*	4.19%
			Cognitive ability	1.447***	44.19%
3 h	−1.821**	−1.813**	Physical Health	0.169**	−9.27%
			Cognitive ability	−0.178	9.75%

t statistics in parentheses *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

face discrimination, bullying, even stigmatization, and they struggle to obtain the same resources as those with normal body shape (Lumeng et al., 2010). And other factors such as obesity may also lead to a decline in self-esteem and confidence, causing anxiety and eventually resulting in a decrease in academic achievement (Kristjánsson et al., 2010). Physical activity can improve body shape, Physical fitness, and enhance student's self-esteem (Biddle et al., 2019), thereby improving their academic achievement.

Compared to students who do not participate in Physical activity, participating in Physical activity can improve students' cognitive abilities and have an impact on their academic achievement. The research results indicate that moderate Physical activity can significantly improve students' cognitive abilities. Physical activity is believed to immediately increase the physiological arousal level of young people, thereby promoting cognitive performance by increasing attention allocation (Roig et al., 2013). Cotman and Berchtold (2002) suggest that Physical activity can trigger a series of neurobiological mechanisms that may enhance memory processing in humans. The primary physiological mechanism of Physical activity functioning on cognitive ability is that it can affect cellular processes and improve energy utilization efficiency (Bélanger et al., 2011). Based on energy utilization, cells can efficiently carry out various biochemical reactions and synthesize substances needed to maintain the survival of neurons, such as neurotransmitters (Dishman et al., 2006; Thomas et al., 2012; Roig et al., 2013). Therefore, Physical activity can promote the development of cognitive ability (XIA, Xia et al., 2018), thereby improving academic achievement. However, some studies have shown that excessive Physical activity can negatively impact cognitive ability due to the body and psychological burden (Tomporowski et al., 2008).

4.3. Differences in physical activity between genders

Through heterogeneity comparison, it was found that the effect of Physical activity on academic achievement differs between boys and girls. Boys exhibit a greater positive effect of Physical activity on academic achievement, with the largest improvement achieved at a

2-h exercise duration. Girls show a significant improvement in academic achievement after exercising for 1 h, but their academic achievement decreases with further increase in exercise duration. Data analysis also shows that girls' overall academic achievement is better than boys by 12.61 standard deviations, and the marginal contribution of Physical activity to academic achievement for girls faces a decreasing trend. In contrast, boys are more affected by marginal effects, so exercising over the weekend can improve their academic achievement, which is consistent with the findings of Fang (2020). Analysis on the mediating variable of Physical fitness shows that boys significantly increase their Physical fitness level through Physical activity, while girls' Physical fitness level only improves significantly when exercising for 1 h, which may be due to differences in the intensity of Physical activity between boys and girls. Research shows that most women choose public sports venues and parks (Meng et al., 2005), and walking as their preferred form of exercise (Liu et al., 2013; Wang et al., 2015), which are relatively low-intensity exercise activities with less energy consumption, therefore, their impact on Physical fitness is not significant. Boys' cognitive abilities are improved by Physical activity of different durations, while girls show a higher improvement in cognitive abilities after 1 h of Physical activity, which may be related to the content of physical activities chosen by girls such as walking forms of exercise, which may not enhance cognitive ability and may even affect their use of study time.

5. Conclusion

1. Different durations of physical activity have different effects on academic performance, and there is an optimal activity time for students' academic performance. When the exercise duration is two hours, the improvement in students' academic performance is the greatest.
2. Physical activity can improve students' physical fitness, enhance their cognitive ability, and thus improve their academic performance.
3. Different durations of physical activity can improve students' physical fitness, but there is an optimal value for the improvement of cognitive ability with respect to the duration of physical activity. There are also differences between male and female students. For the improvement of cognitive ability, the optimal activity time for male students is two hours, while for female students, it is one hour.

6. Recommendations

1. Parents and schools should attach great importance to the value of Physical activity, encourage students to participate in Physical activity, and promote academic growth by improving cognitive abilities and Physical fitness.
2. Students should reasonably arrange the duration of Physical activity, keeping it around 2 h to more effectively promote academic achievement.
3. Schools can assign physical homework on weekends based on students' physical foundation and interests, set the required completion time to be around 2 h, which can improve Physical fitness as well as academic achievement.

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.

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 or patients/participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

GL and XL: conceptualization. GL, XL, and WL: methodology and data curation. GL: writing—original draft. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

The authors thank Renmin University of China for providing the database on the topic of China Education Panel Survey.

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

Álvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sánchez-López, M., Garrido-Miguel, M., and Martínez-Vizcaíno, V. (2017). Academic achievement and physical activity: a meta-analysis. *Pediatrics* 140:1498. doi: 10.1542/peds.2017-1498

Asigbee, F. M., Whitney, S. D., and Peterson, C. E. (2018). The link between nutrition and physical activity in increasing academic achievement. *J. Sch. Health* 88, 407–415. doi: 10.1111/josh.12625

Bai, S., Pan, Z., and Teng, H. (2020). An empirical study of the impact of exercise on academic performance in Middle school students. *China Sport Sci.* 40, 64–72.

Bangsbo, J., Krustrup, P., Duda, J., Hillman, C., Andersen, L. B., Weiss, M., et al. (2016). The Copenhagen consensus conference 2016: children, youth, and physical activity in schools and during leisure time. *Br. J. Sports Med.* 50, 1177–1178. doi: 10.1136/bjsports-2016-096325

Bélanger, M., Allaman, I., and Magistretti, P. J. (2011). Brain energy metabolism: focus on astrocyte-neuron metabolic cooperation. *Cell Metab.* 14, 724–738. doi: 10.1016/j.cmet.2011.08.016

Biddle, S. J. H., Ciaccioni, S., Thomas, G., and Vergeer, I. (2019). Physical activity and mental health in children and adolescents: an updated review of reviews and an analysis of causality. *Psychol. Sport Exerc.* 42, 146–155. doi: 10.1016/j.psychsport.2018.08.011

Breen, R., Karlson, K. B., and Holm, A. (2013). Total, direct, and indirect effects in Logit and Probit models. *Sociol. Methods Res.* 42, 164–191. doi: 10.1177/0049124113494572

Carlson, S. A., Fulton, J. E., Lee, S. M., Maynard, L. M., Brown, D. R., Kohl, H. W. III, et al. (2008). Physical education and academic achievement in elementary school: data from the early childhood longitudinal study. *Am. J. Public Health* 98, 721–727. doi: 10.2105/AJPH.2007.117176

Chan, J. K.-w., and Hui, S. S.-c. (2016). Physical activity participation was not associated with academic performance in ethnic minority students: 3756 board #195 June 4, 8: 00 AM -9: 30 AM. *Med. Sci. Sports Exerc.* 48:1049. doi: 10.1249/01.mss.0000488159.68286.c8

Chen, R., Zheng, Y. H., and Liu, W. J. (2013). Mediation analysis: principles, procedures, bootstrap methods and applications. *J. Market. Sci.* 9, 120–135.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., and Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Med. Sci. Sports Exerc.* 38, 1515–1519. doi: 10.1249/01.mss.0000227537.13175.1b

Cotman, C. W., and Berchtold, N. C. (2002). Exercise: a behavioral intervention to enhance brain health and plasticity. *Trends Neurosci.* 25, 295–301. doi: 10.1016/S0166-2236(02)02143-4

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* 14, 345–356. doi: 10.1038/oby.2006.46

Dong, Y. M., and Zhu, C. G. (2020). A study on the influence of extra-curricular sports on academic performance of teenagers: on the mediating effect of non-cognitive ability. *J. Sports Res.* 34, 52–62.

Dwyer, T., Coonan, W., Leitch, D., Hetzel, B., and Baghurst, R. (1983). An investigation of the effects of daily physical activity on the health of primary school students in South Australia. *Int. J. Epidemiol.* 12, 308–313. doi: 10.1093/ije/12.3.308

Fang, L. (2020). The effect of physical exercise on adolescents' cognitive ability and academic performance. *China Sport Sci.* 40, 35–41.

Fritz, M. S., Taylor, A. B., and Mackinnon, D. P. (2012). Explanation of two anomalous results in statistical mediation analysis. *Multivar. Behav. Res.* 47, 61–87. doi: 10.1080/00273171.2012.640596

Guthold, R., Stevens, G. A., Riley, L. M., and Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc Health* 4, 23–35. doi: 10.1016/S2352-4642(19)30323-2

Han, Z., Lun, Y., and Liu, T. (2022). Influence of URBAN facilities and environment on junior MIDDLE school STUDENTS' physical health: a case study of Dalian city. *Hum. Geogr.* 37, 99–109. (in Chinese)

Hao, W., and Yi, J. (2022). Dilemma and countermeasures of delayed after-school sports Service in Primary and Secondary Schools under the policy of double reduction. *Sports Cult. Guide* 10, 95–101. (in Chinese)

Hayes, A. F., and Scharkow, M. (2013). The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: does method really matter? *Psychol. Sci.* 24, 1918–1927. doi: 10.1177/0956797613480187

Hillman, C., Erickson, K., and Kramer, A. (2008). Be smart, physical activity your heart: physical activity effects on brain and cognition. *Nat. Rev. Neurosci.* 9, 58–65. doi: 10.1038/nrn2298

Jiang, C. M., and Li, S. (2015). Mediation analysis and the application of bootstrap in mediation analysis. *Psychol. Explor.* 35, 458–463.

Kristjánsson, Á. L., Sigfúsdóttir, I. D., and Allegrante, J. P. (2010). Health behavior and academic achievement among adolescents: the relative contribution of dietary habits, physical activity, body mass index, and self-esteem. *Health Educ. Behav.* 37, 51–64. doi: 10.1177/1090198107313481

Legg, J. A., and Gray, D. A. (2000). Performance bounds for polynomial phase parameter estimation with nonuniform and random sampling schemes. *IEEE Trans. Signal Process.* 48, 331–337. doi: 10.1109/78.823961

Lei, W., and Li, Z. (2021). The effect of the non-cognitive ability on Middle school students' academic achievement: an empirical analysis based on CEPS. *J. Central China Normal Univ.* 60, 154–163. (in Chinese)

Liang, Z., and Zhang, Y. (2016). Empirical research of physical shape, cardiopulmonary function and academic scores based on the empirical research of physical shape, cardiopulmonary function and academic scores based on the comparison between National Guideline of student physical fitness 2014 and 2007. *Sports Sci.* 37, 89–97. (in Chinese)

Liu, J., Sun, H., Beets, M. W., and Probst, J. C. (2013). Assessing natural groupings of common leisure-time physical activities and its correlates among US adolescents. *J. Phys. Act. Health* 10, 470–479. doi: 10.1123/jpah.10.4.470

Liu, D., Shen, L., Yu, B., Yu, W., Jia, P., and Yang, S. (2023). Influence of social capital changes on body mass index of Chinese students during COVID-19 lockdown. *Modern Prevent. Med.* 50, 317–322. (in Chinese)

Lumeng, J. C., Forrest, P., Appugliese, D. P., Kaciroti, N., Corwyn, R. F., and Bradley, R. H. (2010). Weight status as a predictor of being bullied in third through sixth grades. *Pediatrics* 125, e1301–e1307.

Martin, A., Booth, J. N., Laird, Y., Sproule, J., Reilly, J. J., Saunders, D. H., et al. (2018). Physical activity, diet and other behavioural interventions for improving cognition and school achievement in children and adolescents with obesity or overweight. *Cochrane Database Syst. Rev.* 2018, 3:CD009728. doi: 10.1002/14651858.CD009728.pub4

Masoomi, H., Taheri, M., Irandoust, K., H'Mida, C., and Chtourou, H. (2020). The relationship of breakfast and snack foods with cognitive and academic performance and physical activity levels of adolescent students. *Biol. Rhythm. Res.* 51, 481–488. doi: 10.1080/09291016.2019.1566994

Maynard, E., Coonan, W., Worsley, A., Dwyer, T., and Baghurst, P. (1987). The development of the lifestyle education program in Australia. *Cardiovascular Risk Factors in Children: Epidemiology and Prevention* 123–149.

McPherson, A., Mackay, L., Kunkel, J., and Duncan, S. (2018). Physical activity, cognition and academic performance: an analysis of mediating and confounding relationships in primary school children. *BMC Public Health* 18:936. doi: 10.1186/s12889-018-5863-1

Meng, W., Guo, Y., Zou, X., and Guo-Ying, Q. (2005). Investigation and research on Chinese Women's participation in mass sports and its general condition in the current period. *J. Beijing Sport Univ.* 28, 295–298.

News, X. (2021). *2019 national student physical health attainment excellent rate of 23.8%*. Available at: https://baijiahao.baidu.com/s?id=1709863679300048449 (Accessed April 08, 2023).

Pei, D., and Gao, P. (2013). Studying on the Physical & Mental Health and the sport participation behaviors of migrant Workers' Children. *Sports Sci.* 34, 94–98. (in Chinese)

Preacher, K. J., and Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behav. Res. Methods* 40, 879–891. doi: 10.3758/BRM.40.3.879

Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Med. Sci. Sports Exerc.* 48, 1197–222.

Roig, M., Nordbrandt, S., Geertsen, S. S., and Nielsen, J. B. (2013). The effects of cardiovascular exercise on human memory: a review with meta-analysis. *Neurosci. Biobehav. Rev.* 37, 1645–1666. doi: 10.1016/j.neubiorev.2013.06.012

Shen, K., and Ma, W. (2022). Research on the characteristics and influence of adolescents on the aesthetic orientation of physical education curriculum. *China Sport Sci.* 42, 50–59. (in Chinese)

Singh, A. S., Saliasi, E., van den Berg, V., Uijtdewilligen, L., de Groot, R. H. M., Jolles, J., et al. (2019). Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. *Br. J. Sports Med.* 53, 640–647. doi: 10.1136/bjsports-2017-098136

Sun, Z., Liu, Z., and Sun, B. (2009). Children's achievements and their families and schools: a study based on the rural areas in Gansu province. *Journal of Beijing Normal University (Social Sciences)* 5, 103–115.

Thomas, A. G., Dennis, A., Bandettini, P. A., and Johansen-Berg, H. (2012). The effects of aerobic activity on brain structure. *Front. Psychol.* 3:86. doi: 10.3389/fpsyg.2012.00086

Tomporowski, P. D., Davis, C. L., Miller, P. H., and Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educ. Psychol. Rev.* 20, 111–131. doi: 10.1007/s10648-007-9057-0

Tomporowski, P. D., and Pesce, C. (2019). Exercise, sports, and performance arts benefit cognition via a common process. *Psychol. Bull.* 145, 929–951. doi: 10.1037/bul0000200

Tremblay, M. S., Inman, J. W., and Douglas Willms, J. (2000). The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatr. Exerc. Sci.* 12, 312–323. doi: 10.1123/pes.12.3.312

Visier-Alfonso, M. E., Álvarez-Bueno, C., Sánchez-López, M., Cavero-Redondo, I., Martínez-Hortelano, J. A., Nieto-López, M., et al. (2021). Fitness and executive function as mediators between physical activity and academic achievement: mediators between physical activity and academic achievement. *J. Sports Sci.* 39, 1576–1584. doi: 10.1080/02640414.2021.1886665

Wang, F., Jiang, C., Wang, M., and Zhang, Y. (2015). Study on the characteristics and F actors of intergenerational change in Chinese Female's physical exercise. *China Sport Science* 35, 24–34. (in Chinese)

Wen, X. (2015). Influence of physical exercise on cognitive function and academic performance in children: history, current status and future. *China Sport Sci.* 35, 73–82.

Wen, Z., and Ye, B. (2014). Analyses of mediating effects: the development of methods and models. *Adv. Psychol. Sci.* 22:731. doi: 10.3724/SP.J.1042.2014.00731

World Health Organization. (2022). Physical activity, Vol. 2023.4.17.

Wunsch, K., Kasten, N., and Fuchs, R. (2017). The effect of physical activity on sleep quality, well-being, and affect in academic stress periods. *Nature Sci. Sleep* 9, 117–126. doi: 10.2147/NSS.S132078

Xia, H., et al. (2018). The brain mechanisms of the physical exercise enhancing cognitive function. *Adv. Psychol. Sci.* 26, 1857–1868. doi: 10.3724/SP.J.1042.2018.01857

Xiang, H., Yang, R., Tu, J., Guan, X., and Tao, X. (2022). Health impacts of high BMI in China: terrible present and future. *Int. J. Environ. Res. Public Health* 19:173. doi: 10.3390/ijerph192316173

Yu, C. C. W., Chan, S., Cheng, F., Sung, R. Y. T., and Hau, K. T. (2006). Are physical activity and academic performance compatible? Academic achievement, conduct, physical activity and self-esteem of Hong Kong Chinese primary school children. *Educ. Stud.* 32, 331–341. doi: 10.1080/03055690600850016

Zhang, Y., Su, F., Song, Y., and Lu, J. (2022). Associations between physical fitness index and body mass index in Tibetan children and adolescents in different high-altitude areas: based on a study in Tibet, China. *Int. J. Environ. Res. Public Health* 19:155. doi: 10.3390/ijerph191610155

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 18 July 2023
DOI 10.3389/fpsyg.2023.1157644

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Yujiro Kawata,
Juntendo University, Japan
Leor Zmigrod,
University of Cambridge, United Kingdom

*CORRESPONDENCE
Anisa Morava
✉ amorava@uwo.ca

RECEIVED 02 February 2023
ACCEPTED 29 June 2023
PUBLISHED 18 July 2023

CITATION
Morava A, Tari B, Ahn J, Shirzad M, Heath M and Prapavessis H (2023) Acute stress imparts a transient benefit to task-switching that is not modulated following a single bout of exercise. *Front. Psychol.* 14:1157644.
doi: 10.3389/fpsyg.2023.1157644

Acute stress imparts a transient benefit to task-switching that is not modulated following a single bout of exercise

Anisa Morava[1]*, Benjamin Tari[1,2], Joshua Ahn[1], Mustafa Shirzad[1], Matthew Heath[1,3,4] and Harry Prapavessis[1]

[1]Faculty of Health Sciences, School of Kinesiology, University of Western Ontario, London, ON, Canada, [2]Department of Psychiatry, University of Oxford, Oxford, United Kingdom, [3]Canadian Centre for Activity and Aging, University of Western Ontario, London, ON, Canada, [4]Graduate Program in Neuroscience, University of Western Ontario, London, ON, Canada

Introduction: Cognitive flexibility represents a core component of executive function that promotes the ability to efficiently alternate—or "switch"—between different tasks. Literature suggests that acute stress negatively impacts cognitive flexibility, whereas a single bout of aerobic exercise supports a postexercise improvement in cognitive flexibility. Here, we examined whether a single bout of aerobic exercise attenuates a stress-induced decrement in task-switching.

Materials and Methods: Forty participants (age range=19–30) completed the Trier Social Stress Test (TSST) and were randomized into separate Exercise or Rest groups entailing 20-min sessions of heavy intensity exercise (80% of heart rate maximum via cycle ergometer) or rest, respectively. Stress induction was confirmed via state anxiety and heart rate. Task-switching was assessed prior to the TSST (i.e., pre-TSST), following the TSST (i.e., post-TSST), and following Exercise and Rest interventions (i.e., post-intervention) via pro- (i.e., saccade to veridical target location) and antisaccades (i.e., saccade mirror-symmetrical to target location) arranged in an AABB task-switching paradigm. The underlying principle of the AABB paradigm suggests that when prosaccades are preceded by antisaccades (i.e., task-switch trials), the reaction times are longer compared to their task-repeat counterparts (i.e., unidirectional prosaccade switch-cost).

Results: As expected, the pre-TSST assessment yielded a prosaccade switch cost. Notably, post-TSST physiological measures indicated a reliable stress response and at this assessment a null prosaccade switch-cost was observed. In turn, post-intervention assessments revealed a switch-cost independent of Exercise and Rest groups.

Conclusion: Accordingly, the immediate effects of acute stress supported improved task-switching in young adults; however, these benefits were not modulated by a single bout of aerobic exercise.

KEYWORDS

antisaccades, cognitive flexibility, executive function, oculomotor, psychosocial stressor

Introduction

Executive function represents a constellation of higher-order processes including the core components of inhibitory control, working memory, and cognitive flexibility (Diamond, 2013). Executive function and health are interrelated such that executive function behaves as an antecedent and consequence of health behaviors (for reviews, see Allan et al., 2016; Williams

et al., 2017). Indeed, an extensive literature has shown that executive function is modulated via a number of external factors including stress and exercise (Chang et al., 2012; Plieger and Reuter, 2020). In the first case, stress represents a state of threatened homeostasis (Chrousos and Gold, 1992) or an experience wherein an individual appraises a situation as exceeding their resources and endangering their wellbeing (Lazarus and Folkman, 1984). Shields et al.'s (2016) meta-analysis concluded that an acute bout of stress provides a transient disruption to the components of executive function. In particular, the authors reported stress impaired performance on tasks assessing cognitive flexibility and working memory. In contrast, effects of acute stress on inhibitory control were mixed. Importantly, cognitive flexibility requires the efficient ability to inhibit extraneous stimuli and hold a currently relevant task set in mind. The stress-induced reduction in executive performance has been attributed to the reallocation of "finite" executive function resources in conjunction with neurobiological alterations associated with activation of the hypothalamic-pituitary-adrenal (HPA) and sympathetic-adrenal-medullary (SAM) axes (Mather and Sutherland, 2011; Plessow et al., 2011; Shansky and Lipps, 2013). In the second case, meta-analytic evidence suggests single bouts of aerobic and/or resistance exercise provide a brief (i.e., <60-min) benefit to executive function (Lambourne and Tomporowski, 2010; Chang et al., 2012; Ludyga et al., 2016). This effect has been attributed to exercise-based increases in cerebral blood flow (Tari et al., 2020), biomolecule concentrations (Zouhal et al., 2008; Knaepen et al., 2010) and resting state functional connectivity (Schmitt et al., 2019) that support improved efficiency of local neural circuits (Moore and Cao, 2008). Notably, a narrative review by Sandi (2013) highlighted stress response systems such as the HPA and SAM axes are heavily integrated with regions supporting executive functions (Joëls and Baram, 2009). A single bout of exercise has also been demonstrated to buffer the effects of stress and promote stress-related recovery as determined by biological (e.g., heart rate, blood pressure, cortisol levels) and perceptual (e.g., State Trait Anxiety Inventory) measures of stress (LaManca et al., 2001; Brownley et al., 2003; Alderman et al., 2007; Wunsch et al., 2019). Taken together, this underscores the use of a single bout of exercise in attenuating the deleterious effects of acute stress.

To our knowledge, however, no research has directly examined the potential by which a single bout of exercise may blunt a stress-induced decrement in executive function. In particular, the current work explored whether a 20-min heavy intensity (80% HR maximum) aerobic exercise bout via cycle ergometer attenuates stress-induced impairments in the cognitive flexibility component of executive function via task-switching. For example, a number of studies by our group have examined cognitive flexibility via a paradigm wherein individuals alternate between pro- and anti-saccades in predictable (i.e., AABB) or unpredictable (i.e., AABABB…) task-switching schedules (Weiler and Heath, 2012a,b, 2014a; Heath et al., 2015; Weiler et al., 2015). Prosaccades are a goal-directed eye movement (i.e., saccade) directed to a veridical target location, whereas antisaccades entail a response mirror-symmetrical to a target. Antisaccades produce longer reaction times (RTs; Hallett, 1978) and "less accurate and more variable endpoints than prosaccades (Gillen and Heath, 2014) and these behavioral 'costs' have been linked to the top-down executive processes of response suppression (i.e., inhibiting a reflexive prosaccade) and vector inversion (i.e., 180° spatial transformation)" (for review see Munoz and Everling, 2004). Further, when a prosaccade is preceded by an antisaccade (i.e., task-switch trial) RTs are "longer than when preceded by its same task-type (i.e., task-repeat trial), whereas antisaccade RTs for task-switch and task-repeat do not reliably differ" (Weiler and Heath, 2012a,b). The basis for the asymmetrical switch-cost is that the executive demands of antisaccades result in a task-set inertia that proactively delays the planning of a subsequent prosaccade (i.e., the unidirectional switch-cost) (Weiler and Heath, 2012a). Notably, Shukla and Heath (Shukla et al., 2020; Shukla and Heath, 2021) demonstrated that a single bout of aerobic exercise provides an immediate and sustained (~47-min) benefit to task-switching performance as evidenced by a decreased magnitude unidirectional prosaccade switch-cost. In particular, Shukla and Heath (2021) had participants complete 20-min of heavy intensity (i.e., 80% of heart rate maximum) aerobic exercise via cycle ergometer and reported a 14 ms decrease in the unidirectional prosaccade switch-cost from a pre- to postexercise assessment and further observed that this benefit was sustained for up to 47-min postexercise (see also Heath and Shukla, 2020).

In the present work, participants ($N = 40$) completed baseline pro- and antisaccades arranged in an AABB task-switching schedule (i.e., A = prosaccade, B = antisaccade) and were then exposed to a validated acute stressor (i.e., Trier Social Stress Test: TSST). Subsequently, participants completed a second set of pro- and antisaccade task-switching trials after which they were assigned to an Exercise or Rest group. The Exercise group ($n = 20$) completed 20-min of the aforementioned exercise protocol, whereas the Rest group ($n = 20$) sat on the cycle ergometer without exercising. Following the Exercise and Rest intervention, participants completed a final set of pro- and antisaccade task-switching trials. Hence, the current protocol provides a basis to quantify whether a stress-induced impairment in task-switching is ameliorated via a 20-min bout of aerobic exercise. As for research predictions, it is anticipated that exposure to the TSST will result in a reliable increase in the magnitude of the unidirectional prosaccade switch-cost; that is, acute stress-induction is predicted to impair cognitive flexibility. In turn, it is anticipated that the unidirectional prosaccade switch-cost *magnitude* will return to baseline following the Exercise—but not Rest—intervention. In other words, we predict that the exercise intervention will attenuate the residual effects of stress induction on the cognitive flexibility component of executive function.

Materials and methods

Participants

Forty participants (21 female and 19 male, mean age = 22, SD = 3, age range = 19–30) volunteered from the Western University community. An *a priori* sample size was generated based on the effect size derived from an independent-samples *t*-test contrasting pre- and postexercise antisaccade RTs ($\alpha = 0.05$, power = 0.95, dz. = 1.19; Petrella et al., 2019). All participants had normal or corrected-to-normal vision, self-declared being right-hand dominant, reported no history of neurological impairment (including concussion) or eye injury, and reported not taking medication for anxiety, depression, or a related mental health condition, nor did they take any medication that may impact their response to exercise. All participants attained a complete score on the Physical Activity Readiness Questionnaire for Everyone

(PAR-Q+ 2021) and completed the Godin Leisure-Time Exercise Questionnaire (Godin, 2011) (Mean = 52, SD =24, Range = 28–99). All participants abstained from engaging in strenuous exercise, caffeine, and alcohol use 12 h prior to the experimental protocol. Participants were also instructed to obtain 8 h of sleep the night prior to the experimental protocol. All study procedures were conducted between 12:00 p.m. and 3:00 p.m. Participants provided informed written consent of a protocol approved by the Health Sciences Research Ethics Board (#118590), Western University. This study was conducted in line with the updated version of the Declaration of Helsinki except for participant registration in a public database.

Procedure

Stress induction

The Trier Social Stress Test (TSST) is an ecologically valid stressor that has been used in hundreds of studies to explore the impact of acute stress of psychological and physiological processes (Kirschbaum et al., 1993; Dickerson and Kemeny, 2004). For the TSST participants were informed that they would perform a filmed task where they would present a job interview-style speech to a panel of two judges trained in public speaking. Notably, participants were not familiar with the individuals who served on the mock judging panel. A camera was visible during the filmed speech to induce a state of social evaluation; however, the camera did not record participants' performance, and following the completion of the study participants were debriefed that filming did not take place. The participant was then left alone in the examination room for 10-min for speech preparation before the judges returned. Participants then delivered their 5-min speech after which they were instructed to perform serial subtractions of 13 from 1,022 (i.e., 1,022 minus 13; 996 minus 13; etc.) in front of the same panel of judges. The serial subtractions lasted for 5-min or until subjects reached 0 (see Birkett, 2011 for further details on the TSST protocol). The nomenclatures TSST-Speech and TSST-Math are subsequently used below to describe the TSST speech and serial subtraction components, respectively. Prior to and immediately following the TSST, participants completed a measure of state anxiety. Throughout all data collection participants wore a heart rate monitor (Polar H10 Wearlink + Coded Transmitter, Polar Electro Inc., Lake Success, NY, United States).

Exercise intervention

Participants ($n = 20$; 11 females, mean age: 20, range: 19–24) assigned to the Exercise Group sat on a cycle ergometer (Monark 818E Ergometer, Monark Exercise AB, Vansbro, Sweden) and completed a single bout of exercise that entailed: (1) a 2.5-min warm-up at an intensity less than 50% of their predicted maximum heart rate (i.e., HR_{max}; 220- age), (2) a step-transition to a 20-min session of heavy intensity exercise (i.e., 80% of HR_{max}), (3) a 2.5 min cool-down matching the intensity associated with the warm-up. The 80% of HR_{max} intensity was used based on previous work by our group demonstrating that a 20-min bout of exercise at the same intensity improves task-switching (Heath and Shukla, 2020; Shukla et al., 2020; Shukla and Heath, 2021). To maintain participants' desired heart rate, the resistance on the cycle ergometer was adjusted as necessary. The postexercise oculomotor assessment (see below) was completed once heart rate returned to below 100 beats per minute (bpm).

Rest intervention

Participants ($n = 20$; 10 females, mean age: 23, range: 18–30) sat on the same ergometer used by the Exercise Group. Here, participants sat for an equivalent time period (i.e., 25-min) as the exercise intervention without cycling and heart rate was measured as per the Exercise Group. Participants chatted with the experimenter during this time. The post-rest intervention oculomotor assessment was completed following the same timeline as per the Exercise Group.

Stress measures

The State Trait Anxiety Inventory (STAI; Spielberger et al., 1983) was used to assess state and trait anxiety for all participants independent of group assignment. Twenty items assessed state anxiety and 20 items assessed trait anxiety with a higher score indicating increased anxiety. Trait anxiety was assessed upon entering the lab, whereas state anxiety was assessed at four time points: (1) upon entering the lab, (2) pre-TSST, (3) post-TSST, and (4) following either the Exercise or Rest intervention (i.e., post-intervention) (for timeline of events see Figure 1). Reliability estimates were computed via Cronbach's alpha (α) and McDonald's omega (ω)for the STAI State (Baseline) and Trait subscales. STAI State Baseline ($\alpha = 0.894$, $\omega = 0.896$) and Trait ($\alpha = 0.944$, $\omega = 0.946$).

Oculomotor task

Prior to the TSST (i.e., pre-TSST), immediately following the TSST (i.e., post-TSST), and after Exercise and Rest interventions (i.e., post-intervention), participants completed an oculomotor task-switching paradigm (see Figure 1). For this assessment, participants sat on a height adjustable chair in front of a table (760 mm in height) with their head placed in a head/chin rest. Visual stimuli were presented on a 30-inch LCD monitor (60 Hz, 8 ms response rate, 1,280 × 960 pixels, Dell 3007WFP, Round Rock, TX, United States) placed 550 mm from the front edge of the tabletop and centered on participants' midline and consisted of 1° luminance matched (40 cd/m^2) red and green fixation crosses, as well as white target circles (2.5° diameter, 127 cd/m^2) located 13° (i.e., proximal target) and 17° (i.e., distal target) to the left and right of fixation. The gaze location of participants' left eye was measured via a video-based eye-tracking system (EyeLink 1000 Plus, SR Research, Ottawa, ON, Canada) sampling at 1,000 Hz. Prior to data collection a nine-point calibration of the viewing space was performed and confirmed via an immediate validation (<1° of error for each of the nine points in the calibration grid). Computer events were controlled via MATLAB (R2018b, The MathWorks, Natick, MA, United States) and the Psychophysics Toolbox extensions (v 3.0; Brainard, 1997; Kleiner et al., 2007)

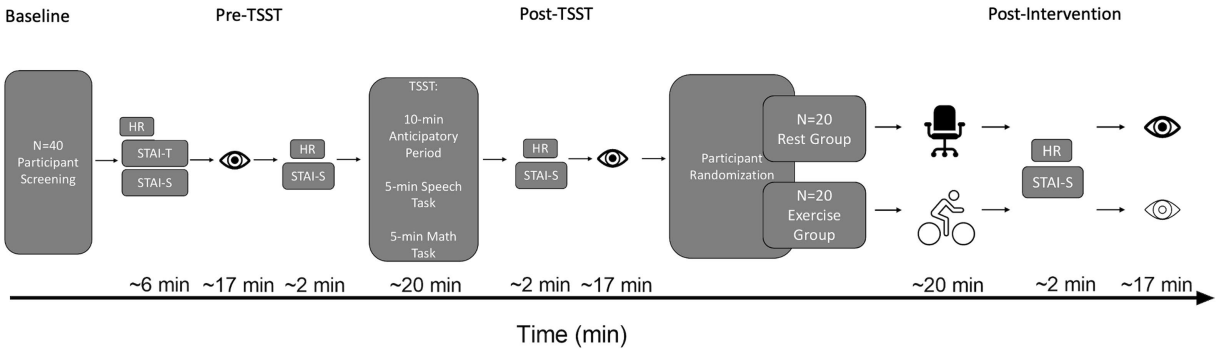


FIGURE 1
Schematic of the timeline of HR, STAI, and oculomotor assessments. The eye icon represents an oculomotor assessment. The desk chair icon represents the Rest group. The cyclist icon represents the Exercise group. HR, Heart rate; STAI-T, Trait Anxiety; STAI-S, State Anxiety; TSST, Trier Social Stress Test.

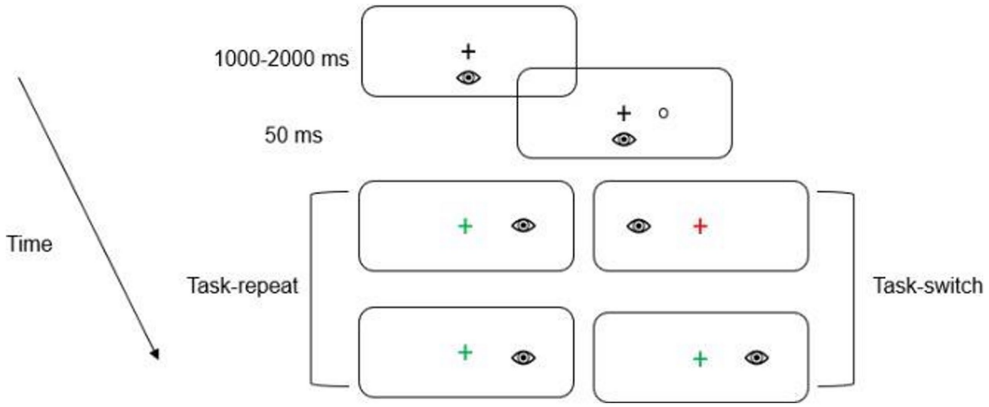


FIGURE 2
Schematic of the timeline of visual events. The first two panels depict the fixation cross and the presentation of the target, respectively. In this schematic, the green fixation cross denotes a saccade to the target's veridical location (i.e., prosaccade), whereas the red fixation cross indicates a saccade to the target's mirror-symmetrical (i.e., antisaccade) location. The subsequent panels depict an example of a task-repeat (i.e., prosaccade followed by a prosaccade) and task-switch (i.e., antisaccade followed by a prosaccade). Participants alternated between pro- and antisaccades after every second trial (i.e., AABB). For this schematic only a single target eccentricity presented in the right visual field is depicted.

including the EyeLink Toolbox (Cornelissen et al., 2002). The lights in the experimental suite were extinguished during data collection.

A trial began with the presentation of a green or a red fixation cross which instructed participants to direct their gaze to its location. The color of the fixation cross indicated the nature of the upcoming trial. A green fixation cross indicated a prosaccade (i.e., saccade to veridical target location), whereas a red fixation cross indicated an antisaccade (i.e., saccade mirror-symmetrical to target location; see Figure 2).

Once a stable gaze was achieved (i.e., ±1.5° for 450 ms), a uniformly distributed randomized foreperiod between 1,000–2000 ms was initiated during which time the fixation cross remained visible. Following the foreperiod, a target was presented for 50 ms after which the target and fixation cross were extinguished (i.e., overlap paradigm). An overlap paradigm was used to minimize the frequency of directional errors (i.e., a prosaccade instead of an instructed antisaccade or vice versa) given that the primary metric for this study was RT for directionally correct responses. The onset of the target cued participants to pro- or antisaccade "as quickly and accurately as possible." Pro- and antisaccades were arranged in a predictable AABB task-switching paradigm such that 40 prosaccade task-switch (i.e., prosaccade on trial N and an antisaccade on trial N-1) and 40 prosaccade task-repeat (i.e., prosaccade on trial N and N-1) trials were completed with an equivalent number of antisaccade task-switch and task-repeat trials (i.e., 160 trials). An AABB paradigm involves the conscious switching between distinct task sets (i.e., from a standard non-executive prosaccade task set to a non-standard, executive antisaccade task set and vice versa). Accordingly, the AABB task arrangement allows for the precise assessment of the cognitive flexibility domain of executive function (Diamond, 2013; see also above in more detail). For each oculomotor assessment an equal number of trials were pseudo-randomly presented to each target location (i.e., left proximal, left distal, right proximal, right distal). As shown in Figure 1, the oculomotor assessment of task-switching occurred pre-TSST, post-TSST and post-intervention. Each oculomotor assessment required ~17 min to complete (including calibration time) and is a time frame known to elicit a positive postexercise executive function benefit (Chang et al., 2012).

Data reduction, dependent variables, and statistical analyses

Stress variables

Mean heart rate (HR) was calculated by averaging data pre-TSST, 5-min TSST (Speech), 5-min TSST (Math) and post-TSST. STAI scores were tabulated for trait and state subscales, and the latter were summed at baseline, pre-TSST, post-TSST, and post-intervention.

Oculomotor variables

Point of gaze data were filtered offline using a dual-pass Butterworth filter employing a low-pass cut-off frequency of 15 Hz. A five-point central-finite difference algorithm was used to compute instantaneous velocities and accelerations. Saccade onset was determined via velocity and acceleration values that exceeded 30°/s and 8,000°/s^2, respectively. Saccade offset was determined when velocity fell below 30°/s for 40 ms. Trials with missing data (e.g., blinks, signal loss) were excluded as were trials with: (1) an anticipatory response (RTs < 50 ms; Wenban-Smith and Findlay, 1991), (2) RTs > 2.5 standard deviations of a participant- and task-specific mean, and (3) trials with amplitudes <2° or >2.5 standard deviations of a participant- and task-specific mean (Gillen and Heath, 2014). Trials involving a directional error were excluded from subsequent analyses because such responses engage planning mechanisms distinct from their directionally correct counterparts (DeSimone et al., 2014). Less than 15% of trials were removed and only 2 and 4% of pro- and antisaccades entailed a directional error. The low error rate is attributed to the use of an overlap paradigm and the predictable nature of the AABB paradigm used here.

Statistical analyses

Stress variables included HR and STAI scores. Mean HR values were analyzed via 4 (time: pre-TSST, concurrent TSST-Speech and TSST-Math, post-TSST) by 2 (group: Rest vs. Exercise) mixed-model ANOVA with group serving as the between-groups factor. STAI values were analyzed via 4 (time: baseline, pre-TSST, post-TSST, and post-intervention) by 2 (group: Rest vs. Exercise) with the former serving as the between-groups factor. This procedure is in keeping with previous studies examining HR and STAI scores during the TSST (Hellhammer and Schubert, 2012). Oculomotor dependent variables included RT (i.e., time from response cueing to saccade onset), saccade duration (i.e., time from saccade onset to saccade offset), and saccade gain variability (i.e., within-participant standard deviation of saccade amplitude/veridical target location). Oculomotor dependent variables were examined via 3 (time: pre-TSST, post-TSST, post-intervention) by 2 (task: prosaccade, antisaccade) by 2 (task transition: task-switch, task-repeat) by 2 group (i.e., Rest vs. Exercise) mixed-groups ANOVA. Huynh-Feldt corrections for violations for sphericity are reported where appropriate (corrected degrees of freedom reported to one decimal place) and an alpha level of 0.05 was used for all ANOVA models. Interactions and appropriate main effects were decomposed via simple effects (i.e., paired-samples *t*-tests). Where appropriate, Bayesian statistics were employed to confirm null results and the two one-sided test (TOST) statistic is reported to determine whether results were within an equivalence boundary (Lakens, 2017). The effect size used to compute the TOST statistic ($d_z = 0.54$) was derived from paired-samples *t*-tests comparing prosaccade task-switch and task-repeat trials following Exercise and Rest interventions.

Results

Stress measures

Heart rate

Results produced a main effect of time, $F(3, 114) = 96.67$, $p < 0.001$, $\eta_p^2 = 0.72$. Figure 3 shows an increase in HR during the TSST-Speech and TSST-Math portions in relation to the pre-TSST [all $t(39) = -11.25$, and -9.28, $ps < 0.001$, $d_z = -1.78$ and -1.47] and that values for the 10-min post-TSST did not reliably differ from the pre-TSST assessment [$t(39) = 0.42$, $p = 0.67$, $d_z = 0.07$]. Notably, a null time by group interaction, $F(3, 114) = 1.32$, $p = 0.27$, $\eta_p^2 = 0.03$, indicated that HR values did not reliably differ between Exercise and Rest groups.

State trait anxiety inventory

Results produced a main effect of time, $F(2.2, 83.9) = 108.03$, $p < 0.001$, $\eta_p^2 = 0.74$. STAI scores increased from pre-TSST to post-TSST [$t(39) = 6.12$, $p = <0.001$, $d_z = 0.97$] (see Figure 4) however, a null time by group interaction, $F(2.2, 83.9) = 1.03$, $p = 0.37$, $\eta_p^2 = 0.03$, indicated that STAI scores did not reliably differ between Exercise and Rest groups.

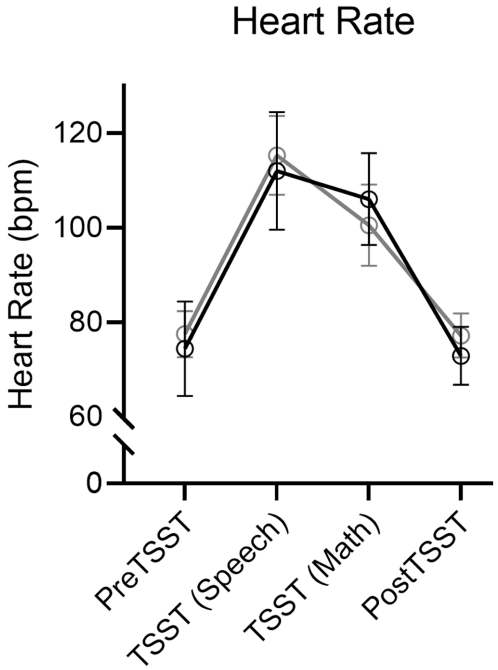


FIGURE 3
Mean heart rate (in beats/min: bpm) and associated 95% confidence intervals for Exercise and Rest groups at baseline, TSST-Speech, TSST-Math, and Post-TSST.

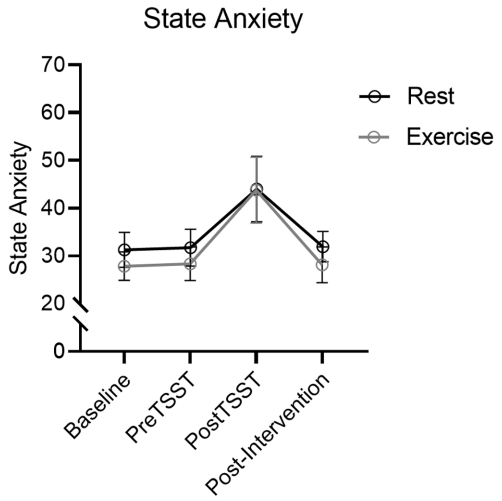


FIGURE 4
STAI mean values for Exercise and Rest groups at baseline, TSST-Speech, TSST-Math and Post-TSST. Error bars represent 95% within-participant confidence intervals.

Oculomotor measures

Reaction time

Results produced main effects of time, $F(2, 76) = 16.91$, $p < 0.001$, $\eta_p^2 = 0.31$, task, $F(1, 38) = 162.24$, $p < 0.001$, $\eta_p^2 = 0.81$, and task transition, $F(1, 38) = 8.48$, $p = 0.006$, $\eta_p^2 = 0.18$, as well as interactions involving task by task transition, $F(1, 38) = 12.54$, $p = 0.001$, $\eta_p^2 = 0.25$, and time by task by task transition, $F(2, 76) = 9.69$, $p < 0.001$, $\eta_p^2 = 0.20$. As expected, RTs for prosaccades (201 ms, SD = 36) were shorter than antisaccades (254 ms, SD = 43)—a finding consistent across task-switch and task-repeat trials. In decomposing the three-way interaction, we computed task by task transition ANOVAs separately for the Pre-TSST, Post-TSST, and Post-intervention oculomotor assessments. Figures 5, 6 demonstrate that pre-TSST and post-intervention assessments produced task by task transition interactions, all $F(1, 38) = 27.22$ and 7.70, $ps < 0.001$ and 0.009, all $\eta_p^2 = 0.42$ and 0.17, indicating that prosaccade task-switch RTs were longer than their task-repeat counterparts [all $t(39) = 4.76$ and 3.39 for pre-TSST and post-intervention, respectively, $ps < 0.001$ and = 0.02, $d_z = 0.75$ and 0.54], whereas antisaccade task-switch and task-repeat trials did not reliably differ [all $t(39) < -1.78$, $ps > 0.08$, $d_z < -0.28$]. In turn, the post-TSST assessment did not yield a task by task-transition interaction, $F(1, 38) = 0.49$, $p = 0.49$, all $\eta_p^2 = 0.01$. In other words, the unidirectional prosaccade switch-cost was observed pre-TSST and following Exercise and Rest interventions but not following TSST administration. Further, and given the nature of our research question, we note that results did not yield a main effect of group, $F(1, 38) = 0.05$, $p = 0.82$, $\eta_p^2 = 0.001$, nor any higher-order interaction involving group, all $Fs(2, 76) < 1.47$, $ps > 0.24$, all $\eta_p^2 < 0.04$. As well, we note that TOST statistics indicated that post-TSST switch-costs for the Exercise (12 ms, SD = 24) and Rest (12 ms, SD = 22) groups were within an equivalence boundary, $t(37.7) = 1.71$, $p = 0.048$ ($d_z = 0.54$).

Given the importance of evaluating the null findings, in addition to the frequentist statistics provided above, we conducted single-sample Bayesian statistics comparing prosaccade switch-costs (i.e., task-switch minus task-repeat trial) separately for each assessment interval (i.e., pre-TSST, post-TSS and post-intervention). Bayes factors for the alternative hypotheses (i.e., BF10) at pre-TSST, post-TSST and post-intervention were 803.36, 0.507, and 19.94, respectively. In line with van Doorn et al.'s (2021) nomenclature such findings evidence "very strong" and "strong" evidence for the alternative hypothesis, respectively, for the pre-TSST and post-intervention assessments. In turn, the value for the post-TSST provided less than 'anecdotal' evidence for the alternative hypothesis. Moreover, evaluation of the post-TSST Bayes factor for the null hypothesis (i.e., BF01 = 4.24) indicated that the null hypothesis was more likely than the alternative. In other words, our exercise manipulation did not modulate the unidirectional prosaccade switch-cost.

Saccade duration and gain variability

Results yielded main effects of task, all $Fs(1, 38) = 20.91$ and 84.36, $ps < 0.001$, all $\eta_p^2 = 0.36$ and 0.69. Antisaccade durations were longer (75 ms, SD = 14) and endpoints were more variable (0.22, SD = 0.08) than prosaccades (saccade duration: 68 ms, SD = 8; saccade gain: 0.12, SD = 0.08).

Discussion

We examined the effects of acute stress and a single bout of aerobic exercise on cognitive flexibility via the AABB pro- and antisaccade task-switching paradigm. In addressing our findings, commentary is first provided regarding the effects of acute stress on cognitive flexibility before discussing whether our exercise manipulation modified a stress-induced disruption to cognitive flexibility.

The TSST produces a reliable and transient stress response

HR was elevated from pre-TSST to TSST-Speech (38 bpm) and TSST-Math (27 bpm) and are values on par to the respective 31 bpm and 27 bpm HR increases in TSST-Speech and TSST-Math reported by Rosenbaum et al. (2018). HR values returned to pre-TSST values approximately 15 min after the TSST. In terms of STAI results, values increased from pre- to post-TSST and the magnitude of this increase is on par with previous work (e.g., Birkett, 2011). Hence, the HR and STAI data demonstrate the TSST elicited a reliable stress response and thus serves as a framework by which to assess stress-induced changes in cognitive flexibility.

An acute stressor boosts task- switching performance

Pre-TSST prosaccade task-switch RTs were longer than their task-repeat counterparts, whereas antisaccade task-switch and task-repeat RTs did not differ. In other words, a unidirectional prosaccade switch-cost was present pre-stress and is in line with prior work by our group (Weiler and Heath, 2012a, 2014a; Weiler et al., 2015; Heath et al., 2016; Tari and Heath, 2019; Tari et al., 2019; Heath and Shukla, 2020; Shukla et al., 2020; Shukla and Heath, 2021) and others (Manoach et al., 2007; Chan and DeSouza, 2013). When considering

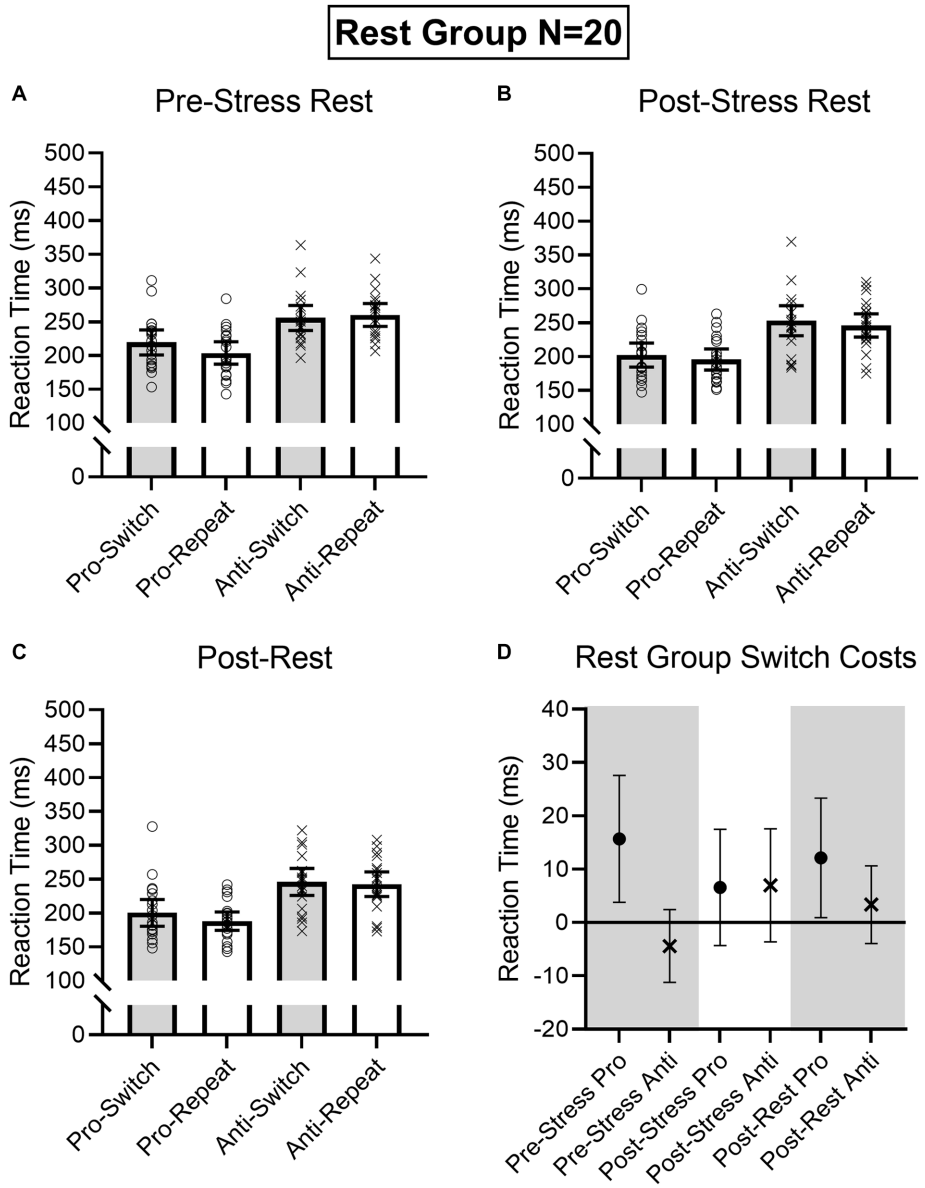


FIGURE 5
Rest group participant-specific pro- and antisaccade task-switch and task-repeat reaction times (i.e., open symbols) and associated group means at baseline **(A)**, post-TSST **(B)**, and post-Rest **(C)**. Error bars represent 95% within-participant confidence intervals. As well, the lower right panel **(D)** shows difference scores and 95% between-participant confidence intervals relating baseline reaction times to each subsequent oculomotor assessment. For this panel, the absence of overlap between the error bar and zero (i.e., the horizontal line) represents a reliable effect inclusive to a test of the null hypothesis.

this finding, it is important to note that some have argued that the RT difference between prosaccade task-switch and task-repeat trials may reflect a repetition; that is, the second of two consecutively performed prosaccades is associated with an RT reduction. Notably, however, a purpose-designed study by our group showed that prosaccade task-repetition trials yield RTs on par to prosaccades executed in a separate block of trials (Weiler and Heath, 2014a). In other words, results support the assertion that the RT difference between prosaccade task-switch and task-repeat trials reflect a switch-cost wherein the planning times for the former trial-type are delayed due to a task-set inertia from a previously completed antisaccade trial (Weiler and Heath, 2014a; Weiler et al., 2015; see also Tari et al., 2019).

Although a unidirectional prosaccade switch-cost was observed pre-stress, it was not present post-stress. The absence of a switch-cost post-stress cannot be attributed to an "implicit – or explicit – control strategy" (Heath and Shukla, 2020) designed to increase prosaccade task-switch trial planning times (i.e., speed-accuracy trade-off) given that saccade durations and endpoint accuracy for all trial-types did not vary across the different assessment intervals. Moreover, and as will be discussed in more detail below, the absence of a prosaccade switch-cost cannot be attributed to a practice-effect given that a switch-cost was observed at the Exercise and Rest group post-intervention assessments. Indeed, at the outset we were surprised by the absence of a post-TSST switch-cost given that a meta-analysis of the extant (Shields et al., 2016) concluded that cognitive flexibility is

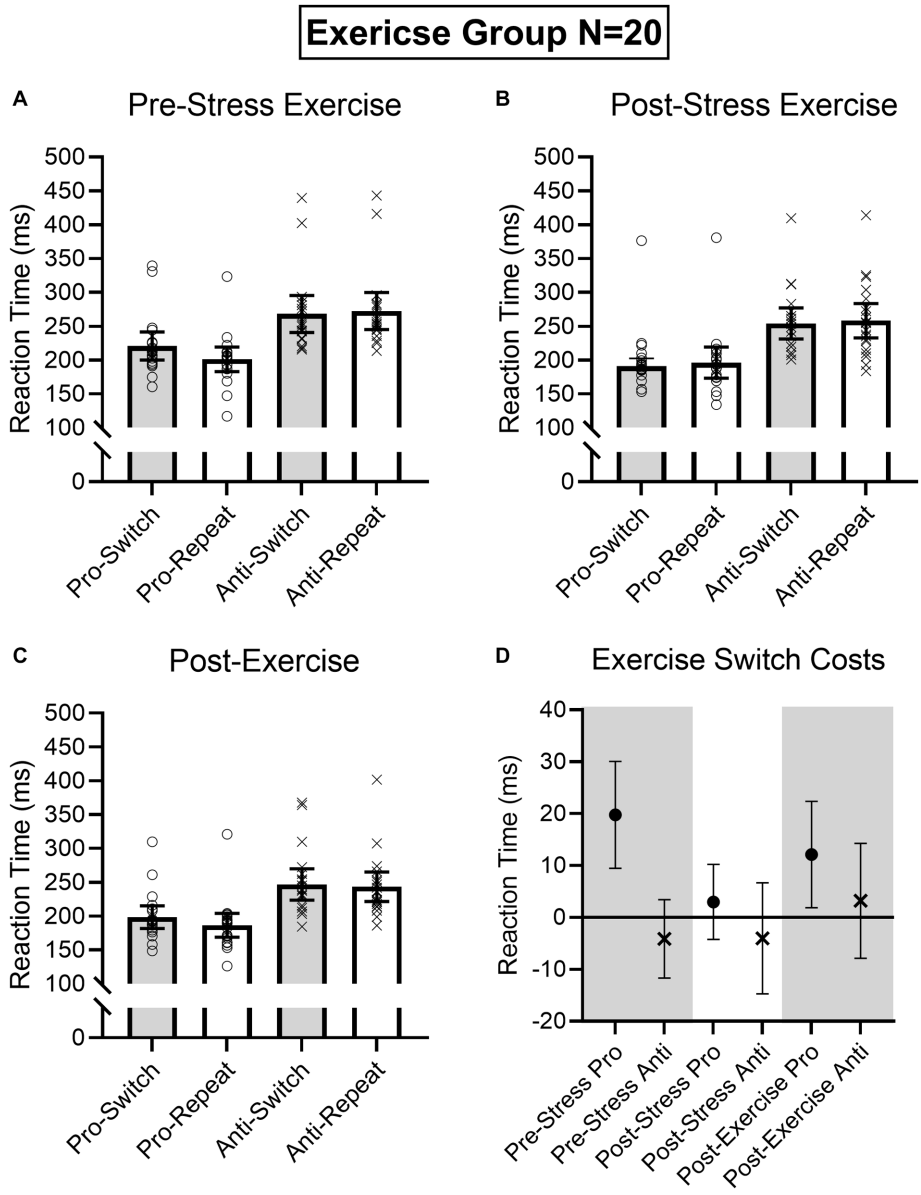


FIGURE 6
Exercise group participant-specific pro- and antisaccade task-switch and task-repeat reaction times (i.e., open symbols) and associated group means at baseline **(A)**, post-TSST **(B)**, and post-Exercise **(C)**. Error bars represent 95% within-participant confidence intervals. As well, the lower right panel **(D)** shows difference scores and 95% between-participant confidence intervals relating baseline reaction times to each subsequent oculomotor assessment. For this panel, the absence of overlap between the error bar and zero (i.e., the horizontal line) represents a reliable effect inclusive to a test of the null hypothesis.

adversely impacted by an acute stressor. However, it is important to acknowledge that prior work has reported findings similar to those observed here. For example, Gabrys et al. (2019) investigated the effects of the TSST on cognitive flexibility via the computer-based Berg Card Sorting Task (BCST). The BCST comprises of an electronic card deck wherein each card contains a different assortment of one of four colors, shapes, and quantities. Target cards are presented and the participants is required to sort response cards according to different sorting rules (which are unknown to the participant). The primary outcome for the BCST was perseverative errors (i.e., sorting cards in accordance with the previous sorting rule) and results showed that participants exposed to the TSST exhibited reduced perseverative errors compared to a control group. Similarly, Goldfarb et al. (2017) examined the effects of the cold pressor task on cognitive flexibility via the modified delayed match-to-sample task. In the first phase of the delayed match-to-sample task, participants learned two colored stimuli, whereas in the second phase participants were required to either remember the colored stimuli or to forget the stimuli and learn two novel stimuli (i.e., a task requiring cognitive flexibility). Participants exposed to the cold pressor task demonstrated improved cognitive flexibility which the authors asserted may be due to the fact that the ability to incorporate newly relevant information relies on the dorsal striatum, which has been documented to show enhanced functioning following acute stress (Packard, 2009; Delgadoy Palacios

et al., 2014). Hence, there is evidence indicating that a stressor may serve to focus or limit attentional resources and support disengagement from task-irrelevant information. In other words, an acute stressor may provide a level of task-engagement and attentional selectively supporting a transient benefit to task-switching.

Exercise does not modulate task-switching following stress

A single bout of aerobic exercise did not modulate post-stress task-switching performance. Instead, our post-stress assessment revealed an equivalent magnitude unidirectional prosaccade switch-cost for Exercise and Rest groups. This represents an unexpected result given a myriad of previous studies showing that a single bout of aerobic exercise provides a positive benefit to each core component of executive function (for reviews see, Lambourne and Tomporowski, 2010; Chang et al., 2012; Morris et al., 2020). Indeed, a previous investigation in our lab showed a 14 ms decrease ($d_z = 0.72$) to the magnitude of the unidirectional switch-cost when completed immediately and up to 47-min following a 20-min single bout of heavy intensity aerobic exercise (i.e., the same exercise protocol as used here; see Heath and Shukla, 2020; Shukla et al., 2020; Shukla and Heath, 2021). In contextualizing the present work with earlier work, the prior studies did not employ an acute stress manipulation. Thus, in the subsequent section we address why an acute stressor may "blunt" a postexercise benefit to executive function.

Neurobiological mechanisms

The interaction of several neurobiological systems likely influences the relationship between stress, exercise and cognitive flexibility (for reviews of stress on neural systems and the prefrontal cortex see, Arnsten, 2009; Joëls and Baram, 2009). It is well-documented that immediately after a stressor there is a rapid increase in the concentration of monoamines and neuropeptides (e.g., dopamine, serotonin, norepinephrine, and corticotropin-releasing hormone) in frontoparietal regions (Joëls and Baram, 2009), and that such a change may alter executive function. For example, increases in dopamine and norepinephrine alter neuronal firing patterns in the prefrontal cortex (Joëls et al., 2006; McMorris, 2016) and this state change in animal models has been shown to facilitate high-level movement planning and decision-making (Barbas, 2000) and in humans has been shown to elicit improved executive function via increased task-based attentional focus (McMorris, 2016). A second mechanism may reflect the release of cortisol from the HPA axis (Joëls and Baram, 2009). Cortisol exerts both fast-acting (i.e., non-genomic) and slow-acting (i.e., genomic) effects on neurobiological systems (Joëls et al., 2011) and is documented to affect the activity of local neural networks supporting executive function (Reul and Kloet, 1985). For example, Schwabe et al. (2013) administered to participants a mineralocorticoid antagonist (i.e., an agent that blocks the stimulating effects of cortisol) or a placebo prior to a stressor (i.e., cold pressor with element of social evaluation) or a non-stressor. After the stressor, participants performed the stop-signal task (i.e., task of inhibitory control) and results indicated that exposure to a stressor enhanced inhibitory control; however, this result was not present following when the stressor was preceded by a mineralocorticoid antagonism. Put another way, acute stress may modulate executive function, in part, via cortisol.

In addressing the absence of a postexercise benefit to task-switching, we note the time-dependent release of cortisol exerts fast (i.e., non-genomic) and slow (i.e., genomic) effects. As the final oculomotor assessment was administered approximately 55 min following completion of the stress-inducing event (i.e., the TSST), this likely coincided with the beginning of the "slow, genomic effects" of cortisol (Joëls and Baram, 2009). The genomic effects of cortisol have been documented to impede components of executive function (Shields et al., 2015) and may blunt the putative neuroprotective benefit that a single bout of exercise provides to task-switching.

Study limitations

First, cortisol was not measured and therefore precludes direct interpretation of how it may have influenced task-switching efficiency. Second, the present work employed only a 20-min bout of high-intensity aerobic exercise and evaluated cognitive flexibility via task-switching at a single postexercise timepoint (i.e., immediately after exercise). Thus, it is unclear whether different exercise durations across the continuum of exercise intensities would induce a similar result and it is unclear whether exercise may produce a delayed improvement in executive function. Third, our results are limited to healthy and recreationally active young adults. As the current work does not include a pre-registered replication, we would strongly encourage future works to consider a replication of this study in similarly aged, middle-aged, and old-aged healthy, cognitively intact individuals. Indeed, given that older adults show differing levels of reactivity to stress-inducing events (Uchino et al., 2005) and to exercise (Ludyga et al., 2016) it remains unknown whether our findings extend to broader populations. Last, including another measure of arousal such as pupillometry (see Ayala and Heath, 2021) would afford insight into the mechanisms underlying changes to cognitive flexibility as a result of acute stress.

Conclusion

The current findings provide insight into the complex dynamics between acute stress and cognitive flexibility. Namely, acute stress reduces the magnitude of a unidirectional prosaccade switch-cost and that a single bout of heavy intensity exercise did not differentially modulate these effects compared to rest.

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 Western University Research Ethics Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AM, BT, HP, and MH conceptualized the study, contributed to the methodology, and data analysis. AM, JA, and MS collected the data. AM wrote the initial manuscript draft. HP and MH reviewed and edited the manuscript, supervised the study. MH acquired grant funding. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by the Natural Sciences and Engineering Research Council Discovery Grant (MH).

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

Alderman, B. L., Arent, S. M., Landers, D. M., and Rogers, T. J. (2007). Aerobic exercise intensity and time of stressor administration influence cardiovascular responses to psychological stress. *Psychophysiology* 44, 759–766. doi: 10.1111/j.1469-8986.2007.00548.x

Allan, J. L., McMinn, D., and Daly, M. (2016). A bidirectional relationship between executive function and health behavior: evidence, implications, and future directions. *Front. Neurosci.* 64, 135–168. doi: 10.1146/annurev-psych-113011-143750

Arnsten, A. F. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nat. Rev. Neurosci.* 10, 410–422. doi: 10.1038/nrn2648

Ayala, N., and Heath, M. (2021). Pupillometry reveals the role of arousal in a postexercise benefit to executive function. *Brain Sci.* 11:1048. doi: 10.3390/brainsci11081048

Barbas, H. (2000). Connections underlying the synthesis of cognition, memory, and emotion in primate prefrontal cortices. *Brain Res. Bull.* 52, 319–330. doi: 10.1016/S0361-9230(99)00245-2

Birkett, M. A. (2011). The Trier social stress test protocol for inducing psychological stress. *J. Vis. Exp.* 56:3238. doi: 10.3791/3238

Brainard, D. H. (1997). The psychophysics toolbox. *Spat. Vis.* 10, 433–436. doi: 10.1163/156856897X00357

Brownley, K. A., Hinderliter, A. L., West, S. G., Girdler, S. S., Sherwood, A., and Light, K. C. (2003). Sympathoadrenergic mechanisms in reduced hemodynamic stress responses after exercise. *Med. Sci. Sports Exerc.* 35, 978–986. doi: 10.1249/01.MSS.0000069335.12756.1B

Chan, J. L., and DeSouza, J. F. (2013). The effects of attentional load on saccadic task switching. *Exp. Brain Res.* 227, 301–309. doi: 10.1007/s00221-013-3452-1

Chang, Y. K., Labban, J. D., Gapin, J. I., and Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Res.* 1453, 87–101. doi: 10.1123/japa.20.4.497

Chrousos, G. P., and Gold, P. W. (1992). The concepts of stress and stress system disorders: overview of physical and behavioral homeostasis. *JAMA* 267, 1244–1252. doi: 10.1001/jama.1992.03480090092034

Cornelissen, F. W., Peters, E. M., and Palmer, J. (2002). The Eyelink toolbox: eye tracking with MATLAB and the psychophysics toolbox. *Behav. Res. Methods Instrum. Comput.* 34, 613–617. doi: 10.3758/bf03195489

Delgadoy Palacios, R., Verhoye, M., Hennigsen, K., Wiborg, O., and Van der Linden, A. (2014). Diffusion kurtosis imaging and high-resolution MRI demonstrate structural aberrations of caudate putamen and amygdala after chronic mild stress. *PLoS One* 9:e95077. doi: 10.1371/journal.pone.0095077

DeSimone, J. C., Weiler, J., Aber, G. S., and Heath, M. (2014). The unidirectional prosaccade switch-cost: correct and error antisaccades differentially influence the planning times for subsequent prosaccades. *Vis. Res.* 96, 17–24. doi: 10.1016/j.visres.2013.12.005

Diamond, A. (2013). Executive functions. *Annu. Rev. Psychol.* 64, 135–168. doi: 10.1146/annurev-psych-113011-143750

Dickerson, S. S., and Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychol. Bull.* 130, 355–391. doi: 10.1037/0033-2909.130.3.355

Gabrys, R. L., Howell, J. W., Cebulski, S. F., Anisman, H., and Matheson, K. (2019). Acute stressor effects on cognitive flexibility: mediating role of stressor appraisals and cortisol. *Stress* 22, 182–189. doi: 10.1080/10253890.2018.1494152

Gillen, C., and Heath, M. (2014). Target frequency influences antisaccade endpoint bias: evidence for perceptual averaging. *Vis. Res.* 105, 151–158. doi: 10.1016/j.visres.2014.10.010

Godin, G. (2011). The Godin-Shephard leisure-time physical activity questionnaire. *Health Fit J Canada* 4, 18–22. doi: 10.14288/hfjc.v4i1.82

Goldfarb, E. V., Frobose, M. I., Cools, R., and Phelps, E. A. (2017). Stress and cognitive flexibility: cortisol increases are associated with enhanced updating but impaired switching. *J. Cogn. Neurosci.* 29, 14–24. doi: 10.1162/jocn_a_01029

Hallett, P. E. (1978). Primary and secondary saccades to goals defined by instructions. *Vis. Res.* 18, 1279–1296. doi: 10.1016/0042-6989(78)90218-3

Heath, M., Gillen, C., and Samani, A. (2016). Alternating between pro-and antisaccades: switch-costs manifest via decoupling the spatial relations between stimulus and response. *Exp. Brain Res.* 234, 853–865. doi: 10.1007/s00221-015-4510-7

Heath, M., Hassall, C. D., MacLean, S., and Krigolson, O. E. (2015). Event-related brain potentials during the visuomotor mental rotation task: the contingent negative variation scales to angle of rotation. *Neuroscience* 311, 153–165. doi: 10.1016/j.neuroscience.2015.10.018

Heath, M., and Shukla, D. (2020). A single bout of aerobic exercise provides an immediate "boost" to cognitive flexibility. *Front. Psychol.* 11:1106. doi: 10.3389/fpsyg.2020.01106

Hellhammer, J., and Schubert, M. (2012). The physiological response to Trier social stress test relates to subjective measures of stress during but not before or after the test. *Psychoneuroendocrinology* 37, 119–124. doi: 10.1016/j.psyneuen.2011.05.012

Joëls, M., and Baram, T. Z. (2009). The neuro-symphony of stress. *Nat. Rev. Neurosci.* 10, 459–466. doi: 10.1038/nrn2632

Joëls, M., Fernandez, G., and Roozendaal, B. (2011). Stress and emotional memory: a matter of timing. *Trends Cogn. Sci.* 15, 280–288. doi: 10.1016/j.tics.2011.04.004

Joëls, M., Pu, Z., Wiegert, O., Oitzl, M. S., and Krugers, H. J. (2006). Learning under stress: how does it work? *Trends Cogn. Sci.* 10, 152–158. doi: 10.1016/j.tics.2006.02.002

Kirschbaum, C., Pirke, K. M., and Hellhammer, D. H. (1993). The 'Trier social stress test'–a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology* 28, 76–81. doi: 10.1159/000119004

Kleiner, M., Brainard, D., and Pelli, D. (2007). What's new in Psychtoolbox-3? *Perception* 36, 1–16. doi: 10.1177/03010066070360S101

Knaepen, K., Goekint, M., Heyman, E. M., and Meeusen, R. (2010). Neuroplasticity - exercise-induced response of peripheral brain-derived neurotrophic factor: a systematic review of experimental studies in human subjects. *Sports Med.* 40, 765–801. doi: 10.2165/11534530-000000000-00000

Lakens, D. (2017). Equivalence tests: a practical primer for t tests, correlations, and meta-analyses. *Soc. Psychol. Personal. Sci.* 8, 355–362. doi: 10.1177/1948550617697177

LaManca, J. J., Peckerman, A., Sisto, S. A., DeLuca, J., Cook, S., and Natelson, B. H. (2001). Cardiovascular responses of women with chronic fatigue syndrome to stressful cognitive testing before and after strenuous exercise. *Psychosom. Med.* 63, 756–764. doi: 10.1097/00006842-200109000-00009

Lambourne, K., and Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: a meta-regression analysis. *Brain Res.* 1341, 12–24. doi: 10.1016/j.brainres.2010.03.091

Lazarus, R. S., and Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer.

Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E., and Pühse, U. (2016). Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: a meta-analysis. *Psychophysiology* 53, 1611–1626. doi: 10.1111/psyp.12736

Manoach, D. S., Thakkar, K. N., Cain, M. S., Polli, F. E., Edelman, J. A., Fischl, B., et al. (2007). Neural activity is modulated by trial history: a functional magnetic resonance

imaging study of the effects of a previous antisaccade. *J. Neurosci.* 27, 1791–1798. doi: 10.1523/JNEUROSCI.3662-06.2007

Mather, M., and Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspect. Psychol. Sci.* 6, 114–133. doi: 10.1177/1745691611400234

McMorris, T. (2016). Developing the catecholamines hypothesis for the acute exercise-cognition interaction in humans: lessons from animal studies. *Physiol. Behav.* 165, 291–299. doi: 10.1016/j.physbeh.2016.08.011

Moore, C. I., and Cao, R. (2008). The hemo-neural hypothesis: on the role of blood flow in information processing. *J. Neurophysiol.* 99, 2035–2047. doi: 10.1152/jn.01366.2006

Morris, T. P., Fried, P. J., Macone, J., Stillman, A., Gomes-Osman, J., Costa-Miserachs, D., et al. (2020). Light aerobic exercise modulates executive function and cortical excitability. *Eur. J. Neurosci.* 51, 1723–1734. doi: 10.1111/ejn.14593

Munoz, D. P., and Everling, S. (2004). Look away: the anti-saccade task and the voluntary control of eye movement. *Nat. Rev. Neurosci.* 5, 218–228. doi: 10.1038/nrn1345

Packard, M. G. (2009). Anxiety, cognition, and habit: a multiple memory systems perspective. *Brain Res.* 1293, 121–128. doi: 10.1016/j.brainres.2009.03.029

Petrella, A. F., Belfry, G., and Heath, M. (2019). Older adults elicit a single-bout post-exercise executive benefit across a continuum of aerobically supported metabolic intensities. *Brain Res.* 1712, 197–206. doi: 10.1016/j.brainres.2019.02.009

Plessow, F., Fischer, R., Kirschbaum, C., and Goschke, T. (2011). Inflexibly focused under stress: acute psychosocial stress increases shielding of action goals at the expense of reduced cognitive flexibility with increasing time lag to the stressor. *J. Cogn. Neurosci.* 23, 3218–3227. doi: 10.1162/jocn_a_00024

Plieger, T., and Reuter, M. (2020). Stress and executive functioning: a review considering moderating factors. *Neurobiol. Learn. Mem.* 173:107254. doi: 10.1016/j.nlm.2020.107254

Reul, J. M. H. M., and Kloet, E. D. (1985). Two receptor systems for corticosterone in rat brain: microdistribution and differential occupation. *Endocrinology* 117, 2505–2511. doi: 10.1210/endo-117-6-2505

Rosenbaum, D., Hilsendegen, P., Thomas, M., Haeussinger, F. B., Metzger, F. G., Nuerk, H. C., et al. (2018). Cortical hemodynamic changes during the trier social stress test: an fNIRS study. *NeuroImage* 171, 107–115. doi: 10.1016/j.neuroimage.2017.12.061

Sandi, C. (2013). Stress and cognition. Wiley interdisciplinary reviews. *Cognitive science* 4, 245–2619. doi: 10.1002/wcs.1222

Schmitt, A., Upadhyay, N., Martin, J. A., Rojas, S., Strüder, H. K., and Boecker, H. (2019). Modulation of distinct intrinsic resting state brain networks by acute exercise bouts of differing intensity. *Brain Plast.* 5, 39–55. doi: 10.3233/BPL-190081

Schwabe, L., Höffken, O., Tegenthoff, M., and Wolf, O. T. (2013). Stress-induced enhancement of response inhibition depends on mineralocorticoid receptor activation. *Psychoneuroendocrinology* 38, 2319–2326. doi: 10.1016/j.psyneuen.2013.05.001

Shansky, R. M., and Lipps, J. (2013). Stress-induced cognitive dysfunction: hormone-neurotransmitter interactions in the prefrontal cortex. *Front. Hum. Neurosci.* 7:123. doi: 10.3389/fnhum.2013.00123

Shields, G. S., Bonner, J. C., and Moons, W. G. (2015). Does cortisol influence core executive functions? A meta-analysis of acute cortisol administration effects on working memory, inhibition, and set-shifting. *Psychoneuroendocrinology* 58, 91–103. doi: 10.1016/j.psyneuen.2015.04.017

Shields, G. S., Sazma, M. A., and Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: a meta-analysis and comparison with cortisol. *Neurosci. Biobehav. Rev.* 68, 651–668. doi: 10.1016/j.neubiorev.2016.06.038

Shukla, D., Al-Shamil, Z., Belfry, G., and Heath, M. (2020). A single bout of moderate intensity exercise improves cognitive fexibility: evidence from task-switching. *Exp. Brain Res.* 238, 2333–2346. doi: 10.1007/s00221-020-05885-w

Shukla, D., and Heath, M. (2021). A single bout of exercise provides a persistent benefit to cognitive flexibility. *Res. Q. Exerc. Sport* 93, 516–527. doi: 10.1080/02701367.2021.1873902

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., and Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Tari, B., and Heath, M. (2019). Pro-and antisaccade task-switching: response suppression—and not vector inversion—contributes to a task-set inertia. *Exp. Brain Res.* 237, 3475–3484. doi: 10.1007/s00221-019-05686-w

Tari, B., Fadel, M. A., and Heath, M. (2019). Response suppression produces a switch-cost for spatially compatible saccades. *Exp. Brain. Res.* 237, 1195–1203. doi: 10.1007/s00221-019-05497-z

Tari, B., Vanhie, J. J., Belfry, G. R., Shoemaker, J. K., and Heath, M. (2020). Increased cerebral blood flow supports a single-bout postexercise benefit to executive function: evidence from hypercapnia. *J. Neurophysiol.* 124, 930–940. doi: 10.3758/s13428-021-01735-x

Uchino, B. N., Holt-Lunstad, J., Bloor, L. E., and Campo, R. A. (2005). Aging and cardiovascular reactivity to stress: longitudinal evidence for changes in stress reactivity. *Psychol. Aging* 20, 134–143. doi: 10.1037/0882-7974.20.1.134

van Doorn, J., van den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., et al. (2021). The JASP guidelines for conducting and reporting a Bayesian analysis. Psychon. *J. Neurosci.* 28, 813–826. doi: 10.3758/s13423-020-01798-5

Weiler, J., Hassall, C. D., Krigolson, O. E., and Heath, M. (2015). The unidirectional prosaccade switch-cost: electroencephalographic evidence of task-set inertia in oculomotor control. *Behav. Brain Res.* 278, 323–329. doi: 10.1016/j.bbr.2014.10.012

Weiler, J., and Heath, M. (2012a). The prior-antisaccade effect influences the planning and online control of prosaccades. *Exp. Brain Res.* 216, 545–552. doi: 10.1007/s00221-011-2958-7

Weiler, J., and Heath, M. (2012b). Task-switching in oculomotor control: unidirectional switch-cost when alternating between pro-and antisaccades. *Neurosci. Lett.* 530, 150–154. doi: 10.1016/j.neulet.2012.10.007

Weiler, J., and Heath, M. (2014a). Oculomotor task switching: alternating from a nonstandard to a standard response yields the unidirectional prosaccade switch-cost. *J. Neurophysiol.* 112, 2176–2184. doi: 10.1152/jn.00352.2014

Weiler, J., and Heath, M. (2014b). Repetitive antisaccade execution does not increase the unidirectional prosaccade switch-cost. *Acta Psychol.* 146, 67–72. doi: 10.1016/j.actpsy.2013.12.005

Wenban-Smith, M. G., and Findlay, J. M. (1991). Express saccades: is there a separate population in humans? *Exp. Brain Res.* 87, 218–222. doi: 10.1007/BF00228523

Williams, P. G., Tinajero, R., and Suchy, Y. (2017). Executive functioning and health. *Oxford Handbooks Online*, 1–53. doi: 10.1093/oxfordhb/9780199935291.013.75

Wunsch, K., Wurst, R., von Dawans, B., Strahler, J., Kasten, N., and Fuchs, R. (2019). Habitual and acute exercise effects on salivary biomarkers in response to psychosocial stress. *Psychoneuroendocrinology* 106, 216–225. doi: 10.1016/j.psyneuen.2019.03.015

Zouhal, H., Jacob, C., Delamarche, P., and Gratas-Delamarche, A. (2008). Catecholamines and the effects of exercise, training and gender. *Sports Med.* 38, 401–423. doi: 10.2165/00007256-200838050-00004

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 31 July 2023
DOI 10.3389/fpsyg.2023.1182575

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Braulio Henrique Magnani Branco,
University Center of Maringá (UniCesumar), Brazil
Simone Battaglia,
University of Bologna, Italy

*CORRESPONDENCE
Özgür Eken
✉ ozgureken86@gmail.com
Halil İbrahim Ceylan
✉ halil.ibrahimceylan60@gmail.com

RECEIVED 09 March 2023
ACCEPTED 11 July 2023
PUBLISHED 31 July 2023

CITATION
Bayraktar I, Cepicka L, Barasinska M, Kazan HH, Zorba E, Ergun MA, Eken Ö, Ceylan Hİ, Bulgay C and Gabrys T (2023) Athletic performance, sports experience, and exercise addiction: an association study on *ANKK1* gene polymorphism rs1800497.
Front. Psychol. 14:1182575.
doi: 10.3389/fpsyg.2023.1182575

Athletic performance, sports experience, and exercise addiction: an association study on *ANKK1* gene polymorphism rs1800497

Isık Bayraktar[1], Ladislav Cepicka[2], Magdalena Barasinska[3], Hasan Huseyin Kazan[4], Erdal Zorba[5], Mehmet Ali Ergun[6], Özgür Eken[7]*, Halil İbrahim Ceylan[8]*, Celal Bulgay[9] and Tomasz Gabrys[2]

[1]Faculty of Sports Sciences, Alanya Alaaddin Keykubat University, Alanya, Türkiye, [2]Department of Physical Education and Sport, Faculty of Education, University of West Bohemia, Pilsen, Czechia, [3]Department of Health Sciences, Jan Dlugosz University, Czestochowa, Poland, [4]Faculty of Medicine, Near East University, Mersin, Türkiye, [5]Faculty of Sports Sciences, Gazi University, Ankara, Türkiye, [6]Faculty of Medicine, Gazi University, Ankara, Türkiye, [7]Department of Physical Education and Sport Teaching, Faculty of Sports Sciences, Inonu University, Malatya, Türkiye, [8]Department of Physical Education of Sports Teaching, Faculty of Kazim Karabekir Education, Atatürk University, Erzurum, Türkiye, [9]Faculty of Sports Sciences, Bingol University, Bingol, Türkiye

Introduction: Exercise addiction is a phenomenon being able to affecting the athletic performance. The gene, *ANKK1* and the polymorphism NM_178510.2:c.2137G > A (rs1800497) has been linked to the exercise addiction. However, further studies on diverse populations and sport branches are needed to totally explore the possible association of this polymorphism with the athletic performance. Thus, the present study aims to decipher any possible relations of the rs1800497 polymorphism with the athletic performance/personal best (PB) and sport experience of elite athletes.

Methods: Sixty volunteer elite athletes (31 sprint/power and 29 endurance) and 20 control/sedentary participated in the study. The polymorphism was genotyped using whole exome sequencing approach and PB were determined according to the International Association of Athletics Federations (IAAF) score.

Results: Our results underlined that there were not any significance differences for both allele and genotype frequencies between the groups in terms of athletic performance, although the frequency of allele G was higher ($p > 0.05$). Nevertheless, sport experience significantly associated with the rs1800496 polymorphism ($p < 0.05$).

Discussion: In conclusion, genotype G/G could be inferred to be linked to the higher sport experience and athletic performance. Still, further studies with higher number of participants are needed to conclude the association of this polymorphism with athletic parameters.

KEYWORDS

***ANKK1*, athletics, athletic performance, exercise addiction, sport experience, rs1800497 polymorphism**

1. Introduction

Since the popularity of sports increases on the whole world, the importance of athletic performance and the factors affecting the performance also advance (Bulgay et al., 2023). Athletic success has been shown to be linked to factors such as society, environment, psychology, and training patterns. Recently, individual characteristics including anaerobic and anaerobic metabolisms have been underlined to be linked to the genetic background. Thus, the current research on athletic performance has focused on the genetic variants significantly contributing to individual performance (Varillas-Delgado et al., 2022). In the late 1990s and early 2000s, research efforts were directed towards identifying specific single nucleotide polymorphisms (SNPs) associated with predisposition to certain sports and exercise-related phenotypes (Semenova et al., 2023). This field of study is commonly referred to as exercise or sports genomics. Several genes have extensively been studied in relation to athletic performance and exercise adaptation (Ahmetov and Fedotovskaya, 2015; Varillas-Delgado et al., 2022). The genes *ACE, ACTN3,* and *PPARGC1A* have been among the most commonly investigated ones in this context. Even though multifactorial approaches are required, it is critical to illuminate the associations of the genes and the variations on these genes with the athletic parameters (Cerit, 2018; Hall et al., 2023; Yang et al., 2023).

Recent studies have suggested that athletic performance or individual characteristics were affected by exercise addiction as well (Cetin et al., 2021; Szabo and Ábel, 2022). The definition of addiction has in the past been limited to the use of drugs and alcohol. Today, however, many behaviors such as exercise, sex, gambling, playing video games and using the internet are considered as potential addictive behaviors. Indeed, when beneficial behaviors become obsessive and excessive, it can lead to various negative outcomes (Szabo and Griffiths, 2007; De La Vega et al., 2016). Moreover, exercise addiction refers to a compulsive engagement in physical activity that is accompanied by a loss of control, withdrawal symptoms, and negative consequences, similar to other addictions (Cicioğlu et al., 2019; Liu et al., 2019). On the other hand, athletic performance refers to an individual's ability to excel in a specific sport or exercise (Juwono et al., 2022). There can be a complex relationship between exercise addiction and athletic performance. While exercise addiction can lead to excessive training, which may improve athletic performance in short periods, the negative consequences of exercise addiction can ultimately lead to poorer athletic performance. Moreover, exercise addiction can result in injuries, burnout and fatigue, which can impair an individual's ability to train and perform optimally (Godoy-Izquierdo et al., 2021). Additionally, exercise addiction can negatively impact an individual's mental health, leading to decreased motivation and focus, which can also hinder athletic performance. Therefore, while exercise addiction and athletic performance can be related, it is essential to maintain a balance between training, and recovery and to seek professional help if addiction symptoms are present (Murakami et al., 2017; Michałowska-Sawczyn et al., 2021; Antrobus et al., 2022a,b).

Exercise addiction may stand out among the factors that have a negative impact on athlete performance. In the relevant literature, it has been observed that different results related to exercise addiction have been found. For example, in a systematic review, the athletes from endurance sports seem associated with the highest risk for exercise addiction (Di Lodovico et al., 2019). Nonetheless, exercise addiction can occur in any type of physical activity or sport. In a study conducted with a sample of Turkish track and field athletes, it was related that the athletes with high levels of exercise addiction displayed poor performance in all branches (Cetin et al., 2021). Another study indicated that loneliness and anxiety may lead to withdrawal and uncontrolled behavior that in turn leads to increased amount of exercise in amateur runners (Lukács et al., 2019).

The genes whose products are related to the dopaminergic system are linked to the addiction profile (Suchanecka et al., 2020). Neurotransmitter substances such as serotonin, and dopamine and the genes that metabolize them are fundamental in determining the effect of psychological factors on athletes. Those substances play a crucial role in the mental health, and addiction and thus physical activity (Shimura et al., 2023; Tanaka et al., 2023) by influencing the grey matter volume or white matter integrity in specific brain regions acting in the reward processing and decision making (Cui et al., 2022; Rajkumar, 2023). Hence, focusing on the genes involved in the dopaminergic system could be informative in the exercise addiction in the frame of the sport genetics.

The gene encoding Ankyrin repeat and kinase domain containing 1 (*ANKK1*) is amongst the genes linked to the addiction. *ANKK1* c.2137G > A (rs1800497) polymorphism was further shown to associate with the addiction specifically. The allele A has previously been associated to the altered cognitive behavioral capacity by changes in D2 receptor expression (Thompson et al., 1997; Lachowicz et al., 2020; Antrobus et al., 2022a,b). Moreover, the genotypes A/A and G/A have been linked to higher risk of certain neuropsychiatric disorders including schizophrenia and emotional eating habits, and obesity and alcohol, nicotine, and drug addiction (Aliasghari et al., 2021; Habibzadeh et al., 2021; Switala and Leonska-Duniec, 2021; Switala et al., 2022). Nevertheless, further studies are needed to comprehensively understand the relationship between this variant and the athletic parameters.

The aim of the present study is to compare the genotype and the allele frequencies of *ANKK1* rs1800497 polymorphism between elite sprinter/power and long-distance athletes in the presence of sedentary controls. The secondary aim of this study is to investigate possible associations between the rs1800497 polymorphism with the athletic performances and sports experience. To our knowledge, this is the first study investigating the association of rs1800497 polymorphism in elite track and field athletes. We hypothesized that significant differences in genotype and allele frequencies of the *ANKK1* rs1800497 polymorphism are expected between sprint/power and endurance athletes, and the G/G genotype is expected to have both better athletic performance and higher sports experience.

2. Materials and methods

2.1. Participants

The study was conducted in accordance with the Declaration of Helsinki and approved by the Gazi University Non-Interventional Clinical Research Ethics Committee (decision dated April 05, 2021, number 09). A total of sixty elite athletes (mean age = 25.07, SD = 4.80; years mean height = 174.97, SD = 7.89; cm mean body weight = 72.50, SD = 22.40; mean sports experience = 9.40, SD = 4.80; mean personal best = 1005.63, SD = 94.55) whom were affiliated with the Turkish Athletics Federation (TAF) and licensed in different clubs participated in this study. The inclusion criteria of the athletes were determined as

that they had achieved a national ranking within the top ten in their respective sports disciplines and participated in International competitions such as the Olympic Games, European Championships, Universidad, Mediterranean Games, and Balkan Championship. The athletes were classified into two groups based on the characteristics of their events, namely sprint/power and endurance athletes. This classification was determined by considering parameters including distance, duration, and energy requirements of their branches. The sprint/power athlete group ($n = 31$) included athletes participating in events with primarily anaerobic energy demands such as 100–400-meter runners ($n = 9$), jumpers ($n = 3$), and throwers ($n = 19$). The endurance athlete group ($n = 29$) included athletes competing in long-distance events predominantly depending on aerobic energy production such as 3,000-meter ($n = 12$), 5,000-meter ($n = 5$), 10,000-meter ($n = 4$), and marathon ($n = 8$) runners. Additionally, a control group consisting of 20 individuals (mean age = 23.51, SD = 7.13 years) was included in the study. The inclusion criteria of the control group were settled as that they were without any known diseases in their families and any competitive sports experiences. The exclusion criteria were the withdrawal of the participants from the study and family connection between the participants.

2.1.1. Sample collection

Before the measurements, participants were informed about the procedures and a voluntary consent form in the presence of a demographic information was obtained. For the molecular studies, 4 mL peripheral blood was obtained from each individual in the hospitals where the participants underwent routine check-ups during the preparation season period. The date of blood sample collection and corresponding code numbers were recorded. The blood samples were promptly transported in a cold chain to the Medical Genetics Laboratory at Gazi University, where the analyses were conducted.

2.2. Athletic performance

In order to assess the performance levels of the athletes in both groups, the International Association of Athletics Federations (IAAF; new name World Athletics) score scale was employed in both groups (sprint/power and endurance athletes), depending on their PBs. The IAAF scales are useful for the determination of performances of athletes from diverse athletics events and genders. For instance, the IAAF scale score of a male athlete who runs 100 m in 10.05 s is 1189, while that of a marathon runner who completes the race in 2 h 20 min 11 s is 997. Thus, the performance scale of the marathon runner is less than that of the 100 m runner (Spiriev, 2017).

2.3. Whole exome sequencing

The participants' peripheral blood was processed using the DNeasy Blood and Tissue Kit (Qiagen, United States) to isolate total DNA, following the manufacturer's instructions. The quality of the isolated DNA was assessed using a 1% agarose gel, and the concentration was measured using a NanoDrop (NanoDrop 1,000 Spectrophotometer V3.8; Thermo Scientific, United States). The Twist Human Comprehensive Exome Panel (Twist Biosciences, United States) was used for library preparation prior to WES, following the supplier's instructions. Enzymatic DNA fragmentation was performed, and Twist Hybridization probes, as well as Dynabeads MyOne Streptavidin T1 (Invitrogen, United States), were used for hybridization. Following library enrichment and determination of library sizes, the samples were loaded onto flow cells and run on the Illumina NextSeq500 (Illumina Inc., United States). The minimum average read depth targeted was 200X. Raw data were processed using the HaplotypeCaller program from the Genome Analysis Toolkit (GATK) to obtain Binary Alignment Map (BAM) files, which were subsequently used to generate an output Variant Call Format (VCF) file using the GRCh38/hg38 reference genome. Finally, ANNOVAR (Wang, 2010; Van der Auwera et al., 2013) was used to annotate the variants.

2.4. Statistical analyses

Data analyses were conducted using Statistical Package for Social Sciences (SPSS) for Windows 25.0. Descriptive statistics, including numerical, percentage, mean, and standard deviation (SD) measures, were used to assess the data. The degree of heterogeneity between the results was evaluated using the Skewness and Kurtosis test (Kline, 2011). Genotype and allele frequencies for the polymorphism were calculated, and Hardy–Weinberg equilibrium (HWE) was assessed using either the chi-square ($\chi 2$) or Fisher's exact test. The association between *ANKK1* rs1800497 polymorphism and sports experience was examined using one-way analysis of covariance (ANCOVA), with age as a covariate. Cohen's d effect size (ES) with 95% confidence interval was calculated to define the magnitude of pairwise comparisons for pre-and post-test. The ES magnitude was defined as follows: <0.2 = trivial, 0.2 to 0.6 = small effect, >0.6 to 1.2 = moderate effect, >1.2 to 2.0 = large effect, and > 2.0 = very large (Hopkins et al., 2009). Data were significant when $p < 0.05$.

3. Results

The present study aims to assess any possible associations between rs1800497 polymorphism and the athletic parameters in Turkish elite sprint/power and endurance athletes in the presence of control group. According to the results, the genotype frequencies of rs1800497 polymorphism was in concordance with the Hardy–Weinberg equilibrium in both athletes and control individuals. Although the number of the allele G was higher compared to the allele A within each group, there were not any significant differences in genotype ($p = 0.461$) and allele distribution ($p = 0.540$) between the groups (Table 1). Additionally, no significant differences for the association of the rs1800497 polymorphism with competitive performance were detected [$t = 1.547$, $p = 0.127$, standardized effect size: 0.42, moderate effect (Table 2; Figure 1A)]. Critically, the association of the rs1800496 polymorphism with sports experience was statistically significant [$t = 2.555$, $p = 0.013$, standardized effect size: 0.72, moderate effect (Table 3; Figure 1B)].

4. Discussion

In the present study, we investigated the genotype and allele frequencies of the *ANKK1* rs1800497 polymorphism between the elite

TABLE 1 Genotype and allele frequencies of *ANKK1* rs1800497 polymorphism in Turkish elite athletes and controls.

	Genotype			*p*-Value	Allele		*p*-Value
	G/G	G/A	A/A	0.461	G	A	0.540
Sprint/Power	18 (58.1%)	13 (41.9%)	–		49 (79.0%)	13 (21.0%)	
Endurance	21 (72.4%)	8 (27.6%)	–		50 (86.2%)	8 (13.8%)	
Controls	14 (70.0%)	6 (30.0%)	–		34 (85.0%)	6 (15.0%)	

TABLE 2 Association of the *ANKK1* rs1800497 polymorphism with the athletic performances.

Genotype	*n*	*M*	SD	*t*	*p*	Cohen's d
G/G	39	1019.33	94.46	1.547	0.127	0.42
G/A	21	980.19	91.49			
A/A	–	–	–			

sprint/power, endurance athletes and matched controls and possible association of this polymorphism with the athletic performance, and sports experience. To our best knowledge, the current study is the first investigation to determine whether the rs1800497 polymorphism influences athletic performance and sports experience of elite athletes in Turkish population in a perspective of the exercise addiction-associated gene, *ANKK1*.

According to our results, that there were not any statistically significant differences in allele and genotype frequencies of the *ANKK1* rs1800497 polymorphism between sprint/power athletes, endurance athletes, and the control group. Despite insignificance, wild-type (G/G) genotype distribution was higher compared to other ones within each group (Table 1). Michałowska-Sawczyn et al. (2021) also obtained similar findings, showing that the number of athletes with the G/G genotype was higher, although there were no significant differences observed in their study that included 258 sportsmen and 284 control individuals. Similarly, in another study involving elite rugby players, it was reported that the prevalence of the G/G genotype was higher (Antrobus et al., 2022a,b). The hypothesis of the present study was not accepted; nonetheless, it can be said that the obtained findings are similar to the literature. It could be due to several reasons which would be low sample size, insufficient methodological issues, conflicting evidences, unforeseen factors and incomplete understanding of the multi-genetic background. Our research group is currently conducting ongoing research to address and resolve these issues for future studies.

In terms of the athletic performance, it was observed that athletes' performances did not reveal any significant correlations with the polymorphism although it was found that the athletes with the G/G genotype tended to have higher PBs than those with the G/A genotype (Table 2). In recent years, genetic factors have begun to emerge as key research topics in addition to environmental factors in terms of influencing the athletic performance. Studies in the field of sport genetics have indicated that while individuals could reach a certain level of optimal performance through accurate and systematic application of training, the level of performance development may be limited by their genetic capacity (Yıldırım et al., 2022). Moreover, specific polymorphisms in the genes encoding such as Alpha-actinin-3 (*ACTN3*), Angiotensin I-converting enzyme (*ACE*), Adenosine monophosphate deaminase-1 (*AMPD1*), Bradykinin receptor B2 (*BDKRB2*), Endothelial nitric oxide synthase 3 (*NOS3*), Alpha-2A adrenergic receptors (*ADRA2A, ADRA2B* and *ADRA2C*), Peroxisome proliferator-activated receptors (*PPAR*), Peroxisome proliferator-activated receptor gamma coactivator 1-alpha (*PPARGC1A*), Vitamin D receptor (*VDR*), Erythropoietin (*EPO*), and C-reactive protein (*CRP*) have been emphasized to be associated with athlete specialization and performance. The involvement of the proteins encoded by the mentioned genes in the muscular system, cellular and systemic metabolism and oxygenation makes any variations that may occur on these genes and subsequent changes in the proteins valuable even if it is not directly associated with diseases (Varillas-Delgado et al., 2022). In addition to the listed genes, *ANKK1* rs1800497 polymorphism influences cognitive behavioral capacity by the modulation of expression of D2 receptors (Thompson et al., 1997). Thus, this polymorphism has been included in the group of key variants involved in the process of addiction (Lachowicz et al., 2020). Moreover, some studies have emphasized that exercise addiction was associated with athletic performance. For instance, Cetin et al. have showed that the athletes with high exercise addiction gave the lower performances independent of the branches (Cetin et al., 2021). The further studies by Cicioğlu et al. (2019) underlined that elite athletes had a higher risk of being exercise addicted group pointing that there would be a correlation between exercise addiction and enhanced athletic performance. In terms of training, a study reported the association of *ANKK1* rs1800497 polymorphism with the exercise habit in the period from childhood to adolescence in Japanese population. The study further figured out that the individuals with A/A genotype were with lower levels of dopamine receptor, resulting in affected exercise habits (Murakami et al., 2017). Recent studies have reported that individuals with the A/A or A/G genotype may be at higher risk for addictive behaviors, including exercise addiction, while those with the G/G genotype may have a lower risk for addictive behaviors (Aliasghari et al., 2021; Habibzadeh et al., 2021; Switala and Leonska-Duniec, 2021; Switala et al., 2022).

In current study, there were not any individuals with A/A genotype. Hence, it was difficult to evaluate the exercise addiction and comment on the performances in the elite athletes. However, the lack of A/A genotypes and high number of G/G genotype may indicate that the individuals in our study could not tend to addict on the exercise/training. Still, more studies with exercise addiction scale and higher number of participants should be conducted to fully understand the role of A/A genotype on exercise addiction and correspondingly athletic performances in Turkish population. Furthermore, it is important to acknowledge that the relationship between *ANKK1* genotype and addiction is likely a complex phenomenon involving multigenetic and environmental factors, and

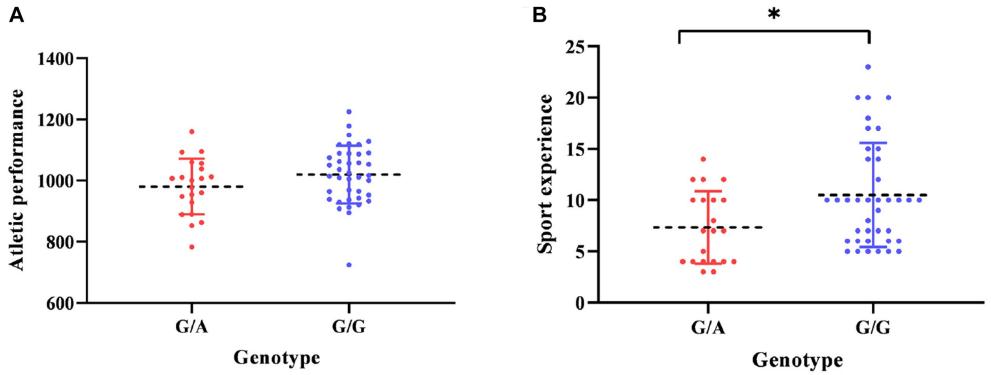


FIGURE 1
The relationship between **(A)** athletic performance, **(B)** sport experiences and two different genotypes (G/A and G/G), *$p < 0.05$.

TABLE 3 Association of the *ANKK1* rs1800497 polymorphism with the sport experiences.

Genotype	*n*	*M*	SD	*t*	*p*	Cohen's d
G/G	39	10.51	5.07	2.555	0.013*	0.72
G/A	21	7.33	3.52			
A/A	–	–	–			

N: Number; M: Mean; SD: Std. Deviation; *Statistically significant differences ($p<0.05$); adjusted by age.

it is not solely determined by a single gene. Overall, our hypothesis pointing the possible association between the rs1800497 polymorphism and athletic performance fails and multi-genetic approaches are needed because of the complexity of the performance-determining mechanisms.

Importantly, the present study indicated that sport experiences significantly associated with the rs1800497 polymorphism. The relevant literature review indicates that sport experience or sport status has been identified as a significant factor in elite rugby (Heffernan et al., 2016), and basketball players (Demirci et al., 2023). Sport experience can significantly vary across different sports disciplines. Indeed, the performance development of marathon runners can be influenced by a combination of environmental and genetic factors, as well as sports experience. However, in sprint disciplines, athletes may retire from sports at earlier ages, and a notable example of this is Usain Bolt, the Olympic record holder in the 100 m event. Conversely, endurance is a bio-motor characteristic that develops over time and different from sprinters where muscular strength plays a crucial role. By aging, there can be a decline in neuromuscular junctions and a decrease in muscle strength, which can negatively impact sprinters' performance (Van Gent et al., 2007; Michaelis et al., 2008; Gómez et al., 2013). Due to the limited number of studies investigating the association between *ANKK1* gene polymorphism and performance, and sports experience, it is challenging to make definitive conclusions in this regard. However, it is believed that in addition to field and laboratory performance tests specific to each sport, the inclusion of genetic analyses in evaluating athletes' performance and training practices could contribute to their high-performance levels more efficiently.

5. Conclusion

The results of the study indicated that there was no significant association between *ANKK1* gene rs1800497 polymorphism and athletic performance. However, when the sports experience was considered, significant association was found, suggesting that the rs1800497 polymorphism may serve as a marker for predicting the length of an elite athlete's professional career. In future research, increasing the sample size and investigating the relationship between this polymorphism and various performance characteristics (such as aerobic capacity, strength, muscular endurance, and body composition) in both male and female athletes competing in different sports could be explored in greater details. Still, according to the current study, it is suggested that the genetic background can be utilized to guide athletes during the professional management period, particularly in the presence of physical factors. This means that understanding an athlete's genetic profile can provide valuable information for personalized training programs, injury prevention strategies and optimizing performances based on individual genetic predispositions. By incorporating genetic information into the management and guidance of athletes, it may be possible to enhance their overall development and maximize their potential in a more targeted and tailored manner.

6. Limitations and future directions

The current study has several limitations that should be acknowledged. Firstly, the sample size of the study is small, which makes it challenging to generalize the findings. Secondly, a structured scale or questionnaire was not used to measure exercise addiction. In future studies, the inclusion of various scales and questionnaires could provide further support for the obtained results. Thirdly, only one polymorphism was utilized in the present research which restricts the cumulative evaluation of the genetic background. Despite these limitations, the current study highlighted the genotype and allele frequencies of the *ANKK1* rs1800497 polymorphism among sprint/power and endurance athletes and demonstrated a potential relationship between the polymorphism and sports experience.

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://figshare.com/, https://doi.org/10.6084/m9.figshare.23254490.v2.

Ethics statement

The studies involving human participants were reviewed and approved by Gazi University Non-Interventional Clinical Research Ethics Committee (decision dated April 05, 2021, number 09). The patients/participants provided their written informed consent to participate in this study.

Author contributions

IB and CB: conceptualization. HK and ME: methodology. EZ and MB: software. ME, TG, and LC: validation. CB and IB: formal analysis. CB, ÖE, and HC: investigation. LC, MB, and TG: resources. IB and HK: data curation. CB, LC, MB, and IB: writing—original draft preparation. CB, ME, HK, HC, and TG: writing—review and editing. CB and HK: visualization. ME: supervision. EZ: project administration. All authors contributed to the article and approved the submitted version.

Funding

The study was supported by Gazi University Rectorate (Scientific Research Projects Coordination's Unit, Project number: TCD-2021-7116). Published with the financial support of the European Union, as part of the project entitled Development of capacities and environment for boosting the international, intersectoral, and interdisciplinary cooperation at UWB, project reg. no. CZ.02.2.69/0.0/0.0/18_054/0014627.

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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Ahmetov, I. I., and Fedotovskaya, O. N. (2015). Current progress in sports genomics. *Advances Clinical Chemistry*, 70, 247–314. doi: 10.1016/bs.acc.2015.03.003

Aliasghari, F., Nazm, S., Yasari, S., Mahdavi, R., and Bonyadi, M. (2021). Associations of the *ANKK1* and DRD2 gene polymorphisms with overweight, obesity and hedonic hunger among women from the northwest of Iran. *Eat. Weight Disord.* 26, 305–312. doi: 10.1007/s40519-020-00851-5

Antrobus, M. R., Brazier, J., Callus, P., Herbert, A. J., Stebbings, G. K., Day, S. H., et al. (2022a). Concussion-associated gene variant COMT rs4680 is associated with elite rugby athlete status. *Clin. J. Sport Med.* Publish Ahead of Print, 10–1097. doi: 10.1097/JSM.0000000000001030

Antrobus, M. R., Brazier, J., Callus, P. C., Herbert, A. J., Stebbings, G. K., Khanal, P., et al. (2022b). Concussion-associated polygenic profiles of elite male rugby athletes. *Genes* 13:820. doi: 10.3390/genes13050820

Bulgay, C., Kasakolu, A., Kazan, H. H., Mijaica, R., Zorba, E., Akman, O., et al. (2023). Exome-wide association study of competitive performance in elite athletes. *Genes* 14:660. doi: 10.3390/genes14030660

Cerit, M. (2018). Hypothetical approach to the location of genotypes (ACE & ACTN3) associated with energy systems for the athletic performance. *Spor Bilimleri Araştırmaları Dergisi* 3, 97–105. doi: 10.25307/jssr.421427

Cetin, E., Bulgay, C., Demir, G. T., Cicioğlu, H. İ., Bayraktar, I., and Orhan, Ö. (2021). The examination of the relationship between exercise addiction and performance enhancement in elite athletes. *Int. J. Ment. Health Addict.* 19, 1019–1030. doi: 10.1007/s11469-019-00208-9

Cicioğlu, H., Tekkurşun Demir, G., Bulgay, C., and Cetin, E. (2019). Elit düzeyde sporcular ile spor bilimleri fakültesi öğrencilerinin egzersiz bağımlılığı düzeyleri. *Bağımlılık Derg* 20, 12–20.

Cui, Y., Zhang, H., Wang, S., Lu, J., He, J., Liu, L., et al. (2022). Stimulated parotid saliva is a better method for depression prediction. *Biomedicine* 10:2220. doi: 10.3390/biomedicines10092220

De La Vega, R., Parastatidou, I., Ruiz-Barquin, R., and Szobo, A. (2016). Exercise addiction in athletes and leisure exercisers: the moderating role of passion, journal of behavioral addictions. *J Behav Addict.* 5, 325–331. doi: 10.1556/2006.5.2016.043

Demirci, B., Bulgay, C., Ceylan, H. İ., Öztürk, M. E., Öztürk, D., Kazan, H. H., et al. (2023). Association of ACTN3 R577X polymorphism with elite basketball player status and training responses. *Genes* 14:1190. doi: 10.3390/genes14061190

Di Lodovico, L., Poulnais, S., and Gorwood, P. (2019). Which sports are more at risk of physical exercise addiction: a systematic review. *Addict. Behav.* 93, 257–262. doi: 10.1016/j.addbeh.2018.12.030

Godoy-Izquierdo, D., Navarrón, E., López-Mora, C., and González-Hernández, J. (2021). Exercise addiction in the sports context: what is known and what is yet to be known. *Int. J. Ment. Health Addict.* 21, 1057–1074. doi: 10.1007/s11469-021-00641-9

Gómez, J. H., Marquina, V., and Gómez, R. W. (2013). On the performance of Usain bolt in the 100 m sprint. *Eur. J. Phys.* 34, 1227–1233. doi: 10.1088/0143-0807/34/5/1227

Habibzadeh, P., Nemati, A., Sheshdeh-Taghipour, A., Paul, P., Sahraian, A., and Faghihi, M. (2021). Investigating the association between common DRD2/*ANKK1* genetic polymorphisms and schizophrenia: a meta-analysis. *J. Genet.* 100:100. doi: 10.1007/s12041-021-01306-1

Hall, E. C., Lockey, S. J., Heffernan, S. M., Herbert, A. J., Stebbings, G. K., Day, S. H., et al. (2023). The PPARGC1A Gly482Ser polymorphism is associated with elite long-distance running performance. *J. Sports Sci.* 41, 56–62. doi: 10.1080/02640414.2023.2195737

Heffernan, S. M., Kilduff, L. P., Erskine, R. M., Day, S. H., McPhee, J. S., McMahon, G. E., et al. (2016). Association of ACTN3 R577X but not ACE I/D gene variants with elite rugby union player status and playing position. *Physiol. Genomics* 48, 196–201. doi: 10.1152/physiolgenomics.00107.2015

Hopkins, W. G., Marshall, S. W., Batterham, A. M., and Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* 41, 3–12. doi: 10.1249/MSS.0b013e31818cb278

Juwono, I. D., Tolnai, N., and Szabo, A. (2022). Exercise addiction in athletes: a systematic review of the literature. *Int. J. Ment. Health Addict.* 20, 3113–3127. doi: 10.1007/s11469-021-00568-1

Kline, R. (2011). *Methodology in the social sciences. Principles and practice of structural equation modeling.* New York, NY, US: Guilford Press.

Lachowicz, M., Chmielowiec, J., Chmielowiec, K., Suchanecka, A., Masiak, J., Michałowska-Sawczyn, M., et al. (2020). Significant association of DRD2 and *ANKK1* genes with rural heroin dependence and relapse in men. *Ann. Agric. Environ. Med.* 27, 269–273. doi: 10.26444/aaem/119940

Liu, S., Xiao, T., Yang, L., and Loprinzi, P. D. (2019). Exercise as an alternative approach for treating smartphone addiction: a systematic review and meta-analysis of

random controlled trials. *Int. J. Environ. Res. Public Health* 16:3912. doi: 10.3390/ijerph16203912

Lukács, A., Sasvári, P., Varga, B., and Mayer, K. (2019). Exercise addiction and its related factors in amateur runners. *J. Behav. Addict.* 8, 343–349. doi: 10.1556/2006.8.2019.28

Michaelis, I., Kwiet, A., Gast, U., Boshof, A., Antvorskov, T., Jung, T., et al. (2008). Decline of specific peak jumping power with age in master runners. *J. Musculoskelet. Neuronal Interact.* 8, 64–70.

Michałowska-Sawczyn, M., Chmielowiec, K., Chmielowiec, J., Trybek, G., Masiak, J., Niewczas, M., et al. (2021). Analysis of selected variants of DRD2 and *ANKK1* genes in combat athletes. *Genes* 12:1239. doi: 10.3390/genes12081239

Murakami, H., Fuku, N., Kawakami, R., Gando, Y., Iemitsu, M., Sanada, K., et al. (2017). DRD2/*ANKK1* gene polymorphism rs1800497 is associated with exercise habit in the period from childhood to adolescence in Japanese. *J. Phys. Fit. Sport Med.* 6, 95–102. doi: 10.7600/jpfsm.6.95

Rajkumar, R. P. (2023). Biomarkers of neurodegeneration in post-traumatic stress disorder: an integrative review. *Biomedicine* 11:1465. doi: 10.3390/biomedicines11051465

Semenova, E. A., Hall, E. C. R., and Ahmetov, I. I. (2023). Genes and athletic performance: the 2023 update. *Genes* 14:1235. doi: 10.3390/genes14061235

Shimura, A., Masuya, J., Yokoi, K., Morishita, C., Kikkawa, M., Nakajima, K., et al. (2023). Too much is too little: estimating the optimal physical activity level for a healthy mental state. *Front. Psychol.* 13:1044988. doi: 10.3389/fpsyg.2022.1044988

Spiriev, B. (2017). IAAF scoring tables of athletics. Available at: https://www.worldathletics.org/news/iaaf-news/scoring-tables. (Accessed November 10, 2022).

Suchanecka, A., Chmielowiec, J., Chmielowiec, K., Masiak, J., Sipak-Szmigiel, O., Sznabowicz, M., et al. (2020). Dopamine receptor DRD2 gene rs1076560, personality traits and anxiety in the polysubstance use disorder. *Brain Sci.* 10:262. doi: 10.3390/brainsci10050262

Switala, K., Bojarczuk, A., Hajto, J., Piechota, M., Buryta, M., and Leonska-Duniec, A. (2022). Impact of the DRD2 polymorphisms on the effectiveness of the training program. *Int. J. Environ. Health Res.* 19:4942. doi: 10.3390/ijerph19094942

Switala, K., and Leonska-Duniec, A. (2021). Physical activity and gene association with human obesity. *Balt. J. Heal. Phys. Act.* 13, 99–111. doi: 10.29359/BJHPA.13.4.10

Szabo, A., and Ábel, K. (2022). "Exercise addiction" in *Behavioral addictions: Conceptual, clinical, assessment, and treatment approaches*, ed. Lane, A. M. (Cham: Springer International Publishing), 189–212.

Szabo, A., and Griffiths, M. (2007). Exercise addiction in British sport science students. *Int. J. Ment. Health Addict.* 5, 25–28. doi: 10.1007/s11469-006-9050-8

Tanaka, M., Diano, M., and Battaglia, S. (2023). Insights into structural and functional organization of the brain: evidence from neuroimaging and non-invasive brain stimulation techniques. *Front. Psych.* 14:1225755. doi: 10.3389/fpsyt.2023.1225755

Thompson, J., Thomas, N., Singleton, A., Piggot, M., Lloyd, S., Perry, E., et al. (1997). D2 dopamine receptor gene (DRD2) taq 1 a polymorphism: reduced dopamine D2 receptor binding in the human striatum associated with the a1 allele. *Pharmacogenetics* 7, 479–484. doi: 10.1097/00008571-199712000-00006

van der Auwera, G., Carneiro, M. O., Hartl, C., Poplin, R., del Angel, G., Levy-Moonshine, A., et al. (2013). From FastQ data to high confidence variant calls: the genome analysis toolkit best practices pipeline. *Curr. Protoc.* 43, 11.10.1–11.10.33. doi: 10.1002/0471250953.bi1110s43

Van Gent, R. N., Siem, D., van Middelkoop, M., Van Os, A. G., Bierma-Zeinstra, S. M. A., and Koes, B. W. (2007). Incidence and determinants of lower extremity running injuries in long-distance runners: a systematic review. *Br. J. Sports Med.* 41, 469–480. doi: 10.1136/bjsm.2006.033548

Varillas-Delgado, D., Del Coso, J., Gutiérrez-Hellín, J., Aguilar-Navarro, M., Muñoz, A., Maestro, A., et al. (2022). Genetics and sports performance: the present and future in the identification of talent for sports based on DNA testing. *Eur. J. Appl. Physiol.* 122, 1811–1830. doi: 10.1007/s00421-022-04945-z

Wang, K., Li, M., and Hakonarson, H. (2010). ANNOVAR: functional annotation of genetic variants from high-throughput sequencing data. *Nucleic Acids Res.* 38:e164. doi: 10.1093/nar/gkq603

Yang, S., Lin, W., Jia, M., and Chen, H. (2023). Association between ACE and ACTN3 genes polymorphisms and athletic performance in elite and sub-elite Chinese youth male football players. *PeerJ* 11:e14893. doi: 10.7717/peerj.14893

Yıldırım, D. S., Erdoğan, M., Dalip, M., Bulgay, C., and Cerit, M. (2022). Evaluation of the soldier's physical fitness test results (strength endurance) in relation to genotype: longitudinal study. *Egypt. J. Med. Hum. Genet.* 23:114. doi: 10.1186/s43042-022-00325-6

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 30 August 2023
DOI 10.3389/fpsyg.2023.1205412

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Francisco Tomás González-Fernández,
University of Granada, Spain
Oleh Khmiliar,
National Defence University of Ukraine named after Ivan Cherniakhovskyi, Ukraine

*CORRESPONDENCE
Zbigniew Wochyński
✉ zbigniew.wochynski@op.pl

RECEIVED 13 April 2023
ACCEPTED 04 August 2023
PUBLISHED 30 August 2023

CITATION
Wochyński Z, Skrzyńska-Rękawek J and Kobos Z (2023) Assessment of the psychomotor fitness level of cadet pilots after a 6-month flight training period - pilot study. *Front. Psychol.* 14:1205412. doi: 10.3389/fpsyg.2023.1205412

Assessment of the psychomotor fitness level of cadet pilots after a 6-month flight training period - pilot study

Zbigniew Wochyński[1]*, Justyna Skrzyńska-Rękawek[2] and Zdzisław Kobos[3]

[1]Department of Air Transport Safety, Polish Air Force University, Deblin, Poland, [2]Air force Institute of Aviation, Warsaw, Poland, [3]Department of Psychology of Work and Stress, Cardinal Stefan Wyszynski University in Warsaw, Warsaw, Poland

Objectives: The aim of the study was to investigate the impact of 6-month aviation practice on the improvement of physical fitness and cognitive abilities of cadet pilots.

Materials and methods: Twenty cadet pilots (men) with an average age of 22 from the Polish Air Force Academy were tested. Two tests of effort were conducted: before (test I) and after (test II) practical flights. Test of physical effort relyed on the number of rotations of looping accomplished. When performing rotations on looping, in tests I and II, the percentage level of task performance was assessed using a diagnostic and training device. Tasks for the exerciser were sent wirelessly to the glasses from the operator's position. The heart rate (HR) and blood pressure were measured with a camera-type Microlife AG.

Results: In test II, there was a statistically significant improvement in the percentage of task completion ($p < 0.01$) and an insignificant improvement in the performance of rotations on looping compared to test I. After Test I and II demonstrated a statistically significant increase in HR and systolic blood pressure when compared to before test values. Test II illustrated a significant decrease in systolic blood pressure after effort ($p < 0.05$) with regard to test I.

Conclusion: The study showed that cadet aviation practice ameliorated their physical fitness and cognitive skills, as well as helped to diminish their situational stress, which resulted in a decrease in systolic blood pressure after test II.

KEYWORDS

diagnostic and training device, rotation, heart rate, blood pressure, mental condition, sensory system, motor system, synthetic memory (working)

Introduction

A high level of psychomotor fitness in pilots is the basis for performing combat tasks (Tomczak et al., 2017; Wochyński, 2021; Prokopczyk and Wochyński, 2022a,b). This issue does not lose relevance with the technological progression of military aircraft. The pilot's psychomotor development is the key to quick decision-making, ordering mental processes, and perfect coordination of motor and mental activities (Tomczak, 2015; Tomczak et al., 2019; Wochyński et al., 2020a; Wochyński, 2021, 2022). At the same time, the level of physical fitness and cognitive

features of a pilot cannot be treated as separate phenomena. A modern pilot must combine them comprehensively, contributing to solving professional tasks in extreme conditions (Tomczak, 2015; Tomczak et al., 2017). From this point of view, psychomotor tests for military pilots must be mandatory and performed comprehensively. The diagnostics of skills and cognitive processes in pilots is an essential factor that conditions the safety and efficiency of flight missions. This is why, in military aviation, psychological (cognitive, space orientation, and stress resilience) and motor skills (sight-movement coordination and balance) tests were introduced. Advancements in technology forced researchers to seek innovative methods for the assessment of psychomotor skills in the pilot's training (Prokopczyk and Wochyński, 2022a,b). These methods have to be adequate to the opportunities created by modern aviation technology, for example with regard to aircraft maneuverability, G-forces, armaments, navigation, flight-speed, etc. The traditional procedures of candidate selection include psychological and physical tests which are separate and do not coincide. These separate procedures to assess one's suitability for a career in aviation negatively influence the diagnostic accuracy of the psychomotor predispositions necessary to perform complicated tasks in the air. The conducted research, reported evaluation, and performed training enable an increase in the diagnostic accuracy of the suitability assessment of the candidates for military aviation training. One of the specialized methods to prepare pilots physically for flight in extreme conditions is training on Special Aerial Gymnastics Instruments (SAGIs; Wochyński et al., 2010). These Instruments are as follows: looping, gyroscope, and aero wheel. Their structure and appearance were presented in the previous papers (Wochyński et al., 2010; Wochyński and Sobiech, 2014, 2015, 2017). The exercises on those instruments partly imitate the real flight mission's environment. Thus, SAGIs help to evaluate the predispositions needed to perform the mission in real time and the capability to utilize the technological and maneuvering abilities of the aircraft. The level of physical and mental fitness depends on the adaptation and integration processes of the motor and sensory systems. In the time criterion imposed on the conduction of the above-mentioned tasks, physical and mental fitness might be a reason for feedback between them. This is why a new method was implemented, a stress test on looping connected with a diagnostic-training device used to evaluate the cognitive processes (including the ability to concentrate and focus attention, to think) and to evaluate the skills (the accuracy of the accomplishment of assigned tasks).

In this article, a hypothesis was made that a half-year-long practical flight training will have an influence on the amelioration of physical fitness and cognitive skills among cadets. At the same time, it was assumed that the use of the diagnostic-training device will have a high diagnostic value and will allow us to assess the maximum psychomotor threshold, at which feedback will appear (decreasing correlation) between the percent of accomplished tasks and the number of performed rotations after a half-year-long practical flight training.

Materials and methods

Participants

Twenty cadet pilots (all men) studying at the Polish Air Force Academy in Dęblin, aged 22 on average, underwent examinations before (test I) and after (test II) a half-year of practical flying training (Table 1). Cadets were a homogeneous material selected by the Military Aeromedical Board, which obtained the highest health category (Z-1A). Looping exercises require special motor adaptation from the participants. Before starting their flight practice, the cadets completed a 40-h program of special exercises on SAGI, preparing for flights within 70 days (Wochyński et al., 2010). Due to the technical difficulty of rotating the looping in the forward direction, the authors did not implement a control group for the study. The criterion for inclusion in the study was: the consent of the subject, exclusion from the study: resignation of the subject, injury, or professional duties.

TABLE 1 Age and somatic data ($n = 20$).

parameter	Test I M ± SD	95% CI	Test II M ± SD	95% CI	p
Age (years)	22.0 ± 1.52	21.2; 22.7	22,0 ± 1.52	21.2;22.7	ns
Body weight (kg)	73.4 ± 4.26	70.4; 76.3	74.0 ± 5.83	71.2;76.7	ns
Body height (cm)	177.8 ± 4.38	175.6;179.8	177.8 ± 4.38	175.7;179.7	ns
BMI (kg.m^{-2})	23.3 ± 1.49	22.5; 23.9	23.4 ± 1.57	22.6;24.1	ns

M ± SD- mean, standard deviation; CI- confidence interval; p-level of significance; ns-statistical insignificance.

Examinations

Cadets' heart rate (HR), systolic, and diastolic blood pressure were measured with an electronic device of the Microlife AG type before and after test I and II.

Method

During the examinations, a stress test on a looping, which is one of the SAGI devices, was used (ability to perform exercises, motor coordination), combined with the application of a diagnostic and training device developed to assess mental agility (the ability to concentrate and focus) as well as abilities and skills (precision of performing the task). Each of the tested cadets was wearing the diagnostic and training device. Looping is an ongoing training tool for pilots and has also been used to develop the psychomotor test (Prokopczyk and Wochyński, 2022a,b) and the assessment of vegetative symptoms (Wochyński et al. 2020a,b). Rotational looping exercises cause overloads of +Gz and-Gz in the subjects, therefore the cognitive processes of cadet pilots were assessed in conditions close to real.

Description the device

The device consists of a backpack with a small computer controlling the cognitive tasks displayed in the goggles. The experimenter's workstation allowed for online monitoring of the reactions of the tested person in whom tasks appeared in the goggles. The task simulation was applied wirelessly from the main workstation to the trainee via a relay station.

Description of the test

After initiating the looping, when their body was moving in the tridimensional space, the cadets were assigned 5 cognitive tasks to complete within the timeframe of 128 s, which were displayed in their goggles. The following were established for each of the tasks: the time cadets waited for a question (5 s), the time the question was displayed (10 s), and the length of the sequence (10 s). The efficiency of the accomplishment of the cognitive tasks was assessed in percentage. Whereas physical fitness was assessed with the number of performed loops (Figure 1). It was assumed that all the tasks were performed correctly. After performing the looping exercises the tested person moved on to performing the sixth task – a synthetic memory test. The synthetic memory test consisted of listing the order of performing the tasks during the exercises.

The type of tasks displayed in the goggles and their evaluation was as follows:

1. To count parachutists in one color - correct
2. To count cars in one color - correct
3. To count shapes of one type - correct
4. Arithmetic operations - correct
5. To count shapes in one color – correct

   Grade: 100%.

The task simulation program had the function of changing the order of their display in the study.

After completing the looping test, the cadets underwent a memory test:

6. Synthetic memory test – correct
   Grade: 100%.

Flying practice program

During their flying practice, the cadets were performing certain types of program flights in the air. Moreover, they were participating in physical education classes. The classes were very intensive to increase the pilot's physical fitness. During the training tasks, repetitive and interval method was applied. The cadets followed the physical education program two times a week, with 2 h each session, while in the scope of directed physical training they also had 2-h-long sports classes once a week. During the implementation of the training program, all subjects were provided with the same accommodation and food conditions.

Statistical analysis

The average and standard deviation of all the variables were counted in a statistical study. A normal distribution of all the examined variables was checked by means of the Kolmogorov–Smirnov test. In order to verify the homogeneity of variance, Levene's test was applied. The difference in results between tests I and II was calculated by analysis of variance (ANOVA) with repeated measurements using the Tukey HSD posthoc test for pairwise comparison. In tests I and II, the r-Pearson's correlation between the task completion percentage and the number of rotations while looping was calculated. In the statistical study of all variables, the value of the effect size was calculated using Cohen's d test. The following criteria were used to evaluate Cohen's d-test: 0.2 to 0.3 small, 0.5 medium, and greater than 0.8 large effect size (Cohen, 1988). The statistical analysis of the test results was performed using the STATISTICA 13.3 statistical program, the G* power program was used to assess the sample size (Faul et al., 2007). To evaluate the sample size with the size effect $f^2 = 0.25$ was assumed an alfa error of 0.05 and a test's power of 0.80. The required size of the total sample was estimated at 25 people. Due to professional duties, the final analysis included 20 people. The differences in averages are considered significant when the calculated value of p is smaller than 0.05.

Results

In test II, in comparison to test I, no significant changes in somatic parameters were observed (Table 1). Test I and II demonstrated a statistically significant increase in HR and systolic blood pressure after the stress test when compared to the values before it.

In test I after the exercise a statistically significant increase in blood systolic pressure was observed in comparison to the value

FIGURE 1
The sequence of forword rotation on a looping with a diagnostic and training device.

10.3389/fpsyg.2023.1205412

TABLE 2 Physiological and psychomotor parameters results in cadets ($n = 20$).

Parameters	Test I M ± SD	95% CI	Test II M ± SD	95% CI	Cohen's d test	*F*	*p*
Systolic pressure before the exercise (mmHg)	141.1 ± 15.2	133.9; 148.2	133 0.6 ± 13.11	127.5; 139.7	0.45	2.76	0.09
Diastolic pressure before the exercise (mmHg)	89.7 ± 9.91	85.1; 94.3	90.7 ± 10.16	85.9; 95.4	0.08	0.08	0.76
Systolic pressure after the exercise (mmHg)	154.9** ±14.53	148.0; 161.7	143.7* ±19.63	134.5; 152.9	0.55	4.16	<0.05
Diastolic pressure after the exercise (mmHg)	93.6 ± 15.37	86.4; 100.7	91.7 ± 11.75	86.1; 97.2	0.10	0.19	0.66
Heart rate (HR) before the exercise (bpm)	84.8 ± 15.96	77.3; 92.3	84.0 ± 13.27	77.8; 90.2	0.04	0.03	0.86
Heart rate (HR) after the exercise (bpm)	125.25** ±24.38	113,8; 136,6	123.65** ±17.92	115.2; 132.0	0.05	0.05	0.81
Execution of rotations forward on looping (number)	49.45 ± 10.5	44.5; 54.3	54.1 ± 11.74	48.6; 59.5	0.34	1.74	0.19
Percentage completion of tasks during doing exercises on a looping (%)	73.7 ± 14.84	66.8; 80.6	87.25 ± 10.85	82.1; 92.3	0.81	10.77	<0.01

M ± SD – mean, standard deviation; CI – confidence interval; *p*-level of significance. *$p < 0.05$ - statistically significant difference in comparison to the pre-exercise value.
**$p < 0.001$ - statistically significant difference in comparison to the pre-exercise value.

TABLE 3 Percentage distribution of the results in test I and II.

Tasks performance percentage	Test I $n = 20$	Test II $n = 20$
33	1	-
50	1	-
66	7	2
83	10	11
100	1	7

before the exercise. An increase in HR, after exercise, in comparison to the value before the exercise, was also observed. Similarly, in test II a statistically significant increase in blood systolic pressure and HR after the exercise was observed, in comparison to the pre-training value. In test II a statistically significant decrease in blood systolic pressure was found in comparison to test I. In test II a statistically insignificant improvement in physical performance (increase in number of performed rotations) and significant mental agility as well as skills and abilities (task simulation) were observed in comparison to test I (Tables 2, 3). In test II, in the assessment of synthetic (operational) memory, an improvement in errors was shown compared to test I (Figure 2).

The rest of the parameters showed no changes. After cadets had 6 months of practice in the air, the effect size (d Cohen) value calculated. For the execution of forward rotation on looping, it was small, and for the percentage of completion of tasks during the exercises, it was large (Table 2).

In test II, a lower correlation was found between the number of rotations and the percentage of task completion compared to test I (Figure 3).

Discussion

Based on the conducted investigation, the authors assumed that the exploited diagnostic-training instrument will be of high diagnostic value and will make it possible to determine the level of cognitive performance depending on the intensity of looping exercises. The performance of the task in extreme conditions of the pilot's working environment determines high physical and mental fitness. The results of the study showed that the physical effort in Test I and II was performed in the aerobic metabolic zone, as indicated by the results of the heart rate (HR) measurement. Looping exercises overburdened the body due to positive +Gz (head-leg direction) and negative-Gz (leg-head direction) overloads. The exercises on the looping are connected with a huge impact on the respective fields of arteries of the cardiovascular system and the body's central nervous system. During these exercises, there is a short-term increase in high blood pressure and HR. Such reactions were also observed by Kłossowski (1994). The observed higher values of physiological parameters than the resting values in cadets before Tests I and II were probably caused by the emotions linked to performing a specific attempt. During the test, the student did not see a point of reference in space for their body (no view of the environment due to goggles covering the eyes). It was found that the somatic features of cadets between Tests I and II did not change significantly (Table 1). The applied maximum performance exercise (forward rotations on the looping) in the experiment combined with a simultaneous simulation of stimuli (tasks) appearing in the central field of vision caused complex sensory reactions in pilot cadets. The instructed response of the person being examined during the dynamic exercises while looping is to receive accurate information, processing it, and give a correct answer. The military pilot frequently encounters such situations during a flight. The execution of rotations was a constant movement stimulus, studied and adapted to the requirements of the military pilot's working environment. The rotations were performed in accordance with the structural scope of the Schmidt motor program (Schmidt, 1976, 1991). It needs to be stressed that the transmitted stimuli (tasks) were displayed unexpectedly within 128 s during the execution of the rotations (the waiting time for displaying a task was unknown to the student). Detecting a stimulus (task), a proper reaction (answer), and speed of information processing, measured in time, forms the basis for an effective test execution by pilot cadets. The factor determining the effectiveness of sensory processes was the compatibility of the stimulus (task) and reaction (answer) during a physical effort (rotations). It was found that the greater the compatibility of a stimulus and a response, the shorter the answer time (Eimer, 1995; Masaki et al., 2000; Worringham and Kerr, 2000). The disturbance between a stimulus and a response could have led to a delay in processing the information with a simultaneous reduction in the number of executed rotations and committing an error in an answer. It was found that the efficiency of

sensorimotor processes is the basis of human motor functioning with regard to the motor response not only of bodily components but also of the whole body (Osiński, 1990). The observations in this study demonstrated a relationship between a complex reaction (answer to questions) in the central field of vision and the intensity of effort (number of forward rotations). The intense physical effort resulted in a prolonged reaction time (answer to questions), which could have caused disturbances in the central nervous system due to decreased cerebral perfusion. The optimum number of rotations affected the response time (answer to questions), which, at the same time, was the borderline between an increase and a decrease in the number of rotations, during which the student was answering all questions correctly. This borderline point is the maximum level of psychomotor capability under extreme exercise conditions. In Test I, a positive correlation r = 0.19 was observed in all examined cadets between the number of performed rotations and the percentage execution of the tasks. This means that among the respondents, a higher level of the sensory response (answer to questions) and a lower level of the motor response (number of forward rotations) were found, while in others an opposite tendency was observed. This is due to the difference in the level of integration of neurosensory network

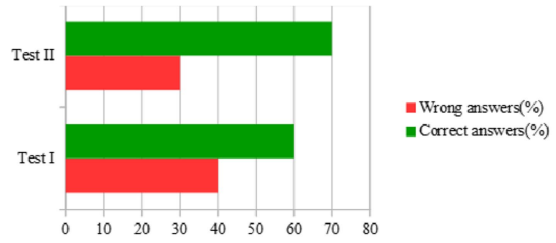


FIGURE 2
Percentage distribution result of the synthetic memory test I and II (n = 20).

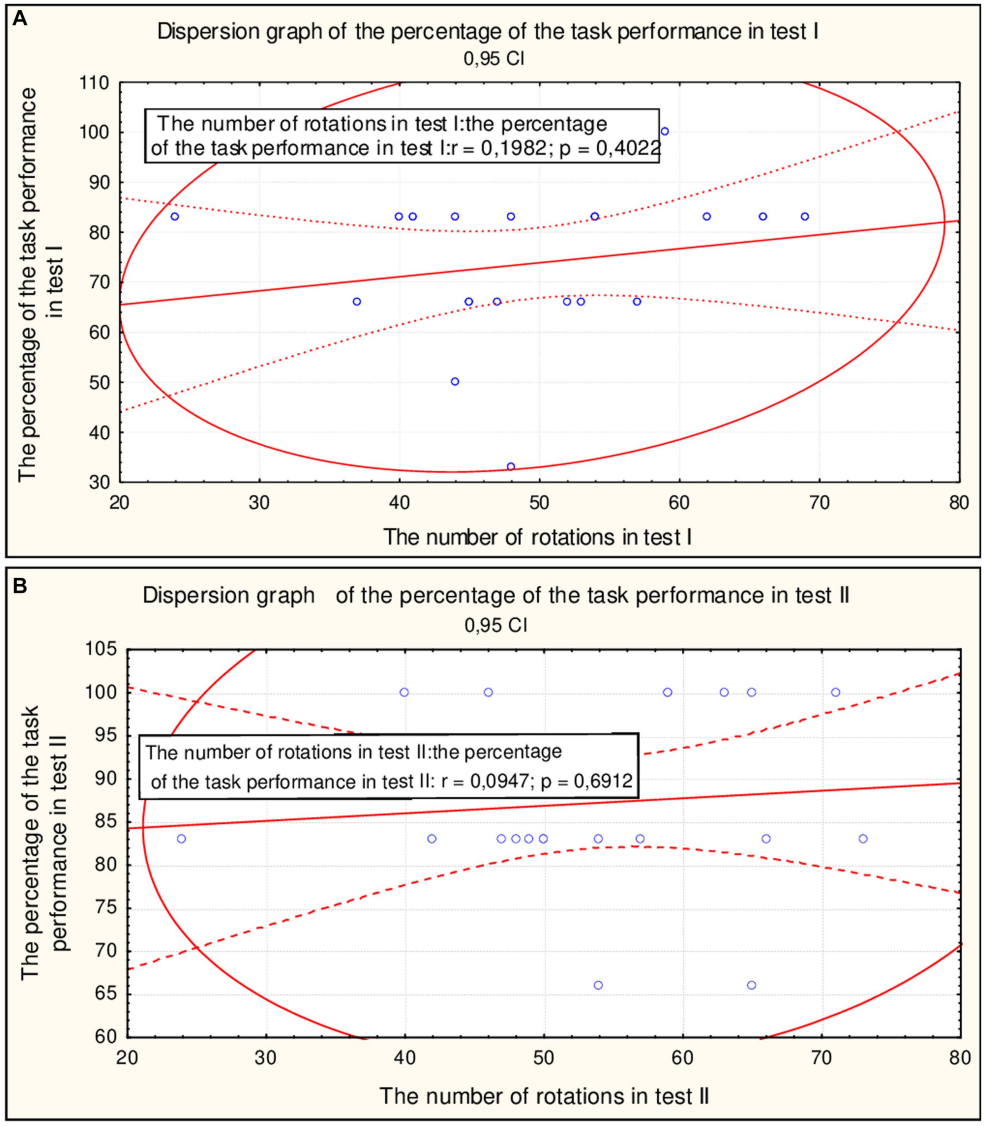


FIGURE 3
The correlation between the percentage of performed tasks' and a number of rotation in the test I **(A)** and II (**B**; n = 20).

connections with the motor ones. An intense physical effort and a delayed response time may cause a delay in the processing of information (Sanders, 1990) and a delay in answering, and, consequently, a reduction in the percentage of the sensory task execution (number of committed errors). This fact is confirmed by the studies of other authors (Yagi et al., 1999; Tomporowski, 2003; Kamijo et al. 2004; Ando et al., 2005; Thomson et al., 2009). Previous research (Prokopczyk and Wochyński, 2022a,b) shows that after the SAGI special training process, the percentage of task completion was statistically significantly higher than before the training process. It should be emphasized that in this study, the difference in the percentage of task completion before and after flight practice was also statistically significant, and their values were higher than in the special training process. The difference in the results of looping rotations before and after the training process was statistically insignificant (Prokopczyk and Wochyński, 2022a,b). Similarly, in this study, there was a non-significant difference in the values before and after the period of flying practice in looping rotations. It was shown that their values were higher than in the special training process. In this study, with a higher value of rotations performance on looping, a higher percentage of task completion was found in relation to the same variables in the training process on SAGI. It follows from this that the cadets after aviation practice had a higher degree of psychomotor skills. This fact is confirmed by the lower correlation between the percentage of task completion and the number of rotations performed on looping in this study in relation to the study of the special training process. The justification for a higher psychomotor level in cadets after air practice in relation to cadets in the training process at SAGI may result from their psychomotor predispositions or adaptation to the pilot's work environment. It may also be a cumulative effect, which consisted of an earlier period of special preparation for flights on SAGIimmediately followed by the start of the aviation practice stage. In Test I, a synthetic (operational) memory test was performed after the looping exercises. The synthetic memory was disturbed in the examined students as a result of ongoing fatigue and stress resulting from time deficit activities, and greater concentration in responding to stimuli (questions). This fact is confirmed by some cadets, since on completion of the attempt, they did not remember the order of the performed tasks during the test. A large percentage discrepancy of tasks and a fewer number of rotations could have been caused by poor integration of the sensory-motor system. The findings of Test II revealed that the level of physical and mental efficiency depends on the course of the adaptation and integration processes of the two systems: the motor and the sensory one. In the timing criteria of executing the above-mentioned tasks, the level of physical and mental fitness may be the cause of the occurrence of feedback between these systems. This was evidenced by a decreasing correlation between the percentage execution of tasks and the number of completed rotations in Test II, as compared to Test I. In Test II (after half a year of flying practice in the air) better synthetic (operational) memory was observed, which is probably a result of increased sensory-motor activity and concentration of attention trained when flying. The test used in the study is a special exercise for pilots and may have triggered specific physiological reactions (lowered HR), indicating whether the pilot is adapted to physical effort in extreme conditions. A six-month practice period combined with physical education may have resulted in the inclusion of adaptive mechanisms, in which proteins and hormones could have played a crucial role. The previous author's papers (Wochyński and Sobiech, 2014, 2015, 2017) demonstrated that the exercises on Special Aviation Gymnastic Instruments (SAGI; looping, gyroscope, aero wheel) lead to the adaptation to physical effort within 70 days, as a result of a special exercise programme for cadet pilots (Wochyński et al., 2010). It was found that dopamine in plasma, at the end of the preparation period, after the training unit, was high than before the training period (Wochyński and Sobiech, 2017). Such a concentration of dopamine, at the end of the training period, may indicate a fatigue delay and a positive regulation of the motor and limbic system. This was confirmed by studies in which dopamine plays an important role in cognitive processes and attention mechanisms (Nieoullon, 2002). The intensity of the looping exercise during the test could have affected the stimulation of the central nervous system. This type of exercise undoubtedly affects the vestibular organ, which undergoes habituation after prolonged exposure (Wochyński et al., 2020b). After a 6-month practice period (Test II), cadets showed a decrease in HR and diastolic pressure. Moreover, the significance of the difference was noted only in systolic blood pressure in relation to resting values and to Test I after the effort. The drop in blood pressure should be associated with smaller stress during Test II. It was observed that along with a decrease in HR, systolic and diastolic pressure, there was a percentage increase in tasks performed on the looping in Test II, which denotes a decrease in errors made by the cadets in Test II. An insignificant increase in the number of rotations in Test II shows an increase in the sensitivity of the neurosensory system (motor adjustment). The percentage enhancement in the task execution in Test II presumably results from improved visual and motor perception related to flying experience. The practical implementation of tasks in the air for half a year possibly resulted in adaptation to the occurring stress or its reduction due to mastering the operational activities in real conditions.

The authors wanted to emphasize that these studies (pilot) will contribute to a future experiment, with the possibility of using greater diagnostic accuracy and a larger number of people including the control group (according to the studied indicator for the entire population) for future candidates for military aviation. They will also be helpful in conducting training for cadets and instructors dealing with these issues in practice. The research will also be the basis for the use of special mental training for pilots, as in athletes (Piepiora et al., 2022).

Conclusion

Summarizing the results of the study, it was found that practical pilotage training for pilot cadets contributed to the improvement of physical fitness and the efficiency of cognitive processes. A six-month practice, in the air, of pilot cadets and conducted physical education classes contributed to a percentage increase in task execution as well as in the number of rotations in Test II. The calculation of the Cohen effect size value shows that the practice period had a large impact on the percentage increase in the completion of tasks during exercises and a small effect on the increase in the number of rotations. The borderline point in maximum psychomotor abilities of the cadets was higher in Test II compared to Test I, together with a decreasing correlation between the percentage execution of tasks and making the rotations. The study has proved that the applied diagnostic and training instrument has a high diagnostic value in the assessment of the course of cognitive processes under conditions of a dynamic change of a body position in space. The device makes it possible to

diagnose the level of pilots' functioning in extreme conditions of the pilot's working environment.

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.

Ethics statement

The authors achieved permission from the appropriate ethical commission to perform the study (decision No. 03A/2009, 08.07.2009, Ethical Commission on biomedical research studies at the Military Institute of Aviation Medicine in Warsaw). The study was conducted considering the guidelines of the Declaration of Helsinki.

Author contributions

ZW contributed to the conception and design of the study and wrote the first draft of the manuscript. JS-R and ZK organized the database. ZW and ZK performed the statistical analysis. JS-R wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

Funding

The research study was financed by the National Centre for Research and Development (No. O R/00 001706).

Acknowledgments

The authors thank the cadets for their participation in this study.

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

Ando, S., Kimura, T., Hamada, T., Kokubu, M., Moritani, T., and Oda, S. (2005). Increase in reaction time for the peripheral visual field during exercise above the ventilatory threshold. *Eur. J. Appl. Physiol.* 94, 461–467. doi: 10.1007/s00421-005-1330-7

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

Eimer, M. (1995). Stimulus-response compatibility and automatic response activation: evidence from psychophysiological studies. *J. Exp. Psychol. Hum. Percept. Perform.* 21, 837–854. doi: 10.1037/0096-1523.21.4.837

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Kamijo, K., Nishihira, Y., Hatta, A., Kaneda, K., Kida, T., Higashiura, T., et al. (2004). Changes in arousal level by differential exercise intensity. *Clin. Neurophysiol.* 115, 2693–2698. doi: 10.1016/j.clinph.2004.06.016

Kłossowski, M. (1994). Assessment of physiological reactions as a result of SAGI practice. Post Med Lotn. 2.

Masaki, H., Takasawa, N., and Yamazaki, K. (2000). An electrophysiological study of the locus of theinterference effect in a stimulus-response capatibility paradigm. *Psychophysiology* 37, 464–472. doi: 10.1111/1469-8986.3740464

Nieoullon, A. (2002). Dopamine and the regulation of cognition and attention. *Prog. Neurobiol.* 67, 53–83. doi: 10.1016/S0301-0082(02)00011-4

Osiński, W. (1990). Notes on the definition and classification of basic concepts characterizing human motor skills. *Antropomotoryka* 3, 3–8.

Piepiora, P., Bagińska, J., Jaśkowska, K., and Witkowski, K. (2022). Mental training in the opinion of the polish national karate kyokushin team. *Arch. Budo* 18, 103–109.

Prokopczyk, A., and Wochyński, Z. (2022a). Influence of a special training process on the psychomotor skills of cadet pilots – pilot study. *Front. Psychol.* 13:1019495. doi: 10.3389/fpsyg.2022.1019495

Prokopczyk, A., and Wochyński, Z. (2022b). Changes in physical fitness and body composition of pilot cadets before and after a process of directed flight preparation. *BMC Sport Sci. Med. Rehab.* 14:153. doi: 10.1186/s13102-022-00547-6

Sanders, A. F. (1990). Issues and trends in the debate on descrete vs. continuous processing of information. *Acta Psychol.* 74, 123–167. doi: 10.1016/0001-6918(90)90004-Y

Schmidt, R. A. (1976). Control processes in motor skills. *Exerc. Sport Sci. Rev.* 4, 229–261. doi: 10.1249/00003677-197600040-00009

Schmidt, RA. (1991). *Motor learning and performance*. Human Kinetics Publishers Inc, Champaign, III.

Thomson, K., Watt, A., and Liukkonen, J. (2009). Differences in ball sports athletes speed discrimination skills before and after exercise induced fatigue. *J. Sports Sci. Med.* 8, 259–264.

Tomczak, A. (2015). Coordination motor skills of military pilots subjected to survival training. *J. Strength Cond. Res.* 29, 2460–2464. doi: 10.1519/JSC.0000000000000910

Tomczak, A., Dąbrowski, J., and Mikulski, T. (2017). Psychomotor performance of polish air force cadets after 36 hours of survival training. *Ann. Agric. Environ. Med.* 24, 387–391. doi: 10.5604/12321966.1232762

Tomczak, A., Różański, P., and Jówko, E. (2019). Changes in coordination motor abilities of naval academy cadets during military survival training. *Aero. Med. Hum. Perform.* 90, 632–636. doi: 10.3357/AMHP.5302.2019

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychol.* 112, 297–324. doi: 10.1016/S0001-6918(02)00134-8

Wochyński, Z. (2021). Evaluation of judo practitioners' motor performance in relation to the criterion of targeted fitness of pilot cadets after a six-month training process. *Arch. Budo* 17, 319–328.

Wochyński, Z. (2022). Changes in the body composition and on fitness levels judo practitioners' in relation to pilot cadets' – effects of special programs. *Arch. Budo.* 18, 193–202.

Wochyński, Z., Jędrys, R., and Stelęgowski, A. (2010). Methodology of training on special aviation gymnastics instruments. Polish Air Force Academy. Dęblin, pp. 43–59.

Wochyński, Z., Krawczyk, P., and Cur, K. (2020a). The assessment of the impact of a training process on the habituation of the vestibular-vegetative system, using a special rotational test as a condition of maintaining flight safety. *Int. J. Occup. Med. Environ. Health* 33, 497–506. doi: 10.13075/ijomeh.1896.01515

Wochyński, Z., Skrzyńska, J., Pilaczyński, P., and Kobos, Z. (2020b). The impact of motor predispositions in pilot cadets upon the results of the execution of aviation-synthetic efficiency test (ASET). *Arch. Budo Sci. Martial Arts Extreme Sports* 16, 105–117.

Wochyński, Z., and Sobiech, K. A. (2014). Effect of exercise on aerial special gymnastics apparatuses on blood serum levels of selected biochemical indices. *Ann. Agricul. Environ. Med.* 1, 106–111.

Wochyński, Z., and Sobiech, K. (2015). Post-exercise proteinuria in cadets trained on special aerial gymnastics instruments. *Int. J. Occup. Med. Environ. Health* 28, 863–873. doi: 10.13075/ijomeh.1896.00454

Wochyński, Z., and Sobiech, K. A. (2017). Impact of special aviation gymnastics instruments training on selected hormones in cadets' blood serum and plasma. *Int. J. Occup. Med. Environ. Health* 30, 655–664. doi: 10.13075/ijomeh.1896.00904

Worringham, C. J., and Kerr, G. K. (2000). Proprioception and stimulus-response compatibility. *Q. J. Exp. Psychol.* 53, 69–83. doi: 10.1080/713755885

Yagi, Y., Coburn, K. L., Estes, K. M., and Arruda, J. E. (1999). Effects of aerobic exercise and gender on visual and auditory P 300, reaction time, an accuracy. *Eur. J. Appl. Physiol.* 80, 402–408. doi: 10.1007/s004210050611

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 16 January 2024
DOI 10.3389/fpsyg.2023.1243658

OPEN ACCESS

EDITED BY
Chong Chen,
Yamaguchi University Graduate School of Medicine, Japan

REVIEWED BY
Ragna Stalsberg,
Norwegian University of Science and Technology, Norway
Jin Yan,
The University of Newcastle, Australia

*CORRESPONDENCE
Weiqiang Zhu
✉ zwq223tyxx@163.com

†These authors have contributed equally to this work and share first authorship

RECEIVED 21 June 2023
ACCEPTED 18 December 2023
PUBLISHED 16 January 2024

CITATION
Zhang X, Yan J, Zhu W and Fu X (2024) Development and validation of the Chinese family environment influencing physical activity habits scale.
Front. Psychol. 14:1243658.
doi: 10.3389/fpsyg.2023.1243658

Development and validation of the Chinese family environment influencing physical activity habits scale

Xulin Zhang[1†], Jingfei Yan[2†], Weiqiang Zhu[1*] and Xiaoya Fu[3]

[1]College of Physical Education and Health, East China Normal University, Shanghai, China, [2]Ministry of Physical Education, Shanghai Institute of Technology, Shanghai, China, [3]College of Physical Education, Ningxia Normal University, Guyuan, China

Introduction: Adolescence represents a pivotal stage in the development of healthy behaviors, where establishing positive physical activity habits can have enduring effects on an individual's overall wellbeing. The ecological model highlights the influence of environmental factors on human behavior, with the family environment playing a significant role in shaping the physical activity habits of adolescents.

Methods: The aim of this scale is to develop a reliable and effective tool, customized for the unique societal context of China, to assess how family factors influence the physical activity habits of Chinese adolescents. Participants were recruited through stratified cluster sampling from 24 secondary schools in six Chinese provinces between October and November 2021, resulting in 1,061 participants. Analysis was conducted on 1,004 valid questionnaires, divided into two samples. Sample 1, consisting of 502 students (248 males and 254 females; $M_{age} = 15.5$), underwent item analysis and exploratory factor analysis. Sample 2, comprising 502 students (267 males and 235 females; $M_{age} = 16.5$), underwent confirmatory factor analysis and internal consistency reliability analysis.

Results: Through exploratory factor analysis, we extracted three factors comprising 15 items: "Family Environment Construction" (4 items), "Family Action Support" (6 items), and "Family Health Awareness" (5 items). The Cronbach's alpha values for these factors ranged from 0.890 to 0.894. Confirmatory factor analysis confirmed a satisfactory model fit (CMIN/DF = 1.45, SRMR = 0.027, GFI = 0.991, TLI = 0.989, RMSEA = 0.03).

Discussion: The scale demonstrated strong internal consistency and test-retest reliability, confirming its effectiveness in empirical research. This study holds significant implications for enhancing the physical activity levels of adolescents, promoting their physical and mental wellbeing, enriching their developmental experiences, and contributing to their overall sense of happiness.

KEYWORDS

Chinese adolescents, physical activity habit, family environment, scale development, factor analysis

1 Introduction

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure, encompassing activities such as walking, cycling, sports, and recreational activities (World Health Organization, 2022). Physical activity contributes significantly to enhancing overall health and reducing the risk of chronic diseases, including cardiovascular diseases, cancer and diabetes (World Health Organization, 2022). Regular engagement in physical activity plays a crucial role in promoting the health and

well-being of individuals, particularly during adolescence, which is a critical period for the development of health behaviors (van Sluijs et al., 2021). Establishing positive patterns of physical activity during this stage can have long-lasting effects on individuals' health and wellbeing throughout their lives.

The application of health behavior theories in physical activity has revealed the role of environmental influences, most commonly "barriers," "facilitating conditions," or "contextual influences" (Godin, 1994). Bandura (1986)'s social cognitive theory provides valuable insights into the interplay among environmental, personal, and behavioral factors. The varying impact of these factors is contingent upon the specific activity, individual characteristics, and environmental context. Transitioning to the work of Sallis and Hovell (1990), who introduced a social cognitive model for physical activity behavior, emphasizes the pivotal role of environmental attributes within a framework where multiple determinants interact across various levels. Within this model (Sallis and Hovell, 1990) the "ecological" model of health behavior provides a holistic understanding of how diverse determinants interact across various levels in individuals' physical and socio-cultural environments. The family environment, as a primary socializing agent, holds significant influence adolescents' exercise behaviors and habits (Roque Garay, 2018; Korom et al., 2023). Families provide the foundation for learning and adopting health behaviors (Hunt et al., 2015). Extensive research has demonstrated the impact of the family environment on the formation of exercise habits among adolescents (Mota, 1998; Zovko et al., 2021). For example, factor such as family support (Kuo et al., 2007; Álvarez Muñoz and Hernández Prados, 2023; Hu and Cai, 2023), parental role modeling (Adkins et al., 2017; Do et al., 2023), and the availability of resources and opportunities for physical activity within the family context (Álvarez Muñoz and Hernández Prados, 2023) have been found to be crucial in influencing adolescents' exercise behaviors. The family environment encompasses various aspects, including parental attitudes (Cleland et al., 2011; Whooten et al., 2023), parental involvement (Kuo et al., 2007), family socioeconomic status (Cleland et al., 2011), and the home physical activity environment (Kuo et al., 2007; Cleland et al., 2011). Understanding the influence of the family environment on adolescent exercise behavior can lead to the development of effective interventions and programs to promote physical activity and cultivate exercise habits among adolescent. According to recent statistics, only 20% of Chinese youth aged 5–17 engage in 60 min of moderate to vigorous activity daily, which fall far below the recommendations set by the World Health Organization (Liu, 2023). The *Childhood Blue Book: China Children's Development Report (2021)* reveals an alarming increase of 8.7 percentage points in the rates of overweight and obesity among elementary and middle school students from 2010 to 2019 (Zhao and He, 2023). This highlights the urgent need for interventions promoting physical activity in this population.

However, a lack of scientific measurement and evaluation tools hinders a comprehensive understanding of how families influence adolescents' physical activity and exercise habits. Prior family-focused models such as the Family Influence Scale (Taylor et al., 1994) and Family Eating and Activity Habits Questionnaire (Golan et al., 2006) have quantified influences like parenting practices and role modeling on youth dietary and activity behaviors. However, these Western-developed tools lack cultural adaptation for the Chinese context. They often emphasize adolescent autonomy (Chai et al., 2018) rather than filial piety norms (Deng et al., 2022) This indicates a need for localized measurement models to fully capture family environment dynamics shaping Chinese adolescents' physical activity habits. To measure the influence of the family environment on adolescent physical activity behaviors, the development of a reliable and valid measurement tool is crucial. Firstly, current assessment tools often lack a comprehensive focus on family factors. Several existing studies exhibit limitations in exploring a wide array of family factors. For example, some studies employ retrospective surveys (Kim et al., 2007), diminishing relevance in understanding contemporary family environment impacts. Additionally, a substantial number rely solely on self-reports from adolescents (Henry et al., 2014), neglecting to incorporate parent perspectives. The lack of instruments evaluating various real-time family influences underscores the necessity for a culturally adapted scale that comprehensively addresses this gap. Others summarize influencing dimensions too broadly, failing to provide comprehensive content (McMurray et al., 1993; Joosse et al., 2008; Moreno et al., 2011). Secondly, within the Chinese context, the localization of evaluation tools for practical applications is not ideal, limiting their effectiveness in research. Chinese researchers mainly rely on foreign questionnaires or scales with revisions to measure physical activity habit of the local population. These primarily focus on family health awareness factors, such as individual physical fitness, health status (Wang, 2011), the importance attached to health (Lin, 2019), and the benefits of physical activity (Hu, 2017). Other factors include the family's economic and educational environment (Lv et al., 2020), parents' educational philosophy (Weng, 2015), parents' personality, and children's time monitoring and allocation (Chu and Xiao, 2020). However, these measurements often lack adequate localization to the unique Chinese context and norms. Concepts such as academic pressure (Xie et al., 2004), parenting style (Xie et al., 2022), filial piety (Cao and Tan, 2021) differ between Western and Chinese cultures. Directly applying measurement tools developed abroad could fail to capture family factors shaping physical activity habits among Chinese adolescents and potentially lead to erroneous interpretations.

Therefore, the primary aim of this study is to develop and validate a scale for assessing the influence of the family environment on the formation of physical activity habits among Chinese adolescents. This research holds significant implications: Firstly, it contributes to a comprehensive understanding of how families influence adolescents' physical activity habits and enhances effective promotion of physical activity. Secondly, it facilitates the development of assessment tools better suited to China's local contexts by specifically focusing on family factors relevant to Chinese adolescents. Lastly, the study aims to gain experience localizing and developing measures of how families impact physical activity for Chinese adolescents.

2 Materials and methods

2.1 Original items for scale development

This study reviewed and analyzed peer-reviewed empirical studies published before January 2023 that employed the social-ecological theory framework to examine how family

environment influences adolescents' physical activity habits. The inclusion criteria were: (1) study population of adolescents; (2) investigation of the relationship between family environment variables and adolescent physical activity; (3) use of social-ecological theory to guide the research. Based on the literature review, an interview guide was developed to elicit perspectives on family factors affecting adolescents' activity habits.

The original item pool was created through the following steps: First, extensive potential items grounded in the social-ecological theory and literature were generated through group discussion by the research team. Next, a panel of seven experts in adolescent development and health behavior research evaluated the items for relevance and specificity, with items endorsed by at least five experts retained. The resulting preliminary item pool underwent two rounds of qualitative interviews to obtain target population feedback on the relevance, clarity and construct coverage of the items. The first round involved 2 in-depth individual interviews (approx. 35 mins each) and 4 focus group discussions with 4–5 adolescents per group (approx. 30 mins each), with a total of 18 adolescents. The second round included 4 in-depth individual interviews (approx. 25 mins each) and 5 focus groups of 4–7 adolescents (approx. 35 mins each), with a total of 34 adolescents. Based on the interview data, items were added, eliminated and modified. Finally, the research team held group discussions to reach consensus on the final selection of items for the initial pool.

Subsequently, seven experts in relevant research fields were invited to evaluate the scale. The experts reviewed and examined the content validity index (item-level CVI, I-CVI) of the scale, identified issues, and provided specific modification suggestions. Based on the experts' recommendations, the item content of the scale was modified and revised, resulting in the development of a preliminary version of the "Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors."

2.2 Participants

The questionnaire survey method was employed in this study, taking into account the regional division of China's three major economic belts, to represent adolescents across China's diverse geographic and socioeconomic areas. To minimize selection bias, multi-stage cluster sampling was utilized. Schools were randomly selected from each region, then classes within chosen schools were randomly sampled to obtain a nationally representative, unbiased participant group. The multistage cluster sampling was utilized to select 1,061 participants from 24 middle schools in six provinces across eastern, central and western China. The effective response rate was 94.6%. Among the collected questionnaires 1,004 were deemed valid and randomly divided into two equal groups: sample 1 and sample 2, each consisting of 502 participants. Scale item analysis and exploratory factor analysis were conducted on sample 1 (248 boys, 254 girls; $M_{age} = 15.5$), while confirmatory factor analysis was performed on sample 2 (267 boys, 235 girls; $M_{age} = 16.5$).

The recruitment process involved a convenience sample of adolescent students from local schools. All participants' parents or legal guardians provided written informed consent, allowing their children to participate in research. The study received ethical approval from the Ethics Committee of East China Normal University, and this approval ensured that written informed consent was obtained from all participating adolescents and their parents or legal guardians (Ethical approval number: HR 476-2020).

2.3 Items and scoring method

Based on previous relevant scientific research findings and expert opinions, a scale was developed to assess the family factors influencing the development of physical activity habits among Chinese adolescents. The scale consists of three factors and 28 items. Factor 1: "Family Environment Construction" (FEC) comprises 8 items; Factor 2: "Family Action Support" (FAS) includes 12 items; and Factor 3: "Family Health Awareness" (FHA) consists of 8 items. The specific content of each factor and its corresponding items can be found in Table 1.

The core evaluation method employed in the scale is the 5-point Likert scale, where respondents indicate their level of agreement or compliance using the following scale: "1" for completely non-compliant, "2" for not very compliant, "3" for average, "4" for compliant, and "5" for very compliant. It is important to note that reverse-scored item is included in the scale, such as the item "Parents do not seem to normally participate in physical activities within the family health awareness factor, as shown in Table 1. Prior to data analysis, the reverse-scored item in the scale is reversed to ensure consistency in scoring.

2.4 Statistical analysis

This study conducted statistical analysis of the data using SPSS24.0 and Mplus 8.3. Initially, descriptive analysis was performed, wherein categorical variables were presented in terms of frequency and percentage, while numerical variables were characterized using the mean and standard deviation (Kim et al., 2020). Subsequently, expert validity evaluation was applied to assess the appropriateness of the scale items, following the methodology proposed by Polit and Beck (2006). The discrimination of each measurement item was tested through item analysis (Raykov and Marcoulides, 2011). Furthermore, exploratory factor analysis was utilized to delve into and optimize the scale structure (Costello and Osborne, 2019), The adequacy of the data for factor analysis was scrutinized using the Kaiser-Meyer-Olkin (KMO) parameter and the Bartlett sphericity test (Kleinbaum, 2013). The reliability of the scale was gauged using Cronbach's coefficient α serving as the reliability measurement index (Tavakol and Dennick, 2011). To verify the scale structure, confirmatory factor analysis was conducted (Brown, 2015), assessing the structural validity of the scale using Composite Reliability and Average Variance Extracted to test combined reliability and convergent validity, respectively. Finally, based on sample 2, content validity was reevaluated.

TABLE 1 Initial scale composition.

Factor	Variation	Item description	References
Family environment construction (FEC)	Family planning settings	1 Parents can discuss physical activity goals with me	Timperio et al., 2013
		2 Parents can make physical activity plans with me	Nakahori et al., 2016
		3 Parents can make physical activity plans that conform to my actual situation	Qiao, 2011
	Family atmosphere building	1 The family is equipped with sports equipment capable of physical activity	
		2 There is room for physical activity at home	
		3 My parents often tell me about physical activities	
		4 My parents often share their experience of physical activity with me	
		5 Parents often do physical activities at home	
Family action support (FAS)	Example of action	1 Parents can master 1–2 sports skills	Dai and Chen, 2019
		2 My parents often provide guidance when I am physically active	Chu and Xiao, 2020
		3 My parents often do physical activities with me	Bauer et al., 2008
		4 Parents never do physical activities at home	Rhodes et al., 2019
	Emotional support	1 My parents often agitate me when I encounter setbacks in physical activities	
		2 My parents often affirm me when I get achievements in physical activities	
		3 My parents often tolerate me when I have bad emotions in physical activities	
		4 When I am doing physical activities, my parents often stand beside me as an audience	
	Economic support	1 My parents can meet my needs for sports equipment	
		2 My parents can meet my need to watch sports games on the spot	
		3 My parents often give me material rewards after I participate in physical activities	
		4 My parents can meet my requirements for participating in sports interest classes	
Family health awareness (FHA)	Parental lifestyle	1 Physical activity is a part of parents' daily life	Tenjin et al., 2020
		2 Parents attach great importance to healthy lifestyle	Du, 2013
		3 Parents attach great importance to the study of health knowledge	Li and Liang, 2020
		4 Parents don't seem to take part in physical activities at ordinary times	Xie et al., 2004
	Parents' health awareness	1 Parents think that participating in physical activities can improve health	
		2 Parents think that physical activity can relieve stress	
		3 Parents think PE is as important as the main course	
		4 Parents believe that physical activity can promote all-round development	

3 Results

3.1 Expert assessment of the initial scale

In this study, seven experts were invited to inspect and analyze the survey scale that was designed and compiled in advance. The evaluation criteria used by the experts are outlined in Table 2. According to the guidelines, when the number of expert evaluations exceeds six, the I-CVI value should be >0.78 (Fleiss et al., 2013). After statistically summarizing the evaluations provided by the experts, items with I-CVI values lower than 0.78 in the initial scale were deemed inadequate and subsequently removed. The remaining items that met the requirements I-CVI criteria were retained.

Based on expert feedback, inappropriate items were removed. The qualified and reasonable scale items were compiled into a test scale, resulting in a preliminary measurement scale that demonstrated expert validity. The preliminary measurement scale was then evaluated by experts, and items such as items 4, 6, 7, 8, 9, 10, 12, 16, 18, 20, 21, 23, and 24, which had low I-CVI values 0.78 or below, were excluded. The remaining 15 items were retained for further analysis.

10.3389/fpsyg.2023.1243658

TABLE 2 Expert evaluation results of the initial scale.

Factor	Item	Expert evaluation results							A	n-A	I-CVI	Evaluation
		1	2	3	4	5	6	7				
Family environment construction (FEC)	1 Parents can discuss physical activity goals with me	4	4	4	4	4	4	4	7	0	1.00	Excellent
	2 Parents can make physical activity plans with me	4	4	4	4	4	4	4	7	0	1.00	Excellent
	3 Parents can make physical activity plans that conform to my actual situation	4	4	4	4	4	4	4	7	0	1.00	Excellent
	4 The family is equipped with sports equipment capable of physical activity	4	4	4	3	3	4	4	5	2	0.71	Good
	5 There is room for physical activity at home	4	4	4	4	4	4	4	7	0	1.00	Excellent
Family action support (FAS)	6 My parents often tell me about physical activities	4	4	3	4	3	4	4	5	2	0.71	Good
	7 My parents often share their experience of physical activity with me	4	3	4	4	3	4	4	5	2	0.71	Good
	8 Parents often do physical activities at home	4	4	4	3	4	3	4	5	2	0.71	Good
	9 Parents can master 1–2 sports skills	3	4	3	4	4	4	3	4	3	0.57	Fair
	10 My parents often provide guidance when I am physically active	4	4	4	4	4	4	4	5	2	0.71	Good
	11 My parents often do physical activities with me	4	4	4	4	4	4	4	7	0	1.00	Excellent
	12 Parents never do physical activities at home	4	4	3	4	4	4	3	5	2	0.71	Good
	13 My parents often agitate me when I encounter setbacks in physical activities	4	4	4	4	4	4	4	7	0	1.00	Excellent
	14 My parents often affirm me when I get achievements in physical activities	4	4	4	4	4	4	4	7	0	1.00	Excellent
	15 My parents often tolerate me when I have bad emotions in physical activities	4	4	4	4	4	4	4	7	0	1.00	Excellent
	16 When I am doing physical activities, my parents often stand beside me as an audience	4	3	4	4	4	3	4	5	2	0.71	Good
	17 My parents can meet my needs for sports equipment	4	4	4	4	4	4	4	7	0	1.00	Excellent
	18 My parents can meet my need to watch sports games on the spot	4	3	4	4	4	3	4	5	2	0.71	Good
	19 My parents often give me material rewards after I participate in physical activities	4	4	4	4	4	4	4	7	0	1.00	Excellent
	20 My parents can meet my requirements for participating in sports interest classes	4	4	4	4	4	4	4	5	2	0.71	Good
Family health awareness (FHA)	21 Physical activity is a part of parents' daily life	4	3	4	4	3	4	4	5	2	0.71	Good
	22 Parents attach great importance to healthy lifestyle	4	4	4	4	4	4	4	7	0	1.00	Excellent
	23 Parents attach great importance to the study of health knowledge	4	4	3	4	4	4	3	5	2	0.71	Good
	24 Parents don't seem to take part in physical activities at ordinary times	4	4	3	4	4	4	3	5	2	0.71	Good
	25 Parents think that participating in physical activities can improve health	4	4	4	4	4	4	4	7	0	1.00	Excellent
	26 Parents think that physical activity can relieve stress	4	4	4	4	4	4	4	7	0	1.00	Excellent
	27 Parents think PE is as important as the main course	4	4	4	4	4	4	4	7	0	1.00	Excellent
	28 Parents believe that physical activity can promote all-round development	4	4	4	4	4	4	4	7	0	1.00	Excellent

TABLE 3 Inspection results of scale items.

Item	Extreme group comparison	Item-total correlation test			Homogeneity test		Substandard index	Note
	Critical value	ITC	CITC	CAID	Commonalities	Factor loading		
Q1	20.876	0.709**	0.650	0.901	0.827	0.859	0	Retain
Q2	20.794	0.700**	0.642	0.902	0.802	0.844	0	Retain
Q3	20.589	0.709**	0.652	0.901	0.765	0.810	0	Retain
Q4	18.125	0.641**	0.570	0.904	0.652	0.759	0	Retain
Q5	19.139	0.659**	0.595	0.903	0.515	0.634	0	Retain
Q6	19.081	0.689**	0.629	0.902	0.696	0.800	0	Retain
Q7	19.756	0.735**	0.685	0.900	0.806	0.858	0	Retain
Q8	19.165	0.694**	0.641	0.902	0.707	0.801	0	Retain
Q9	19.688	0.722**	0.672	0.901	0.677	0.755	0	Retain
Q10	**0.627**	**0.034**	**−0.001**	**0.914**	0.985	0.992	4	**Delete**
Q11	14.803	0.606**	0.535	0.905	0.554	0.712	0	Retain
Q12	15.818	0.655**	0.593	0.903	0.655	0.760	0	Retain
Q13	16.800	0.646**	0.586	0.903	0.772	0.854	0	Retain
Q14	18.175	0.687**	0.637	0.902	0.770	0.834	0	Retain
Q15	17.022	0.681**	0.622	0.902	0.716	0.795	0	Retain
Q16	14.539	0.579**	0.514	0.906	0.629	0.770	0	Retain
Judgment criteria	≥3.0	≥0.40	≥0.40	≤0.92	≥0.20	≥0.45		

**$p < 0.01$.

3.2 Item analysis

After the evaluation by experts, the original 28 items of the scale were reduced to 15 items. In sample 1, which consisted of the 502 valid adolescent questionnaires, the average score for each adolescent's family environment factor was calculated based on the scoring method using the 15-items pre-test scale. The total scores of all subjects were ranked in ascending order. The low group was defined as the material information below 27%, the middle group as the data between 27% and 73%, and the high group as the data above 73% (Kelley, 1939).

Independent samples *t*-test were conducted to determine if there were significant differences between the high and low groups. Table 3 presents the analysis results of the family environment factor subscale items. The family environment factor subscale was analyzed using the critical ratio analysis method based on various indicators. The score for the first 27% was 147, while the score for the last 27% is 139. After conducting the resolution coefficient test and *t*-test, items with *t*-values > 3 and $P < 0.001$ were retained. As a result, item Q29 was eliminated, and the scale was reduced to 15 items.

3.3 Exploratory factor analysis and optimization of the scale

The study first tested the suitability of the remaining 15 items related to family environment factors for factor analysis.

TABLE 4 Kaiser-meyer-olkin test and bartlett sphericity test.

Kaiser-meyer-olkin (KMO)	Bartlett sphericity test		
	Approx. Chi-Square	df	Sig.
0.916	4,704.563	105	0.000

The Kaiser-Meyer-Olkin (KMO) value was found to be 0.916, which is >0.8, indicating that the variables are suitable for factor analysis. The Bartlett's sphericity test yielded an approximate chi-square value of 4,704.563 with a significance of 0.000, meeting the significance level ($P < 0.05$) (Table 4). These results suggest that the items are not independent and that there are common factors present in the overall correlation matrix, supporting the suitability of factor analysis for the "Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors."

Principal component analysis was conducted to extract common factors with eigenvalues >1, and items with factor loadings exceeding 0.5 were retained. The exploratory factor analysis results in Table 5 indicate that each item's communalities are higher than 0.4, indicating effective extraction of research item information. Through this process, a total of three factors were obtained, each with eigenvalues >1. The variance explanation by these three factors after rotation was 25.938%, 23.747%, and 20.410%, respectively, with a cumulative variance explanation of 25.938%, 49.686% %, and 70.096%. These factors effectively capture

10.3389/fpsyg.2023.1243658

TABLE 5 Results of exploratory factor analysis.

Item	Component			Communalities
	1	2	3	
Q1 Parents can discuss physical activity goals with me			0.860	0.827
Q2 Parents can make physical activity plans with me			0.846	0.802
Q3 Parents can make physical activity plans that conform to my actual situation			0.810	0.764
Q4 There is room for physical activity at home			0.759	0.652
Q5 My parents often do physical activities with me	0.635			0.512
Q6 My parents often agitate me when I encounter setbacks in physical activities	0.799			0.695
Q7 My parents often affirm me when I get achievements in physical activities	0.856			0.800
Q8 My parents often tolerate me when I have bad emotions in physical activities	0.799			0.701
Q9 My parents can meet my needs for sports equipment	0.755			0.676
Q10 My parents can meet my need to watch sports games on the spot	0.713			0.546
Q11 Parents attach great importance to healthy lifestyle		0.759		0.655
Q12 Parents think that participating in physical activities can improve health		0.854		0.771
Q13 Parents think that physical activity can relieve stress		0.834		0.770
Q14 Parents think PE is as important as the main course		0.795		0.715
Q15 Parents believe that physical activity can promote all-round development		0.769		0.628
Eigen value (Rotated)	3.891	3.562	3.062	
% of Variance (Rotated)	25.938	23.747	20.410	
Cumulative % of Variance (Rotated)	25.938	49.686	70.096	

the relevant information. The optimized scale consists of 15 items, which were categorized into three factors.

Factor 1 comprises 6 items (Q1, Q2, Q3, Q4, Q5, and Q6) that reflect family members' support, encouragement and rewards, and it is named "Family Environment Construction" (FEC). Factor 2 consists of 5 items (Q7, Q8, Q9, Q10, and Q11) that primarily reflect the parents' healthy lifestyle and their recognition of healthy behaviors, leading to its naming as "Family Action Support" (FAS). Factor 3 includes 4 items (Q12, Q13, Q14, and Q15) that reflect family-related information on physical activity, goal planning, and the creation of physical activity space, thus termed "Family Health Awareness" (FHA).

3.4 Reliability analysis of scale content

As shown in Table 6, presents the results of the internal consistency analysis of the measured data. The Cronbach α values for the three dimensions "FEC," "FAS," and "FHA" are 0.894, 0.890, and 0.894, respectively. The Cronbach α value of the overall scale is 0.914. These values indicate high reliability, as each dimension and the total scale surpass the recommended threshold of 0.8. Furthermore, the overall scale demonstrates excellent reliability with a value exceeding 0.9. These findings indicates that the "Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors" is reliable and effectively captures the family environment factors that influence the development of physical activity habits among adolescents.

Primarily, with the application of Cronbach α, the corrected item-total correlation (Corrected Item-Total Correlation, CITC) and the Cronbach's α coefficient after item deletion (Cronbach's Alpha if Item Deleted, CAID) to determine the structure and dimensions of the research. The reliability was quantified, and Table 7 indicates the results of the reliability analysis based on sample 2. It shows that the CITC value of each measurement item is >0.4, the CAID value is lower than the Cronbach's α coefficient of the corresponding variable, the Cronbach's α of FEC, FAS, and FHA is higher than 0.7, and the total Cronbach's α coefficient of the scale is 0.915. The analysis results indicate that the family environment factor and its dimensions have high reliability. This demonstrates that the actual situations of the selected samples are relatively stable and consistent.

3.5 Confirmatory factor analysis of the scale

The validity of the research structure and its dimensions was assessed through Confirmatory Factor Analysis (CFA) (Wu, 2010). The results of confirmatory factor analysis, as shown in Table 8, indicate a good fit with $\chi^2 = 126.175$, df = 87, $\chi^2/df = 1.45$, RMSEA = 0.03, SRMR = 0.027, CFI = 0.991, TLI = 0.989. These indices meet the fitting requirements established by Hu and Bentler (1999). The χ^2/df value falls within an acceptable range below 5 (Bentler and Bonett, 1987). In this study, suggesting that the first-order 3-factor confirmatory factor analysis model adequately represents the home environment based on the data. Therefore, the confirmatory factor model demonstrates a sound structure.

10.3389/fpsyg.2023.1243658

TABLE 6 Reliability analysis results of the scale based on sample 1.

Factor	Cronbach α	Item
Family environment construction	0.894	4
Family action support	0.890	6
Family health awareness	0.894	5
Family environmental factors	0.914	15

The standardized factor loading of the items ranged from 0.667 to 0.849, and the composite reliability (CR) value for each variable exceed 0.7. These findings indicate that all variables analyzed exhibited desirable composite reliability. Additionally, the average variance extracted (AVE) of each variable exceeds 0.5, indicating good convergent validity. In summary, the family environment factor and its dimensions demonstrated good reliability and validity in this study.

3.6 Test-retest reliability

In this study, we surveyed a sample of 56 high school students using the Chinese Youth Activity Habit Formation Scale. To prevent the results of the initial test from affecting the second test, we introduced a 2-week interval between the pre-test and post-test. The retest reliability coefficient ranged from 0.79 to 0.84, and the correlation coefficients for the three dimensions were 0.832, 0.863, and 0.832, respectively. All these coefficients surpassed 0.7, with an overall coefficient of 0.890. The retest correlation coefficients of the scale meet the necessary criteria, confirming that the reliable retest reliability of Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors is reliable and fulfills the retest requirements.

4 Discussion

4.1 Results interpretation

Existing studies have predominantly concentrated on family factors influencing adolescents' physical activity. For instance, research have delved into the impact of parental behaviors, such as role modeling (Madsen et al., 2009; Yao and Rhodes, 2015) and parental support (Edwardson et al., 2013; Langer et al., 2014) on youth activity levels. Other have investigated the effects of the family's physical home environment on adolescent behaviors (Trost et al., 2003; Spurrier et al., 2008). However, there has been limited theoretical discussion and few studies exploring factors within the family environment that contribute to the development of adolescents' physical activity habits.

The findings of this study make several notable contributions by identifying three key family environment factors influencing Chinese adolescents' physical activity habits: Family Environment Construction (FEC), Family Action Support (FAS), and Family Health Awareness (FHA). The identification of these specific elements provides new evidence that aspects of the family environment play a crucial role in shaping activity patterns

TABLE 7 Reliability analysis results of the scale based on sample 2.

Reliability					
Factor	Item	CITC	SMC	CAID	Cronbach α
Family environment construction (FEC)	FEC1	0.756	0.573	0.822	0.871
	FEC2	0.734	0.553	0.830	
	FEC3	0.748	0.569	0.825	
	FEC4	0.661	0.440	0.861	
Family action support (FAS)	FAS1	0.641	0.418	0.876	0.886
	FAS2	0.704	0.527	0.866	
	FAS3	0.752	0.604	0.858	
	FAS4	0.742	0.578	0.860	
	FAS5	0.746	0.561	0.860	
	FAS6	0.625	0.415	0.879	
Family health awareness (FHA)	FHA1	0.657	0.433	0.868	0.880
	FHA2	0.770	0.616	0.841	
	FHA3	0.781	0.620	0.840	
	FHA4	0.723	0.541	0.852	
	FHA5	0.645	0.423	0.870	

during adolescence. Family Environment Construction (FEC) appears to be a particularly relevant factor in China, possibly due to the cultural emphasis on parental management of children's time. Furthermore, Family Environment Construction (FEC) was found to impact activity time, type, space and interests, aligning with previous literature that illustrates the multifaceted influences of the family environment on youth behaviors (McIver et al., 2009). Family Action Support (FAS) positively predicted physical activity, aligning with previous research that indicates family support enhances adolescent self-efficacy, facilitating participation (Quarmby and Dagkas, 2010; Dai and Chen, 2019). This underscores the necessity for interventions aimed at enhancing parental support. Moreover, results from Family Health Awareness (FHA) revealed that parental modeling positively influenced adolescents' activity levels (Ren et al., 2012; Sigmundová et al., 2014), highlighting the necessity for widespread public health messaging regarding parental impacts. Overall, these findings underscore the family environment's role as a key determinant of healthy physical activity habits during adolescence in China, while also suggesting cultural variations in the relative strength of specific family influence factors.

To address the limitations of using foreign-related scales in measuring family environment factors influencing the formation of physical activity habits, this study focuses on addressing issues such as poor measurement relevance and a failure to capture the key elements affecting habit formation. Drawing on classic questionnaires and scales from both domestic and international sources, this study developed a localized "Chinese Adolescents' Physical

10.3389/fpsyg.2023.1243658

TABLE 8 Results of confirmatory factor analysis.

Factor	Item	CFA		
		Standard	CR	AVE
Family environment construction (FEC)	FEC1	0.833	0.872	0.631
	FEC2	0.806		
	FEC3	0.820		
	FEC4	0.714		
Family action support (FAS)	FAS1	0.684	0.889	0.572
	FAS2	0.758		
	FAS3	0.819		
	FAS4	0.806		
	FAS5	0.790		
	FAS6	0.667		
Family health awareness (FHA)	FHA1	0.704	0.883	0.603
	FHA2	0.838		
	FHA3	0.849		
	FHA4	0.792		
	FHA5	0.686		

Activity Habit Formation Scale: Family Environmental Influencing Factors."

While the scale development process was rigorous, a key innovation lies in the cultural specificity tailored to Chinese adolescents, differentiating it from existing family influence scales. For instance, Western scales often emphasize adolescent autonomy (Chai et al., 2018), while this scale captures Chinese cultural values such as filial piety (Peng and Li, 2023) and parental authority over play time (Deng et al., 2022). The localized conceptualization enhances the validity of measuring family dynamics influencing physical activity behaviors among Chinese youth.

The scale development process was both rigorous and comprehensive. It drew on previous research findings, used the Harman single-factor test to assess common method bias, conducted item analysis to test item discrimination, explored and optimized the scale's structure, and employed Cronbach's α as a reliability measurement index. The scale's structure was further validated through confirmatory factor analysis, and CR and AVE were used to assess the scale's reliability and validity, respectively.

This study systematically refined the initial scale, measuring family environmental influences on physical activity among Chinese adolescents. Expert advice was incorporated to optimize the questionnaire, enhancing its precision. Refinements involved consolidating related factors, revising dimensions, and eliminating items through rigorous statistical testing and expert review. Specifically, factors related to activity space design and atmosphere creation were combined into "space atmosphere creation." The initial 28 items were reduced after an evaluation process that included content validation by experts and subsequent statistical analysis. Items such as Q4, Q6, Q16, and Q23 were eliminated due to inadequate relevance based on an item-CVI threshold.

TABLE 9 Formal scale.

Factor	No.	Item
Family environment construction (FEC)	FEC1	Q1 Parents can discuss physical activity goals with me
	FEC2	Q2 Parents can make physical activity plans with me
	FEC3	Q3 Parents can make physical activity plans that conform to my actual situation
	FEC4	Q4 There is room for physical activity at home
Family action support (FAS)	FAS1	Q5 My parents often do physical activities with me
	FAS2	Q6 My parents often agitate me when I encounter setbacks in physical activities
	FAS3	Q7 My parents often affirm me when I get achievements in physical activities
	FAS4	Q8 My parents often tolerate me when I have bad emotions in physical activities
	FAS5	Q9 My parents can meet my needs for sports equipment
	FAS6	Q10 My parents can meet my need to watch sports games on the spot
Family health awareness (FHA)	FHA1	Q11 Parents attach great importance to healthy lifestyle
	FHA2	Q12 Parents think that participating in physical activities can improve health
	FHA3	Q13 Parents think that physical activity can relieve stress
	FHA4	Q14 Parents think PE is as important as the main course
	FHA5	Q15 Parents believe that physical activity can promote all-round development

Q29 was deleted due to poor discrimination between respondent groups. This iterative refinement process ensured that only the most valid and reliable items were retained. Specifically, items with I-CVI scores below 0.78 were eliminated to retain the most pertinent survey questions. The remaining items then underwent additional evaluation of discrimination, reliability, and validity, resulting in the removal of any that did not meet psychometric standards. This rigorous scale development methodology focused on refining the initial family environmental influences scale through expert input and statistical testing. The adjustments successfully optimized item content and dimension structure while eliminating inadequate components. This systematic approach resulted in a 15-item scale demonstrating strong psychometric properties.

This study developed a culturally-adapted scale assessing family environmental influences on Chinese adolescents' physical activity through a rigorous multiphase process involving expert reviews and statistical optimization. The methodology ensured retention of only the most valid and reliable items, resulting in a precise, highly reliable 15-item scale tailored to the Chinese context, as shown in Table 9. This newly developed scale makes important

theoretical contributions by filling a significant research gap—the prior lack of quantitative models customized to assess family environment influences specific to Chinese adolescents. Availability of a validated tool tailored to the Chinese context represents an essential advancement, enabling more rigorous investigation of culturally-specific familial factors affecting youth physical activity. Practically, the scale provides an empirical foundation to inform the development of culturally-appropriate family-based interventions aimed at modifying key environment elements to promote healthy adolescent activity habits.

In conclusion, the rigorous methodology undertaken to develop and optimize this culturally-adapted scale, coupled with its enhanced precision and reliability, represents an important contribution. The scale will allow deeper investigation of Chinese familial determinants shaping youth activity patterns. Additionally, findings generated can inform family-focused intervention strategies to promote healthy adolescent physical activity behaviors in China.

4.2 Limitations and areas for future research

In this study, it is crucial to acknowledge certain limitations. Firstly, despite conducting a thorough review and inclusion of item sources during the formation of the item pool, with a concerted effort to encompass a wide range of potential family factors, some items were still excluded based on expert evaluation, potentially resulting in the oversight of certain assessment details. Therefore, it is imperative to recognize the significance of further enhancing the scale's specificity and intricacy in future research, building upon the foundation established in this study.

Secondly, while our comprehensive survey covered multiple cities across diverse regions of China, validating the universality and efficacy of the scale, there is still room for expanding the sample size. Obtaining a more diverse range of samples would contribute to further confirming the scale's applicability.

Thirdly, given the focus of our study on the specific Chinese context, congruent with Chinese policy and cultural background, potential limitations might arise concerning the scale's practicality in other cultural and national contexts.

Notwithstanding these limitations, the scale holds substantial research value in terms of fostering localization and comprehensiveness, aligning seamlessly with the initial objectives. It represents the most extensive scale developed to date for assessing the impact of family environmental factors on the formation of physical activity habits among Chinese adolescents. Consequently, our scale provides invaluable insights into the cultivation of physical activity levels among Chinese adolescents.

5 Conclusion

In conclusion, this study developed and validated the "Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors," comprising three key factors: "Family Environment Construction" (FEC), "Family Action Support" (FAS), and "Family Health Awareness" (FHA). Reliability and validity analysis indicate this scale provides an objective and effective tool to measure family environmental influences on adolescent physical activity habits.

In summary, the development and validation of the "Chinese Adolescents' Physical Activity Habit Formation Scale: Family Environmental Influencing Factors" represents a significant advancement for research on family determinants of physical activity and wellbeing among Chinese youth. The availability of a reliable and valid scale tailored to the Chinese adolescent population will enable a more robust quantitative investigation into how family environmental factors, unique to the Chinese cultural context, shape physical activity habits. This culture-specific tool can inform targeted interventions involving Chinese families, schools, and communities to promote participation in regular physical activity among adolescents, with significant implications for improving youth wellbeing at the national level in China. Overall, the scale provides an essential culturally grounded tool for deepening understanding and improving key family-level determinants of healthy adolescent development in China.

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.

Ethics statement

This study has been reviewed and approved by the Ethics Committee of East China Normal University (HR 476-2020). The studies were conducted in accordance with local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

XZ, JY, WZ, and XF contributed to the conception and design of the study. JY and XF were involved in implementing the study and data collection. XZ undertook data analysis and wrote the first draft of the manuscript. XZ, JY, and WZ polished and revised the draft. All authors contributed to the article and approved the submitted version.

Funding

This study was funded by the 2023 Youth Fund for Humanities and Social Science Research of the Ministry of Education, research title: "Model Construction and Empirical Research on Influencing Factors of physical Activity Habit Formation of Chinese Adolescents" (Project No. 23XJC890048).

Acknowledgments

The authors thank all the participants who made this study possible.

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

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adkins, M., Bice, M. R., Heelan, K., and Ball, J. (2017). Enhancing physical education with a supplemental physical activity program. *J. Phys. Educ. Recreat. Dance* 88, 28–34. doi: 10.1080/07303084.2017.1356765

Álvarez Muñoz, J. S., and Hernández Prados, M. Á. (2023). Types of family leisure activities in families with adolescents. *J. Family Issues* 10, 0192513X221150995. doi: 10.1177/0192513X221150995

Bandura, A. (1986). Social foundations of thought and action: a social cognitive theory. *Englewood Cliffs* [Preprint]. Available at: https://cir.nii.ac.jp/crid/1570854174839355904 (accessed December 15, 2023).

Bauer, K. W., Nelson, M. C., Boutelle, K. N., and Neumark-Sztainer, D. (2008). Parental influences on adolescents' physical activity and sedentary behavior: longitudinal findings from Project EAT-II. *Int. J. Behav. Nutr. Phys. Activ.* 5, 12. doi: 10.1186/1479-5868-5-12

Bentler, P. M., and Bonett, D. G. (1987). Citation-classic-significance tests and goodness of fit in the analysis of covariance-structures. *Curr. Contents/Soc. Behav. Sci.* 37, 16–16.

Brown, T. A. (2015). *Confirmatory Factor Analysis for Applied Research.* Second Edition. London: Guilford Publications.

Cao, G., and Tan, X. (2021). The study on the process of adolescents' adolescent - parent conflict regarding schoolwork. *Youth Stud.* 3, 82–93.

Chai, H. Y., Niu, G. F., Chu, X. W., Wei, Q., Song, Y. H., and Sun, X. J. (2018). Fear of missing out: what have I missed again? *Adv. Psychol. Sci.* 26, 527. doi: 10.3724/SP.J.1042.2018.00527

Chu, X., and Xiao, H. (2020). Teenager physical exercise habit formation influencing factor model establishment and analysis. *J. Phys. Educ.* 27, 116–123. doi: 10.16237/j.cnki.cn44-1404/g8.2020.03.018

Cleland, V., Timperio, A., Salmon, J., Hume, C., Telford, A., and Crawford, D. (2011). A longitudinal study of the family physical activity environment and physical activity among youth. *Am. J. Health Promot.* 25, 159–167. doi: 10.4278/ajhp.090303-QUAN-93

Costello, A., and Osborne, J. (2019). Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. *Pract. Assess. Res. Eval.* 10, 7. doi: 10.7275/jyj1-4868

Dai, J., and Chen, H. (2019). An social ecological perspective of analyzing factors influencing Chinese adolescents' in-school physical activity levels. *J. ShangHai Univ. Sport* 43, 85–91. doi: 10.16099/j.sus.2019.03.013

Deng, J., Lv, Z., Long, Z., Liu, T., and Lu, Y. (2022). Parental educational expectations and adolescents' perceived academic stress: moderating role of physical activity. *J. Phys. Educ.* 38, 37–45. doi: 10.16419/j.cnki.42-1684/g8.2022.05.009

Do, B., Lopez, N. V., Dunton, G. F., and Mason, T. B. (2023). Motivational and self-regulatory processes associated with weight-related parenting behaviors. *Obesity Pillars* 5, 100049. doi: 10.1016/j.obpill.2022.100049

Du, Y. (2013). *Studies on the cultivation of the adolescent physical exercise habit—taking Yantai city as an example*. Master Dissertation. Ludong University.

Edwardson, C. L., Gorely, T., Pearson, N., and Atkin, A. (2013). Sources of activity-related social support and adolescents' objectively measured after-school and weekend physical activity: gender and age differences. *J. Phys. Activ. Health* 10, 1153–1158. doi: 10.1123/jpah.10.8.1153

Fleiss, J. L., Levin, B., and Paik, M. C. (2013). *Statistical Methods for Rates and Proportions*. New York, NY: John Wiley and Sons.

Godin, G. (1994). "Social-cognitive models," in *Advances in Exercise Adherence,* ed. R. K. Dishman (Champaign, IL, England: Human Kinetics Publishers) 113–136.

Golan, M., Kaufman, V., and Shahar, D. R. (2006). Childhood obesity treatment: targeting parents exclusively v. parents and children. *Br. J. Nutr.* 95, 1008–1015. doi: 10.1079/BJN20061757

Henry, B. W., Smith, T. J., and Ahmad, S. (2014). Psychometric assessment of the: measuring parents' views on food and behavior and attitudes questionnaire for healthy habits physical activity. *Public Health Nutr.* 17, 1004–1012. doi: 10.1017/S136898001200554X

Hu, L., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct. Equat. Model.* 6, 1–55. doi: 10.1080/10705519909540118

Hu, S., and Cai, D. (2023). Development of perceived family support and positive mental health in junior high school students: a three-year longitudinal study. *J. Early Adolesc.* 43, 216–243. doi: 10.1177/02724316221101534

Hu, Y. (2017). *Construction and application of evaluation index system of exercise and fitness of children and youth in China*. Ph.D. Dissertation. Shanghai University of Sport.

Hunt, P., Barrios, L., Telljohann, S. K., and Mazyck, D. (2015). A whole school approach: collaborative development of school health policies, processes, and practices. *J. School Health* 85, 802–809. doi: 10.1111/josh.12305

Joosse, L., Stearns, M., Anderson, H., Hartlaub, P., and Euclide, J. (2008). Fit kids/fit families: a report on a countywide effort to promote healthy behaviors. *Wisconsin Med. J.* 107, 231.

Kelley, T. L. (1939). The selection of upper and lower groups for the validation of test items. *J. Educ. Psychol.* 30, 17–24. doi: 10.1037/h0057123

Kim, D. H., Kang, I. S., and Lee, S. (2007). Social support, self-concept and self-efficacy as correlates of adolescents' physical activity and eating habits. *J. Korean Acad. Family Med.* 28, 292–301.

Kim, M., Mallory, C., and Valerio, T. (2020). *Statistics for Evidence-Based Practice in Nursing*. Burlington, MA: Jones and Bartlett Learning.

Kleinbaum, D. G. (2013). *Applied Regression Analysis and Other Multivariable Methods*. Fifth edition. Boston, MA: Cengage Learning.

Korom, B., Malloy, M., Remmers, C., Cevilla, M., Dione, K., Papanek, P., et al. (2023). "It's about being healthy"; a novel approach to the socio-ecological model using family perspectives within the Latinx community. *BMC Public Health* 23, 1–10. doi: 10.1186/s12889-023-15005-2

Kuo, J., Voorhees, C. C., Haythornthwaite, J. A., and Young, D. R. (2007). Associations between family support, family intimacy, and neighborhood violence and physical activity in urban adolescent girls. *Am. J. Public Health* 97, 101–103. doi: 10.2105/AJPH.2005.072348

Langer, S. L., Crain, A. L., Senso, M. M., Levy, R. L., and Sherwood, N. E. (2014). Predicting child physical activity and screen time: parental support for physical activity and general parenting styles. *J. Pediatr. Psychol.* 39, 633–642. doi: 10.1093/jpepsy/jsu021

Li, J., and Liang, S. (2020). Development and validation of the adolescent physical activity promoting factor scale—grounded theory construction based on the "three non-disconnection models of family-school-community". *J. Sports Sci.* 41, 84–103. doi: 10.13598/j.issn1004-4590.2020.01.027

Lin, J. (2019). *Research on the characteristics and development mechanism of learning interests in physical education*. Ph.D. Dissertation. Northeast Normal University.

Liu, Y. (2023). A study on the influence parents' physical behavior and pupils' participation in sports. *J. Jilin Sport Univ.* 39, 96–108. doi: 10.13720/j.cnki.22-1286.2023.03.012

Lv, H., Wang, K., and Liu, H. (2020). Family sports environment and young children's physically active lifestyle: the mediating role of family social capital. *J. Beijing Sport Univ.* 43, 77–88. doi: 10.19582/j.cnki.11-3785/g8.2020.05.008

Madsen, K. A., McCulloch, C. E., and Crawford, P. B. (2009). Parent modeling: perceptions of parents' physical activity predict girls' activity throughout adolescence. *J. Pediatr.* 154, 278–283.e2. doi: 10.1016/j.jpeds.2008.07.044

McIver, K. L., Brown, W. H., Pfeiffer, K. A., Dowda, M., and Pate, R. R. (2009). Assessing children's physical activity in their homes: the observational system for recording physical activity in children-home. *J. Appl. Behav. Analy.* 42, 1–16. doi: 10.1901/jaba.2009.42-1

McMurray, R. G., Bradley, C. B., Harrell, J. S., Bernthal, P. R., Frauman, A. C., and Bangdiwala, S. I. (1993). Parental influences on childhood fitness and activity patterns. *Res. Quart. Exer. Sport* 64, 249–255. doi: 10.1080/02701367.1993.10608809

Moreno, J. P., Kelley, M. L., Landry, D. N., Paasch, V., Terlecki, M. A., Johnston, C. A., et al. (2011). Development and validation of the family health behavior scale. *Int. J. Pediatr. Obes.* 6, e480–486. doi: 10.3109/17477166.2011.575148

Mota, J. (1998). Parents' physical activity behaviors and children's physical activity. *J. Hum. Move. Stud.* 2, 89–100.

Nakahori, N., Sekine, M., Yamada, M., and Tatsuse, T. (2016). The relationship between home environment and children's dietary behaviors, lifestyle factors, and health: super food education school project by the japanese ministry of education, culture, sports, science and technology. *Japanese J. Public Health* 63, 190–201. doi: 10.11236/jph.63.4_190

Peng, J., and Li, N. (2023). Controlling parenting style: historicalevolution, generative logic and crack path. *Renmin Univ. China Educ. J.* 3, 153–165.

Polit, D. F., and Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Res. Nurs. Health* 29, 489–497. doi: 10.1002/nur.20147

Qiao, Y. (2011). Forming mechanism and affecting factors of exercising habits of teenagers. *J. Phys. Educ.* 18, 87–94. doi: 10.16237/j.cnki.cn44-1404/g8.2011.03.023

Quarmby, T., and Dagkas, S. (2010). Children's engagement in leisure time physical activity: exploring family structure as a determinant. *Leisure Stud.* 29, 53–66. doi: 10.1080/02614360903242560

Raykov, T., and Marcoulides, G. A. (2011). *Introduction to Psychometric Theory*. London: Routledge. doi: 10.4324/9780203841624

Ren, J., Ping, J., Shu, S., Yang, Y., and Dai, J. (2012). Building of physical and health education model of adolescent and intervention strategies —based on a survey of primary and secondary students in Shanghai. *China Sport Sci.* 32, 31–36. doi: 10.16469/j.css.2012.09.006

Rhodes, R. E., Berry, T., Faulkner, G., Latimer-Cheung, A. E., O'Reilly, N., Tremblay, M. S., et al. (2019). Application of the multi-process action control framework to understand parental support of child and youth physical activity, sleep, and screen time behaviours. *Appl. Psychol.* 11, 223–239. doi: 10.1111/aphw.12150

Roque Garay, A. (2018). Promoción de estilos de vida saludable en el entorno familiar. *Nutr. Clin. Dietet. Hospit.* 4, 183–188. doi: 10.12873/374roquegaray

Sallis, J. F., and Hovell, M. F. (1990). Determinants of exercise behavior. *Exer. Sport Sci. Rev.* 18, 307. doi: 10.1249/00003677-199001000-00014

Sigmundová, D., Sigmund, E., Vokáčová, J., and Kopková, J. (2014). Parent-child associations in pedometer-determined physical activity and sedentary behaviour on weekdays and weekends in random samples of families in the Czech Republic. *Int. J. Environ. Res. Public Health* 11, 7163–7181. doi: 10.3390/ijerph110707163

Spurrier, N. J., Magarey, A. A., Golley, R., Curnow, F., and Sawyer, M. G. (2008). Relationships between the home environment and physical activity and dietary patterns of preschool children: a cross-sectional study. *Int. J. Behav. Nutr. Phys. Activity* 5, 1–12. doi: 10.1186/1479-5868-5-31

Tavakol, M., and Dennick, R. (2011). Making sense of Cronbach's alpha. *Int. J. Med. Educ.* 2, 53–55. doi: 10.5116/ijme.4dfb.8dfd

Taylor, W. C., Baranowski, T., and Sallis, J. F. (1994). "Family determinants of childhood physical activity: a social-cognitive model," in *Advances in Exercise Adherence,* ed. R. K. Dishman (Champaign, IL, England: Human Kinetics Publishers) 319–342.

Tenjin, K., Sekine, M., Yamada, M., and Tatsuse, T. (2020). Relationship between parental lifestyle and dietary habits of children: a cross-sectional study. *J. Epidemiol.* 30, 253–259. doi: 10.2188/jea.JE20190015

Timperio, A. F., van Stralen, M. M., Brug, J., Bere, E., Chinapaw, M. J. M., De Bourdeaudhuij, I., et al. (2013). Direct and indirect associations between the family physical activity environment and sports participation among 10–12 year-old European children: testing the EnRG framework in the ENERGY project. *Int. J. Behav. Nutr. Phys. Activ.* 10, 1–10. doi: 10.1186/1479-5868-10-15

Trost, S. G., Sallis, J. F., Pate, R. R., Freedson, P. S., Taylor, W. C., and Dowda, M. (2003). Evaluating a model of parental influence on youth physical activity. *Am. J. Prev. Med.* 25, 277–282. doi: 10.1016/S0749-3797(03)00217-4

van Sluijs, E. M., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., et al. (2021). Physical activity behaviours in adolescence: current evidence and opportunities for intervention. *Lancet* 398, 429–442. doi: 10.1016/S0140-6736(21)01259-9

Wang, K. (2011). *A study of conceptual model,evaluation methods and educational intervention of physical exercise habits of college students*. Ph.D. Dissertation. East China Normal University.

Weng, M. (2015). *Research on the habits of physical exercise of middle school students in china – taking Hainan province as an example*. Ph.D. Dissertation. Shaanxi Normal University.

Whooten, R., Horan, C., Aguirre, A., Dartley, A. N., and Taveras, E. (2023). Parent and pediatrician perspectives on physical activity promotion in pediatric primary care: a preliminary mixed methods study. *Am. J. Health Promot.* 37, 65–76. doi: 10.1177/08901171221113317

World Health Organization (2022). *Physical activity.* Available online at: https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed November 12, 2023).

Wu, M. (2010). *Questionnaire Statistical Analysis Practice - SPSS Operation and Application*. Chongqing: Chongqing University Press.

Xie, Y., Fang, Y., and Wang, H. (2004). Current situation and speculation of sport exercise habit. *Shandong Sports Sci. Technol.* 1, 42–44. doi: 10.14105/j.cnki.1009-9840.2004.01.016

Xie, Y., Shi, Z., Yin, L., and Lan, L. (2022). A meta-analysis of the relationships between Chinese parenting styles and child academic achievement. *Best Evid. Chinese Educ.* 12, 1589–1595. doi: 10.15354/bece.22.ab009

Yao, C. A., and Rhodes, R. E. (2015). Parental correlates in child and adolescent physical activity: a meta-analysis. *Int. J. Behav. Nutr. Phys. Activ.* 12, 10. doi: 10.1186/s12966-015-0163-y

Zhao, J., and He, J. (2023). Values, dilemmas and strategies of parents'participation in children's family sports. *J. Shenyang Sport Univ.* 42, 62–68.

Zovko, V., Djuric, S., Sember, V., and Jurak, G. (2021). Are family physical activity habits passed on to their children? *Front. Psychol.* 12, 741735. doi: 10.3389/fpsyg.2021.741735

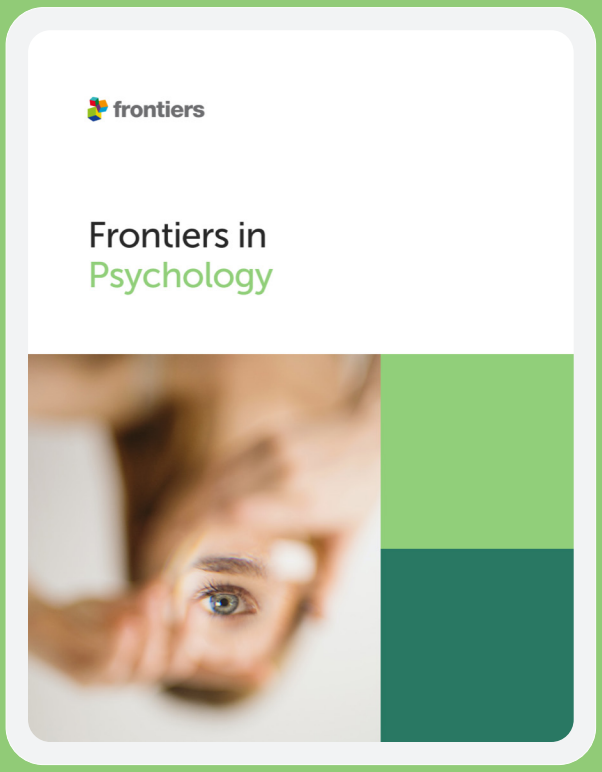
Frontiers in Psychology

Paving the way for a greater understanding of human behavior

The most cited journal in its field, exploring psychological sciences - from clinical research to cognitive science, from imaging studies to human factors, and from animal cognition to social psychology.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact