BIO-PSYCHO-SOCIAL PERSPECTIVES ON THE INDIVIDUAL RESPONSE TO PHYSICAL ACTIVITY

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BIO-PSYCHO-SOCIAL PERSPECTIVES ON THE INDIVIDUAL RESPONSE TO PHYSICAL ACTIVITY

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METHODS
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Utilizing Incentivized Economic Experiments to Test for Social Skills Acquisition Through Physical Education: Study Protocol of the *Movigen* Project

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Besides cognitive skills, non-cognitive skills—social skills in particular—are crucial for outcomes in various domains of life. The present work describes the design of the *Movigen* project, an intervention study with children aged 10–13 years using enhanced physical education lessons to foster social skills in a playful way. Utilizing a novel methodological approach various incentivized economic experiments were applied to test for spillover effects of the intervention on social skills. At three points during the course of the study individuals participated in a series of incentivized economic experiments to elicit economic preferences and personality traits. Additional information about physical activity and free time activities, different psychometric scales, and family background were elicited with questionnaires. Furthermore, a subset of individuals was equipped with accelerometers for 7 days to validate the answers on physical activity in the questionnaire. The data set comprises a treatment group which received enhanced physical education lessons and a control group which received regular physical education lessons at school. The comparison of individuals' decision in the economic experiments between both groups allows to study the impact of our intervention on social skills.

Keywords: physical education, intervention, economic experiment, social skills, spillover, randomized controlled trial

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INTRODUCTION

Success in various domains of life, e.g., at school or at the workplace, does not only depend on cognitive skills, but also on non-cognitive skills. In particular, inputs from both realms are frequently necessary to attain desirable results (Borghans et al., 2008). Whereas, cognitive skills refer to attributes which can be measured in terms of scores achieved in standardized tests, non-cognitive skills are more difficult to capture (Heckman and Kautz, 2012; Heckman et al., 2019). One reason is the difficulty to define the construct precisely in the first place (Duckworth and Yeager, 2015). A comprehensive overview on aspects which are comprised by the term non-cognitive skills can be found in, e.g., Farrington et al. (2012) and Gutman and Schoon (2013). The focus of the presented study design is on social skills which are a subset of non-cognitive skills and social competencies, respectively. In particular, social skills cover a set of behavioral facets

which are a crucial determinant for effective interaction with other people. Notable instances of social skills are cooperation, interpersonal skills, empathy, assertion, and responsibility (Farrington et al., 2012; Gutman and Schoon, 2013).

Whereas, requirements at the workplace increasingly emphasize the importance of non-cognitive skills (Deming, 2017; Bode et al., 2019; see also Weidmann and Deming, 2020), employers are at the same time concerned with a lack of social skills in applicants which is detrimental for employability (European Commission, 2016, 2017). One approach to enhance social skills are intervention programs. As non-cognitive skills are especially malleable at young ages, these programs are often directed toward children and adolescents (see Kautz et al., 2014, for an overview). The aim of the present study is to convey social skills in a playful way during purposefully designed physical education lessons (see Woll et al., 2018, for a description of the curriculum).

Besides positive effects on health (Warburton et al., 2006; Reiner et al., 2013; Pedersen and Saltin, 2015), physical activity and sports participation are often conjectured to improve outcomes in other domains of life as well. One explanation is that being involved in an organizational structure, e.g., in a sports club, yields spillover effects which foster the development of social skills as individuals have to get along with other individuals from diverse backgrounds to pursue common goals (Pfeifer and Cornelißen, 2010; Cabane and Clark, 2015; Felfe et al., 2016). Causal evidence on the impact of physical activity and sports participation on the development of social skills is, however, scarce (Pawlowski et al., 2018). Yet, the meta-study by Schüller and Demetriou (2018) finds positive effects of sports-related interventions at schools using randomized controlled trials on social skills of children and adolescents for the vast majority of the underlying studies.

For the purpose of this study we developed a novel methodological approach. To investigate the impact of our intervention and to assess potential spillover effects, individuals' social skills were measured at three different times. This is done by a series of well-established economic experiments. These experiments employ an incentive-compatible reward structure based on the individuals' decisions (and decisions of their class mates in some instances) in various economic environments which induce participants to reveal their true preferences. Whereas, responses on batteries of self-reported questions may be subject to individual biases due to different readings of the underlying scales, the current approach uses an objective scale provided all participants value monetary payoffs in the same way (Golsteyn and Schildberg-Hörisch, 2017; see also Heckman et al., 2019). To our best knowledge, there are no previous studies using a comparable approach to test for spillover effects of a sports-related intervention on other domains of life utilizing incentivized economic experiments.

OUTLINE OF THE STUDY

Participants and Allocation

Students at four different upper secondary schools in Karlsruhe (Germany) participated in the study. In total, students attending eight different classes of the sixth grade participated in the study. To assess the impact of the intervention on students' personal and social skills, a randomized controlled trial employing a treatment and a control group was necessary. This allows to disentangle the effect of the intervention from other influences outside the control of this study as the latter can be assumed to affect students in the treatment and the control group in the same way. At each school, one class was, therefore, randomly allocated to the treatment and control group, respectively. Due to fairness concerns, we offered the classes of the control group to receive enhanced physical education lessons as conducted during the intervention in the treatment group after the end of the study.

To be eligible for participation, parental consent in written form was mandatory. Therefore, we distributed letters inviting their children to participate in a scientific study during regular lessons to the parents via the respective schools. No information about the purpose of the study was disclosed, neither to the parents nor to the teachers. Furthermore, the superintendent of the local school district (ref.-no. 71 c2-6499.25) and the Board of Ethics of the Karlsruhe Institute of Technology approved the study.

One hundred and Sixty-six of the 197 students attending the classes under study (84.3%) returned the consent form and were, thus, allowed to participate in the study. Due to absence in one or more parts of the study, data are not complete for some individuals. Hence, the final data set contains observations on 111 individuals aged 10–13 years (mean: 11.7 years, standard deviation: 0.44 years). **Table 1** provides an overview on the distribution female and male individuals in the respective groups who participated in all parts of the study.

Set-Up

Figure 1 presents an outline of the study. Individuals participated in three measurements to elicit social skills in a series of different economic experiments during the course of the study. Repeated measurements were necessary to study both, individuals' immediate responses to the intervention as well as long-term effects. This information is complemented with data from questionnaires on free time activities (DIW/SOEP, 2015c) and engagement in physical activities (Schmidt et al., 2016) as well as several psychometric scales such as the Big Five inventory (Weinhardt and Schupp, 2011), social self-efficacy, self-efficacy of working in a team, perspective-taking (Jerusalem et al., 2009), rivalry (Eder, 1998; see also Kunter et al., 2002), and understanding of democracy (Abs et al., 2007). These psychometric scales were included to control for impacts of the intervention on individuals' personalities which has been proposed in the literature (e.g., Schmidt and Conzelmann, 2011). Questionnaires for individuals participating in the study were distributed after each measurement and were answered at home. Parents also answered a questionnaire after the first measurement to provide additional information about their children, characteristics of the household, and their own educational background (based upon DIW/SOEP, 2015a,b). At one school, individuals in the treatment and control group wore accelerometers for 7 days after the first measurement to collect

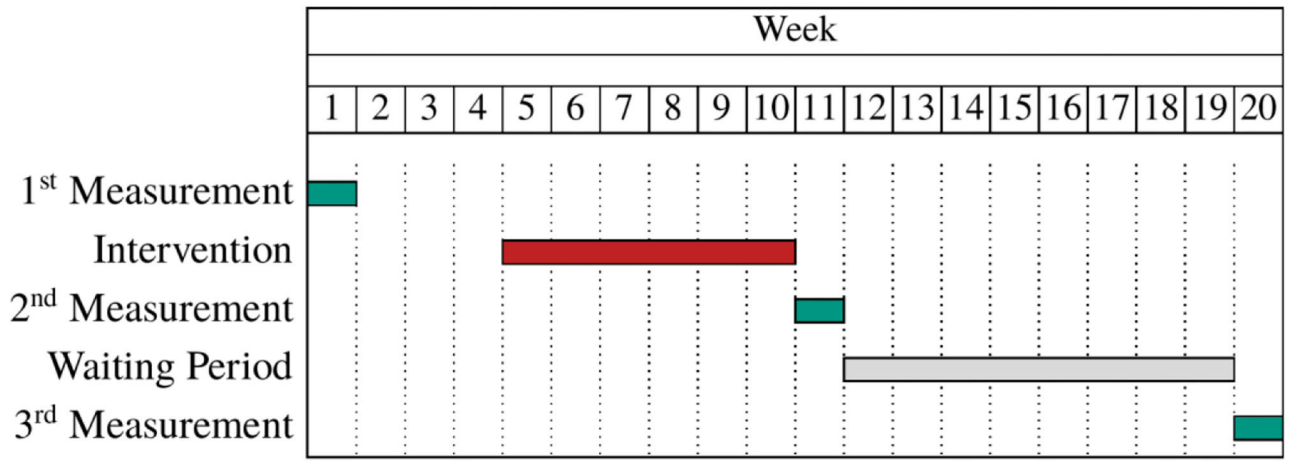

FIGURE 1 | Study set-up.

data about their overall physical activity in order to validate the corresponding answers in the questionnaire.

Intervention

Individuals of the treatment group participated in an intervention for a period of 6 weeks between the first and second measurement. The intervention took place during regular physical education lessons and had been designed to enrich the curriculum with a novel concept which conveys social skills in a playful way. Students participated in one lesson per week. Topics of the intervention were cooperation and willingness to work in a team, formal and informal fairness, self-assessment, and conflict resolution with one specific topic being covered in each lesson. To put individuals in situations which require them to actively work on solutions, the main part of each lesson consisted of physical activities related to the respective topic of a lesson. To foster the transfer of social skills to situations in their everyday lives, students were encouraged to share their experiences and impressions during the first and final 10 min of each lesson. Note that the social skills elicited in the incentivized economic experiments and the topics covered in the intervention are only loosely related. This is a deliberate decision in the design of the present study since it is not its purpose to teach particular behavioral patterns. In fact, the goal is to provide a playful environment which encourages individuals to develop skills which enable them to solve challenges in various domains of life on their own.

Lessons were conducted by university students of sports science and physical education who had experience in instructing children and adolescents in sports classes. They had received additional training prior to conducting the intervention, but were otherwise not aware of the purpose of this study. Woll et al. (2018) contains a description of the intervention in more detail. For a period of 6 weeks, classes which had been assigned to the treatment group received one lesson per week. Each lesson had been outlined for a slot of 80 min:

- The first 15 min (approximately) were used for a warm-up to prevent injuries.
- After that, the topic of the specific lesson was introduced to the class (approximately 8 min). Students were asked to contribute own experiences related to the respective topic to establish a common understanding.
- The main part of the lesson (approximately 50 min) addressed the respective topic utilizing a playful approach. Therefore, the topic of a lesson was presented in a sports-related context, e.g., in terms of an additional rule imposed on a game which required the students' consideration. To achieve a transmission beyond the setting of the intervention, students were encouraged to actively develop a way to deal with this kind of constraint within their classes. It is important to note that—although the intervention is designed to supplement regular physical education lessons—the goal of this study is not to promote physical activity in the first place. Rather, the specific setting of physical education lessons provides an environment which allows to pursue a playful approach to foster social skills as students receive instantaneous feedback from their peers which enables them to adapt their behavior accordingly.
- Each lesson was concluded by a short period of reflection (approximately 7 min) in which students had the opportunity to share their impressions and take private notes in a diary which had been handed out upfront.

Moreover, the design of the intervention took particular consideration to establish an environment which promotes the acquisition of new behaviors and their transmission beyond the setting of the intervention. As one element of the intervention was the development of own solution concepts by students, instructors were told to monitor their classes during the main part of each lesson but not to intervene unless to prevent injuries or turmoil. Feedback was another important parameter. Students

TABLE 1 | Number of individuals by group and gender.

	Female	Male	Total
Control	27 (44%)	35 (56%)	62
Treatment	25 (51%)	24 (49%)	49
	52 (47%)	59 (53%)	111

were, therefore, instructed to provide each other non-judgmental feedback based on their behavior in specific situations and suggestions for future improvements—or appreciation.

EXPERIMENTAL DESIGN

As mentioned above, a wide range of individual behaviors is summarized under the umbrella term social skills which are not trivial to measure. Whereas, this term is not used uniformly across different disciplines, we take reference to the understanding proposed in behavioral economics and economic psychology, respectively, where social skills comprise—among others—economic preferences and other determinants which are crucial for various life outcomes (Humphreys and Kosse, 2017). This enables us to build on a range of incentivized tasks which allow to draw inferences on underlying preference parameters (Ertac, 2020). To elicit individual preferences and traits in different economic environments we used a series of economic experiments. To establish an incentive-compatible setting for the elicitation of social skills, one experiment was selected for payout at the end of each measurement (see section Procedures).

Table 2 provides an overview of preferences and traits which are of particular interest in context of the present study as well as the corresponding economic experiments used for elicitation and the outcome variables of interest. Moreover, this section provides an overview on predictions of individuals' behavior in the economic experiments. A comprehensive overview on children's decisions in different economic experiments is provided by Sutter et al. (2019).

TABLE 2 | Overview of social skills measured by different economic experiments.

Social skills	Economic experiments	Outcome variables
Altruism	Ultimatum game (sender)	Amount passed to the receiver (ratio scale)
	Dictator game	Amount passed to the receiver (ratio scale)
Negative reciprocity	Ultimatum game (receiver)	Negatively reciprocal if positive offer is rejected (binary scale)
Cooperation	Public good game	Amount contributed to the collective account (ratio scale)
	Prisoner's dilemma	Three types: (i) always cooperate; (ii) never cooperate; (iii) conditionally cooperate (categorical scale)
Time preferences	Piggy bank	Patient if delayed gratification is chosen (binary scale)
Honesty	Mind game	Honesty on *aggregate* level if share of matching numbers does not exceed 1/6 (binary scale)
Risk preferences	Lottery	Three types: (i) risk-neutral; (ii) risk-averse; (iii) risk-seeking (categorical scale)
Competitiveness	Self-selection into payment scheme*	Competitive if tournament scheme is chosen (binary scale)
Overconfidence	Estimation of relative performance*	Overconfident if result falls into a lower tercile than estimated (binary scale)
	Selection of task difficulty*	Overconfident if threshold of chosen difficulty level is not achieved (binary scale)

** Operationalized using the encryption task.*

Ultimatum and Dictator Game

The ultimatum game (Güth et al., 1982; Güth and Kocher, 2014) depicts a bargaining situation between two individuals, sender and receiver. To elicit a complete strategy profile for each individual, we employ the strategy method (Selten, 1967). In the first stage, all individuals make their individual decision in the role of the sender. They are endowed with 600 tokens each and have to decide which fraction $x \in \{0, 120, 300, 480, 600\}$ they pass to the receiver who is one randomly selected individual of the same class. The remaining $600 - x$ tokens are kept by the sender. In the second stage, all individuals decide individually for each potential offer x a sender can make whether or not they want to accept this offer. If this experiment is chosen for payment, two individuals are randomly matched who are assigned the role of the sender and receiver, respectively. If the receiver chose "accept" for the respective sender's offer, the receiver receives x tokens and the sender receives $600 - x$ tokens. If the receiver chose "not accept," both individuals receive a payoff of zero tokens.

The ultimatum game employs a sequential structure. Thus, backward induction is used to derive predictions for both, the sender and the receiver. In the second stage, the receiver has to decide for each potential offer x the sender can make whether she wants to accept the offer or not. A selfish receiver who maximizes her own payoff accepts any positive offer. Thus, the sender offers the smallest positive amount, i.e., 120 tokens, while keeping the remaining 480 tokens for herself—and the receiver accepts. The dictator game, in contrast, does not incorporate any decision by the receiver. Hence, the sender will pass the smallest possible amount, i.e., 0 tokens, to the receiver and keep the entire endowment of 600 tokens for herself (Hoffman et al., 2008).

The dictator game is a modification of the ultimatum game (Forsythe et al., 1994). Again, individuals are endowed with 600 tokens. They decide which fraction $x \in \{0, 120, 300, 480, 600\}$ they pass to the receiver while keeping the remaining $600 - x$

tokens. Unlike in the ultimatum game, the receiver cannot reject the allocation of the sender. Moreover, the receiver in this setting is not another individual of the same class. Instead, tokens sent to the receiver are donated to a charity which supports children and their families in developing countries if this experiment is selected for payment.

In contrast to standard theoretical predictions, offers between 40 and 50% of the initial budget by senders are commonly observed in ultimatum games. Receivers regularly accept these offers. As offers decline, rejection rates increase—in particular for offers below 20% of the initial budget which are rejected in most of the cases (Camerer, 2003). With a share of about 30% of the initial budget which is passed to the recipient in the dictator game the amount ranges below the frequently observed offers in the ultimatum game. In particular, a substantial fraction of more than one-third of dictators decide to keep the entire budget (Engel, 2011). On the majority, fifth-graders aged 10–11 years in the study of Angerer et al. (2015) pass one to three tokens of an endowment of six tokens to a charity. Only 13% of the individuals keep their entire endowments and a fraction of <10% of the individuals passes more than half of their endowments to the charity.

A positive amount passed to the receiver in the ultimatum and dictator game reflects the sender's unconditional and conditional altruism, respectively. More precisely, the amount passed to the receiver is a measure for the extent of the sender's unconditional and conditional altruism. A receiver in the ultimatum game who rejects a positive amount offered by the sender is demonstrates negatively reciprocal behavior.

Prisoner's Dilemma and Public Good Game

The prisoner's dilemma is a two-player experiment which constitutes a social dilemma (Roth, 1995). Each individual can choose between two strategies, "Cooperate" and "Defect." The payoff matrix is depicted in **Figure 2**. To elicit a complete strategy profile for each individual, we use the strategy method. In the first stage, each individual decides independently whether she wants to cooperate or defect. In the second stage, individuals face the same decision contingent on the other individual's possible decision to (i) cooperate and (ii) defect. If the experiment is selected for payment, two individuals of a class are randomly matched. Within each group, one individual is randomly selected whose independent decision is relevant for payoff. For the other player, the corresponding dependent decision is evaluated. Both individuals' payoffs are denoted by the values of the resulting cell of the payoff matrix.

The public good game is closely related to the prisoner's dilemma as it constitutes a social dilemma in groups with two or more individuals (Ledyard, 1995; Roth, 1995; Cipriani et al., 2013). Individuals are endowed with 120 tokens and form a group with three other randomly selected individuals of the same class. They can allocate their endowment to a private or a public account in intervals of 24 tokens. If the experiment is selected for payment, the number of tokens allocated to the collective account by all individuals of the group is totaled. Each individual receives a return of 1 token for every token contributed to the collective account—no matter by whom. Additionally, each individual receives a return of 2 tokens for every token allocated to her private account. Thus, the payoff π_i of individual i is given by

$$\pi_i = 2(120 - c_i) + (c_1 + c_2 + c_3 + c_4),$$

where $c_i \in \{0, 120, 300, 480, 600\}$ is individual i's contribution to the collective account as multiple of 24 tokens. The marginal per-capita return (MPCR) is 0.5, i.e., every token contributed to the collective account by an individual herself yields a return which is half the quantum of the return from a contribution of one token to her private account.

Using the strategy method in the prisoner's dilemma allows to identify three types of contributors (similar to Fischbacher et al., 2001). Individuals who always cooperate or defect, irrespectively of the other individual's decision ("always cooperate" and "never cooperate," respectively) and "conditional cooperators" who cooperate if the other individual does so and vice versa if the other individual defects. In the public good game, the amount of tokens contributed to the collective account indicates the individual level of cooperativeness.

Lottery

The lottery consists of two experiments (conceptually similar to Deckers et al., 2017; see also Castillo et al., 2018). In each experiment, individuals choose between two envelopes. In the first experiment, envelope A contains six green cards and envelope B contains three red cards and three blue cards. If this experiment is selected for payment, a card is drawn from each envelope A and B. An individual who chose envelope A receives 200 tokens if a green card is drawn (probability: 100%). An individual who chose envelope B receives 600 tokens if a red card is drawn (probability: 50%) and zero tokens if a blue card is drawn (probability: 50%). The second experiment is identical to the first except the names of the envelopes and the colors of the cards: Envelope C contains six orange cards and envelope D contains three purple cards and three yellow cards. If this experiment is selected for payment, an individual who chose envelope C receives 400 tokens if an orange card is drawn (probability: 100%). An individual who chose envelope D receives 600 tokens if a purple card is drawn (probability: 50%) and zero tokens if a yellow card is drawn (probability: 50%).

Envelopes A and C represent degenerate lotteries with a sure payoff of 200 tokens and 400 tokens, respectively. Envelopes B and D represent the same non-degenerate lottery $L = (0.5 \circ 600, 0.5 \circ 0)$ with an expected payoff $\mathrm{E}[L] = 300$ tokens. An individual who chooses the lottery (envelope B) in the first experiment ($\mathrm{E}[L] > 200$) and the sure option (envelope C) in the second experiment ($400 > \mathrm{E}[L]$) is labeled risk-neutral. Similarly, an individual who always chooses the sure payoff (envelopes A and C) or the lottery (envelopes B and D) is labeled risk-averse or risk-seeking, respectively. In a comparable setting, Deckers et al. (2017) identify about 44% of children aged 7–9 years in their sample as risk-neutral. While this is independent of their socio-economic status, children from households with high socio-economic status are less often risk-seeking and more often

		Individual 2	
		Cooperate	Defect
Individual 1	Cooperate	R, R	S, T
	Defect	T, S	P, P

FIGURE 2 | Prisoner's dilemma. T (Temptation) > R (Reward) > P (Punishment) > S (Sucker's payoff) and $2R > T + S$.

risk-averse than their counterparts from households with low socio-economic status.

Encryption Task

In a real-effort task adopted from Erkal et al. (2011) individuals have to replace letters of a given word. The difficulty of the task increases in the number of iterations which are required for the encryption. For the one-fold encryption, the letters of the original word have to be replaced once by another letter from a given table. The two-fold variant requires an additional step, i.e., the letters of the original word have to be replaced in two subsequent steps according to two different given tables, and so forth. The number of correctly encrypted letters in a 2-min working period is the outcome variable of interest. The task is employed in three different experiments with a specific payoff structure each:

(1) At the beginning of this experiment, individuals can familiarize with the task during a trial period of 30 s in which they are asked to apply a two-fold encryption on a word with five letters. The main part also requires two-fold encryption. Before they start working, individuals give an estimate about their performance in the main part relative to the performance of the other individuals of their class, i.e., they indicate whether they expect themselves to be among the top, middle, or lower third (Almås et al., 2016). If this experiment is selected for payment, a correct estimation yields 300 tokens while an incorrect estimation results in a payoff of zero tokens. Additionally, individuals receive 3 tokens for each correctly encrypted letter with a cap at 300 tokens.

(2) In this setting, individuals work again on the two-fold encryption with different replacement tables. Before they start working, individuals can choose whether they prefer a piece-rate or a payment based on a tournament scheme (Niederle and Vesterlund, 2007; Booth and Nolen, 2012; Samak, 2013; Almås et al., 2016). The piece-rate is 3 tokens for every correctly encrypted letter with a cap at 300 tokens, whereas the tournament scheme comprises a loser prize of zero tokens and a winner prize of 600 tokens. An individual who chose the tournament scheme receives the winner prize if this experiment is selected for payoff if she obtained a higher output than another randomly chosen individual of the same class. If the individual under question obtained a lower output, she receives the loser prize. Ties are broken randomly.

TABLE 3 | Payoff by level of task difficulty in the encryption task.

Task difficulty	Piece-rate	Threshold	Cap
One-fold encryption	1 token	5 letters	100 tokens
Two-fold encryption	3 tokens	15 letters	300 tokens
Three-fold encryption	10 tokens	35 letters	1,000 tokens

(3) In this variant, individuals can choose between three different levels of task difficulty (similar to Falk et al., 2015)[1] which require one-, two-, and three-fold encryption, respectively. If this experiment is selected for payment, the remuneration depends on the level of task difficulty according to **Table 3**. For each level of task difficulty, the payoff is contingent on a threshold which specifies a minimum number of letters which have to be encrypted correctly. At the same time, the maximum amount of tokens which can be achieved is capped for each level of task difficulty.

The specific payment schemes in the encryption task relate to different personality traits. The first and the third variant are concerned with relative and absolute self-assessment, respectively. These personality traits refer to individuals' ability to estimate their own performance accurately in comparison to their peers or in absolute terms. Individuals who expect themselves to perform better in the relative ranking of their class than they actually do are deemed overconfident. Similarly, individuals who do not achieve the minimum number of correctly encrypted letters required under the level of task difficulty of their choice fall into the same category. Falk et al.[1] find 37% of the children in their sample with an average age of 8 years to be overconfident prior to their intervention.

The choice between two compensation schemes either based on an individual's absolute performance or on her relative performance compared to another randomly selected individual of the same class is an indicator for individuals' competitiveness. More precisely, competitive individuals choose the tournament-based compensation scheme. The seminal paper by Niederle and Vesterlund (2007) reports that male individuals are more competitive than females as three quarter of men and one-third of women prefer the tournament scheme. This gender

[1] Falk, A., Kosse, F., and Schildberg-Hörisch, H. (2015). *Reducing Overconfidence*. Unpublished manuscript.

gap also occurs among children, although its magnitude is less pronounced (e.g., Almås et al., 2016).

Mind Game

In the mind game (Jiang, 2013; see also Kajackaite and Gneezy, 2017; Abeler et al., 2019), individuals are first asked to imagine an integer number between one and six. After that, they receive an envelope each. The envelope contains a set six cards with one number from one to six printed on each card. Individuals are then asked to draw one card from the envelope and to indicate whether the number on the drawn card matches the integer they had imagined before. If this experiment is selected for payment, individuals who reported a match between the imagined and the drawn number receive 600 tokens and zero tokens otherwise.

The mind game addresses dishonesty. The experiment deliberately does not allow to derive conclusions whether an individual who reported matching numbers was actually dishonest or not. On the aggregate level, however, the fraction of individuals who report matching numbers is expected to be 1/6 in a sufficiently large sample. Hence, a share of matching numbers reported which exceeds 1/6 indicates dishonest behavior on an aggregate level. In a similar setting in which children aged 5–15 years in Italy received a payment conditional on the outcome of a fair coin toss, about 85% of the individuals reported an outcome which entitled to receive the payment. This fraction was substantially higher than the theoretical share of 50% (Bucciol and Piovesan, 2011).

Piggy Bank

This experiment offers the choice between two alternatives which differ in the amount of the payoff and its date (Bauer et al., 2014; Angerer et al., 2015; Deckers et al., 2017). If the experiment is selected for payoff, individuals who chose the first alternative receive 300 tokens on the same day, whereas individuals who opted for the second alternative receive 600 tokens with a delay of 1 week.

The decision in the piggy bank experiment measures time preferences. Individuals who trade off an earlier gratification for a higher payoff exhibit a low discounting rate and are deemed patient. In a similar setting, 63% of the children between 4 and 12 years (average age about 8 years) who participated in a study in the Czech Republic chose the higher payoff with a delay of 1 week (Bauer et al., 2014).

Procedures

As described in section Set-Up, individuals participated at three times during the course of the study in a measurement using a series of standard economic experiments to elicit different social skills. Measurements took place in classrooms during regular lessons and were conducted by students of different fields of study who were pursuing a university degree which qualifies for teaching at upper secondary schools; they were not aware of the purpose of this study.

To identify individuals across different stages of the study while maintaining anonymity, they received a card with their ID number at the beginning of each measurement from their teacher. Individuals' identities were not disclosed to the experimenters. During the measurements, individuals were allocated in the classroom such that they were able to make their decisions independently and without being disturbed. General instructions were read aloud before the first experiment. After clarifying questions about the general procedure had been answered, individuals received the answer sheet for the first experiment. The experimenter ensured that each individual received an answer sheet with the correct ID number. Answer sheets contained a description of the experiment, in particular the choice set and related consequences for the payoff, and space to write down the decision. Instructions were read aloud by the experimenter. Individuals did not write down their decisions before all clarifying questions had been answered. The subsequent experiments followed the same procedure and were standardized. For a detailed description of each experiment, see **Supplementary Material**.

To choose the experiment which was relevant for payoff, the teacher was asked to open an envelope which contained a card stating the number of the experiment. The payoff of each individual in the corresponding experiment was calculated and converted into Euro. The exchange rate rate was 75 tokens = 1.00 Euro. Individuals received an additional participation fee of 2.00 Euro per session. Payoffs were handed out to each individual in sealed envelopes by the teacher in exchange for the ID card. We ensured that the maximum possible payoff per session was 10.00 Euro which corresponds to approximately 50% of the recommended monthly amount of pocket money for children aged 11–12 years in Germany (Langmeyer and Winklhofer, 2014). The average individual payoff per session was 6.27 Euro.

STATISTICAL ANALYSIS

The primary interest of this research is on differences in decisions between the treatment and control group in various economic experiments. As data gathered in economic experiments are rarely normally distributed, we rely on non-parametric tests in the first place. The appropriate-ness of a hypothesis test depends on the level of measurement of our outcome variables (Stevens, 1946). When dealing with categorical or binary data, a χ^2-test for independence is applied, whereas the Mann-Whitney U-test is the choice for ratio data. As hypothesis tests only draw an incomplete picture and have been subject to severe criticism recently (e.g., Büsch and Strauß, 2016; Calin-Jageman and Cumming, 2019), we additionally calculate effect sizes (Cramér's V and the correlation coefficient r; see Tomczak and Tomczak, 2014) and the corresponding confidence intervals to provide insights on the magnitude of the actual differences between the treatment and the control group.

Beyond plain comparisons between the treatment and control group, we are interested in the causal effect of the intervention on decisions in the economic experiments. The panel structure of the data set allows to address this question using regression analyses. As repeated measurements are not independent, a random effects-model is employed. This allows to control for

time-constant independent variables such as gender and socio-economic status (Andreß et al., 2013). To account for correlation within classes, standard errors are clustered.

SUMMARY

The aim of the study design is to investigate the impact of physical activity and sports participation on social skills using purposefully designed physical education lessons. To test for intervention effects, we utilized a novel approach in this field by applying various incentivized standard economic experiments. To contribute to the existing literature, we designed the *Movigen* (Latin: motio—motion; genitor—creator) project to address two research questions:

(1) Are different levels of physical activity associated with different outcomes regarding social skills?
(2) Is the intervention using a novel concept for physical education effective in enhancing social skills?

The first question is motivated by the discussion whether sports participation can be considered as investment good. The rationale is that sports participation may not just invoke pleasure but also foster skills which are assumed to translate into favorable outcomes in other domains of life, e.g., success in the labor market (Leeds, 2015). In the present study, this issue can be addressed with data from the first measurement, i.e., before the beginning of the intervention in the treatment group by a comparison of differences in individuals' decisions in the economic experiments contingent on their levels of physical activity. This approach is, however, not appropriate to draw causal conclusions on the relation between the intensity of sports participation and social skills as factors which may affect both domains simultaneously, e.g., due to selection effects, are not explicitly incorporated.

Having a treatment and control group, however, does allow to examine the causal effect of the intervention on decisions in the economic experiments. Due to the repeated measurements in both groups, we are able to disentangle the effect of the intervention on individuals in the treatment group from experience effects which occur if the same series of economics experiments is repeated. Moreover, our design employs an active approach of learning and encourages individuals to develop skills which enable them to solve challenges in various domains of life on their own. This method is expected to be more effective in inducing changes in behavior as compared to approaches which already provide the solution to attain the desired outcome (Durlak et al., 2010). To our best knowledge, there are no previous studies using a comparable approach to test for spillover effects of a sports-related intervention on other domains of life.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Board of Ethics of the Karlsruhe Institute of Technology. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AW and PN conceived the original idea. PN and AH designed the measurements. HW and AW designed the intervention. RW coordinated its implementation. AH drafted the manuscript. RW and HW revised this draft. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2021.587764/full#supplementary-material

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Perceived Time, Frequency, and Intensity of Engagement and Older Masters Athletes' Subjective Experiences

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Masters athletes are a unique group of older adults whose experiences may provide valuable insights into the role of sport for successful aging. The purpose of this study was to explore whether masters athletes' social and psychological experiences vary with their time, frequency, and perceived exertion in training and competition. Semi-structured interviews were conducted with 40 men and women older masters athletes, aged 50–79 years (M = 66), who were active at the competitive level across a variety of sports (e.g., volleyball, curling, rowing, dragon boating, running, swimming, and basketball) at the time of the study. Results indicate that all participants experienced social and psychological benefits from engaging in masters sport. Only the high-frequency engagement subgroup (participating five to seven times per week in training and/or competition) reported social downsides, in terms of missing time with family and friends outside of masters sport. However, some participants described the positive family support (e.g., spouse who endorses sport participation) that overrides some of the social costs. These findings have implications for realizing positive experiences with minimal engagement in masters sport, yet an apparent threshold of participation beyond which negative social consequences may be experienced. This is an important consideration for the design and promotion of sport for older adults.

Keywords: older adults, sports, benefits, training, competition

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INTRODUCTION

The rate of sport participation continues to steadily decline with age in several countries, including Canada (Statistics Canada, 2020). Despite this steady drop in participation, there is a unique cohort—and upward trend (Dionigi et al., 2018)—of adults who continue with competitive sport past the typical age for top performance (Weir et al., 2010; Dionigi et al., 2013). Individuals who continue to train and participate in athletic competitions designed for older participants are masters athletes. Eligibility for masters competition is based on age, with the minimum qualifying category as young as 30 years, although this differs across sports (e.g., swimming, athletics, and basketball; Weir et al., 2010). The focus of this paper is masters athletes aged 50 years and older; a cohort that Dionigi (2006) and Dionigi et al. (2018) distinguish as "older" (vs. younger and mid-life) masters athletes, and an age that represents a critical point for reduced cardiac output (Nikolaidis et al., 2018).

Masters athletes typically maintain higher than average levels of physical activity in comparison to their same-age peers through training and competition (Baker et al., 2010). Geard et al. (2017) present a strong case for *older* masters athletes being exemplars of successful aging, as they may derive a variety of benefits directly from their sport engagement (Kusy and Zieliński, 2006). There is value, then, in better understanding who these masters athletes are, what they do, and their sport experiences. Geard et al. define successful aging as a late-life process of change characterized by high functioning across the physical, psychological, cognitive, and social domains. They argue that research is needed to better understand the successful aging benefits derived from competitive sport.

The physical benefits of training for older adults, including greater strength and power (Seguin and Nelson, 2003), and improved cardiorespiratory fitness (Nakamura et al., 2007), are well-known. Moreover, there is recent evidence that masters athletes also have an attenuated aging profile associated with preserved DNA sequencing when compared to age-matched non-athletes (Aguiar et al., 2020). Regular strength training (defined as three times per week) by older adults in general has been shown to not only produce expected benefits such as building muscle strength and mass, and preserving bone density, but also prolong independence and increase vitality (Seguin and Nelson, 2003). In a review, Bouaziz and colleagues (2016) found that combining different modalities of training (multi-component training; e.g., endurance and strength training) improved not only fitness and metabolic outcomes such as diabetes, along with improved cognitive performance, but also overall feelings of well-being (Bouaziz et al., 2016). Evidence suggests that older adults' participation in competitive sport may result in better physical health (i.e., better sleep patterns, better diet, and healthier lifestyle overall; Shephard et al., 1995). Recently, Geard et al. (2018, 2020) established that masters athletes have higher physical functioning (fewer physical limitations in daily life) than adults of similar ages who do not participate in competitive sport. While masters athletes have higher rates of injury with their competitive sport participation, they are likely to have much lower rates of chronic disease compared to their less active counterparts (Patelia et al., 2018).

Psychological and social benefits of older adults' sport participation have also been highlighted (Eime et al., 2013), including greater meaning to life, enjoying the competitive challenge, and meeting new friends (Smith and Storandt, 1997; Ogles and Masters, 2000; Dionigi et al., 2011; Young et al., 2018). There is also some evidence suggesting that participation by older adults in competitive sport may result in more prosocial behavior, passion, community involvement, and travel benefits (Lyons and Dionigi, 2007; Dionigi et al., 2011). These social benefits also extend into athletes' homes, as family members have been reported to play an important role in supporting the continued participation of these athletes (Hodge et al., 2008; Young and Medic, 2011; Dionigi et al., 2012). Athletes have reported training with their spouse and children as beneficial to bringing their families closer and a reciprocal effect on each other's participation in sport (Dionigi et al., 2012). As with the physical component, potential negative psychological and social consequences of masters sport engagement have been identified, including family opposition, negative emotions, difficulty maintaining social relationships, burnout, and regret (Dionigi et al., 2012; Young, 2013; Young et al., 2015; Appleby and Dieffenbach, 2016).

Research further indicates that physical benefits can be positively affected by the frequency, intensity, and volume of training by older adults (Maharam et al., 1999). However, to our knowledge, there has been no consideration of any possible effect of training time or frequency, or perceived intensity on subjective psychological and social experiences. Understanding the nature of older adults' sport training and competition that may promote experiencing positive benefits or avoiding the downsides of participation can be an important contribution to insights into successful aging.

The present study aimed to build on the existing body of research and to address the call for qualitative studies on masters athletes that consider aspects that have previously been considered only quantitatively (i.e., frequency, intensity and time; Dionigi, 2006). Therefore, the purpose of the present study was to explore whether time, frequency, and perceived intensity of training and competition align with psychological and social experiences of older masters athletes (50+). We used a cross-sectional qualitative research design to achieve this purpose.

METHODS

Participants and Context

Semi-structured interviews were conducted with masters athletes who, following IRB approval, were recruited based on the following inclusion criteria: (a) must be 50 years of age and older, (b) must be able to read and write in English in order to give consent, and (c) must be actively competing at any level in masters sport (regional, national, and international). These criteria ensured our focus on the cohort of older masters athletes (Dionigi, 2006; using the usual 50–60 year age category as the lower limit; Weir et al., 2010) who were competitive athletes. Interviewees were recruited through local masters teams and clubs in Ontario, Canada, and through Masters Ontario (the provincial sport governing body for masters sport). Coaches and club managers were first contacted to distribute recruitment posters. For interested athletes, recruitment information included contact information for the researchers in order to schedule an interview. After connecting with prospective participants, interview times were set with individuals interested in participating in the study.

A total of 40 masters athletes (19 women, 21 men) were interviewed individually by one of two research assistants, with each session ranging from 22 to 75 min (M = 48 min). The athletes were engaged with 15 different sports (with some athletes competing in more than one): volleyball ($n = 4$), dragon boat racing ($n = 3$), tennis ($n = 1$), running ($n = 6$), triathlon ($n = 2$), swimming ($n = 14$), rowing ($n = 2$), track and field ($n = 2$), curling ($n = 2$), basketball ($n = 3$), ice hockey ($n = 1$), squash ($n = 1$), cycling ($n = 2$), and slo-pitch ($n = 1$). At 40 interviews, we determined that saturation was reached (Hennink et al., 2017; Braun and Clarke, 2019), as

we were hearing consistent descriptions of a range of training and competition engagements, and a variety of social and psychological experiences. Participants were interviewed over the phone or in person at a location that was most convenient for them (e.g., the University lab or local sports club/practice area). The interviews were transcribed verbatim and participants were then invited by email to review the transcription at their convenience and provide any corrections to ensure that the information was conveyed in its intended manner (Doyle, 2007). The profile of athletes by age, gender, hours, and frequency of training and competition, and perceived intensity is presented in **Table 1**.

Interview Guide

The semi-structured interview guide was developed by the authors. It enabled the interviewers to guide the discussion while exploring emergent topics and allowed the participants more freedom to answer openly (Rubin and Rubin, 1995). In addition to providing background information about their age, gender, and sport involvement, participants were asked about their time (hours) and frequency (number of sessions) of training and competition per week. They were also asked to describe their perceived level of exertion in training and in competition using a scale from 1 (*no exertion*) to 10 (*maximal exertion*). Participants were then asked about the social and psychological experiences associated with their engagement in masters sport. Specifically, they were asked to describe the following: "How do you feel being a competitive masters athlete has benefitted you socially?," "How has it benefitted you psychologically?," "What are the social downsides of being a competitive masters athlete?," and "What are the psychological downsides?" Probes were used to further explore athletes' responses, as the semi-structured design allowed for flexibility and reflexivity to explore some topics that varied between participants in the very conversational approach (Patton, 2015).

Data Analysis

The entire research team composed of physically active men and women—including three who are older masters athletes—was involved in data analysis. The first step was organizing the data (Gibson and O'Connor, 2003). Each interview was transcribed into Microsoft Word and imported into NVivo8©. Transcripts from those participants who took the opportunity to review and change their document to reflect their true thoughts were downloaded and used to replace the original transcript. Our analytical framework was based on previous research on the social and psychological experiences of masters sport participation—specifically, psychological benefits, social benefits, psychological downsides, and social downsides (Dionigi, 2017)—which were presented in the interview questions. Thus, responses to "How do you feel being a competitive masters athlete has benefitted you (socially, psychologically)?" were coded as "Social Benefits" and "Psychological Benefits," respectively. We applied the process of convergence and divergence in coding to ensure data belonged in one theme and not another (Patton, 2015). This was also helpful to highlight the core meanings of each theme (Patton, 2015). The first author read and coded all 40 transcripts, with the remaining authors reading and coding at least four transcripts each. Very few discrepancies in coding and description of core meanings were indicated, and these were discussed and reconciled by the team (inter-rater reliability; Smith and McGannon, 2018), enriching the overall analysis and findings (Gibson and O'Connor, 2003).

In order to determine whether the participant characteristics of interest aligned with the perceived social and psychological benefits and downsides of masters sport, the athletes were first grouped by frequency of engagement into subgroups of one to two sessions per week ($n = 5$), three to four sessions per week ($n = 15$), and five to seven sessions per week ($n = 19$) for further analysis. To better understand the athletes' pattern of engagement (i.e., individuals may train only once a week for 5 h or five times a week for 1 h), a correlation analysis was conducted. It revealed that frequency of sessions and time or hours per week committed to training and competition were highly correlated ($r = 0.73$, $p < 0.001$). Thus, time was not employed as a separate grouping variable and the focus was on number of sessions per week. Perceived exertion in training ranged from as low as 1 (no exertion) to as high as 10 (maximal exertion) on the 10-point scale. There was very little variation among participants, with 70% indicating an intensity level of 4–6/10 for training (overall M = 5.3, median = 5). There was even less variation among participants in perceived exertion in competition, with 70% indicating an intensity level of 8–10 when competing (overall M = 8.5, median = 10). Thus, perceived intensity of engagement was not employed as a grouping variable for further analysis. Subjective experiences were not distinguished for training vs. competition during the interviews and so further analysis based on different intensity in these masters sport contexts was not possible.

RESULTS

Variation in the participants' psychological and social experiences with masters' sport by frequency of engagement are described below (and in **Table 2**), along with representative quotations of numbered participants. There was evidence of psychological and social benefits, and social downsides only, with no indication of psychological downsides among the sample of participants.

Psychological Benefits

All masters athletes, whether they were engaged in their sport one to two times per week ($n = 5$), three to four times per week ($n = 15$), or five to seven times weekly ($n = 19$), experienced positive psychological benefits, described as stress relief, greater self-confidence, and a sense of pride. Participant 26 (one to two times per week) shared that, "I get away from the nonsense around the house, so mentally I think I get a break from the everyday run of the mill type tasks and crazy things that are going on." Similarly, Participant 6 (three to four times per week) indicated that, "I think it's important for mental health and staying resilient." Participant 17, who was engaged five or more times per week, said, "It's a distraction and a stress release. It's a huge coping mechanism for me, which isn't maybe healthy but it's what I do." Their masters sport involvement was also reported to

TABLE 1 | Participant profile (age, gender, training/competition frequency [times/week], training/competition time [hours/week], and perceived intensity [/10]).

Variable	Frequency	%	Mean (SD)	Median	Range
Age (years)			66.34 (7.7)	67	50–79 years
Gender					
Women	19	47.5%			
Men	21	52.5%			
Frequency* (times/week)			4.6 (1.6)	4	1–7
1–2/week	5	12.5%			
3–4/week	15	37.5%			
5–7/week	19	47.5%			
Hours (per week)			5.2 (3.2)	3	1–12
Perceived intensity					
Training (/10)			5.3 (1.2)	5	1–10
Competition (/10)			8.5 (1)	10	3–10

**Frequency includes number of training and/or competition sessions per week.*

TABLE 2 | Frequency table of older masters athletes' who perceived benefits and downsides to participation, by frequency of training/competition sessions.

	1–2 times per week ($n = 5$)	3–4 times per week ($n = 15$)	5–7 times per week ($n = 19$)
Psychological benefits (stress relief, greater self-confidence, sense of pride)	5 (100%)	15 (100%)	19 (100%)
Social benefits (positive relationships with family and with masters sport friends)	5 (100%)	15 (100%)	19 (100%)
Social downsides (missed family time and events, change in circle of non-sport friends)	0	0	16 (84%)
Psychological downsides	0	0	0

"help our self esteem [since] we're still able to compete and play well at our age and it helps the self-image and things like that" [Participant 25 (five to seven times per week)]. Other participants shared that it is "fun to test yourself to see if you do or don't make shots, and if it does happen, I overcame … and I am proud of myself for having done it" [Participant 3 (three to four times per week)], and "Just to win at something, to succeed, that's satisfying" [Participant 14 (one to two times per week)].

Social Benefits

Similarly, all masters athletes in each of the subgroups indicated experiencing social benefits as a result—and regardless of the frequency—of their engagement. The social benefits were described as positive relationships with both family and friends in masters sport. As Participant 1 (three to four times per week) shared, with a laugh, "My kids think I rock now!" For Participant 26 (one to two times per week), the positive relationships were founded on enjoying sport with family: "Ya, my kids are involved as well a little bit with volleyball, so we have fun when we do get together, we play." A masters triathlete shared that, "My son does triathlons. My grandkids do triathlons. Now I have four great grandkids; 2 of them … they've done triathlons, so they're all into [the] sport" [Participant 5 (five to seven times per week)]. Additionally, Participant 19 (one to two times per week) noted that, "Socialization is a big part, we are all friends, it's kind of like family. There is nothing we wouldn't do to help each other out." Participant 39 (three to four times per week) shared that, with not participating in masters sport "I probably would miss the people that I would see and the type of people they are. I think we, as a group, have a more positive outlook." Participant 34 (three to four times per week) said:

It's possible that swimming isn't the best social sport, but a number of us often go out for breakfast after. I usually try to go on Mondays and Wednesdays, so 6 or 7 of us go out to the local restaurant here and have breakfast and chat and there is usually a good discussion, these are people from different backgrounds with different views and so on.

Social Downsides

The masters athletes who trained and competed five or more times per week were the only ones to indicate some negative impact from their sport engagement, with 16 of the 19 participants identifying this experience. They described missing family time and functions due to their sport schedule and a change in their circle of friends due to time spent with those involved in their sport. Participant 32 (five to seven times per week) discussed that, "It's changed my friendships I guess, because I dedicate so much time to this activity … my lifelong friends, they don't really get it." The negative consequences to relationships of greater engagement in one's sport was described by Participant 4 (five to seven times per week) who stated, "…it takes time and you may find that you are putting this ahead

of other things." Participant 21 (five to seven times per week) reiterated this by discussing how family sometimes does not understand the commitment:

My family from [another city] was here … and I was going to the pool and they were like "why do you have to go? '…' why do you have to go for three hours?" So, they don't fully understand my commitment and how important it is to me. So, there are times where that happens.

Participant 37 (five to seven times per week) agreed: "You know doing an Iron Man is tough, tough on family, even relationships because it takes a lot more dedication."

However, 8 of these 16 participants (50%) specifically indicated that the social downsides to their relatively heavy engagement in their sport were offset, and not as "negative" as they seemed, due to supportive friends and family. As Participant 22 (five to seven times per week) shared, "Of course, this commitment takes away from family time ... The lucky thing is, is that I met a [life] partner who thinks the same way that I do." Participant 5 (five to seven times per week) added, "I have a good family. Everybody understood that I like to do this."

DISCUSSION

The findings revealed no apparent variation in the psychological benefits experienced by older athletes who train and compete as little as one to two times per week, three to four times per week, and as much as five or more times per week. Overall, participants indicated a very positive psychological experience or benefits gained from masters sport, regardless of how often they were engaged on a weekly basis. Hours per week was significantly associated with frequency of engagement, and so it may be expected that perceived benefits hold for this factor as well. Masters athletes spoke about having less stress, greater self-confidence, and a sense of pride as a result of their participation. These positive aspects are an important part of successful aging (Geard et al., 2017), with evidence that well-being and self-achievement contribute to successful aging (Cho, 2002; Bowling, 2007; Geard et al., 2017, 2018). The psychological benefits of masters sport participation have been indicated in previous research (Ogles and Masters, 2000; Dionigi et al., 2011; Eime et al., 2013). However, the current study provides insight specifically into the older masters athlete (aged 50+ years) experience with evidence that suggests that these benefits may be realized regardless of time committed.

Similar to previous work (Lyons and Dionigi, 2007; Dionigi et al., 2011; Young, 2013), we also found that there were social benefits to participation in masters sport. Our study extends that work with evidence that these benefits were experienced similarly by older masters athletes across the different levels of frequency of participation. Whether participants were engaged from one to two times per week to five or more times per week, they experienced social benefits with both their families and friends. Athletes discussed a network of like-minded friends, which also extended beyond their sport with social gatherings among teammates outside of the sport environment, such as team meals or book clubs.

While social benefits were discussed by the masters athletes across all three groups of training and competition frequency and thus may be expected regardless of how often one is engaged, participants engaged five or more times per week were the only ones who discussed possible negative social consequences or downsides. They indicated missing family gatherings to compete or train and noted the toll it can take on one's family. They also described a shift in their friendship group, with their masters sport associates becoming a more important social circle. The loss or reduced time with friends outside their sport circle was seen as a downside of their engagement. This aligns with previous research which found that commitment to leisure time activity, such as running, was linked with perceived spousal conflict and constraints on families, especially those who are unable to adapt (Goff et al., 1997; Goodsell and Harris, 2011). Building on that work, our study suggests that there is a threshold of frequency of older masters athlete engagement, beyond which negative social consequences are likely to be experienced. Compromised family commitments and changed social circles may be expected with almost daily engagement or more. This may explain why some decrease or limit their masters sport participation or disengage completely.

However, while masters athletes who engaged in sport five or more times per week described the challenges to family commitments with greater time dedicated to their sport, several also indicated that this could be offset with supportive spouses and families. This aligns with the sport commitment model (SCM; Scanlan et al., 2003) which states that significant others can be either a social constraint on sport participation or a form of support. Adopting this model, Young and Medic (2011) found five sub-groups that influence the commitment of master's swimmers, with children and spouses likely to be both social supports and social constraints for older athletes' engagement. Some of the participants in our study indicated that their spouses were also masters athletes and that the shared training and similar experiences facilitated a greater understanding of their own commitment and compromised family time.

An apparent threshold of frequency of training and competition, beyond which negative social consequences may be experienced by older masters athletes, aligns with evidence of the direct association between frequency, time, and exertion and increased incidence of muscle fatigue, joint degeneration, and injury in this cohort (Maharam et al., 1999). Together, this work highlights that there can be too much of a good thing when it comes to masters sport. It is not surprising that there can be negative physical consequences of training and competition beyond a certain point (overtraining syndrome; Armstrong and Vanheest, 2002; Kreher, 2016), and our study adds to that understanding of masters athletes by revealing the negative social consequences that may occur beyond a certain point of engagement. Specifically, participants indicated that they needed to be able to miss (or give up) certain other aspects of life, such as time with friends and family outside of sport, to maintain their commitment to their sport. Importantly, however, our findings also suggest that the many positive psychological and social benefits of training and competition in masters sport may be realized with even minimal engagement.

There are several possible limitations of this study that must be noted, and which may provide directions for future research. Despite its many benefits, qualitative studies may be limited by self-reporting that is cross-sectional at a given point in time and influenced by social desirability bias (Brewer et al., 2011). Participants in this study may have been biased, for example, by particular benefits or negative consequences that they had very recently experienced at the time of the interview, or by a selective memory of the upsides of masters sport engagement. In addition, we relied on subjective measures of training and competition time, frequency, and intensity and participants may have overestimated or underestimated their engagement levels (Busse et al., 2009). Future research may build on the findings here and utilize objective measures of training and competition time, frequency, and intensity. This would allow for the determination of more nuanced patterns and thresholds of engagement for perceived benefits and downsides of masters sport participation.

Future research may also explore masters athletes' experiences specific to training and to competition (cf. Dionigi and O'Flynn, 2007), including any possible effect of differences in perceived exertion as identified here. Our study did not delve into those different contexts separately, yet nuances regarding psychological and social experiences in each may be expected. Variation by sport modality (e.g., aerobic, anaerobic, strength, and power; individual, paired, and team; competitive and recreational) should also be considered in future work, as type of sport may be a meaningful factor in frequency and intensity of training and competition and for masters athletes' experiences (Kusy and Zielinski, 2015). Additionally, the apparent impact of frequency of training and competition on social relationships outside the sport environment warrants further examination to better understand the role that, for example, family support plays in offsetting negative social consequences.

The findings of our study provide new insight into the older masters athlete's experience in sport with regard to time and frequency of training and competition, and perceived intensity of engagement. That common benefits can be experienced regardless of frequency of engagement is an important consideration for the design and promotion of sport for older adults. The findings also provide a springboard for further research to better understand features of masters sport that may ensure it is a positive part of successful aging through social connections, increased confidence, and resilience.

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

All authors have contributed equally to this work.

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Applying P-Technique Factor Analysis to Explore Person-Specific Models of Readiness-to-Exercise

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Recent research in exercise prescription and periodization has emphasized the importance of subjective experience, both in medium- and long-term monitoring, but also in the acute experience. Emerging evidence also highlights an important role of subjective readiness (pre-exercise mental and physical states) in determining how exercise is experienced, and in acutely modifying the prescribed exercise intensity. The concept of "readiness-to-exercise" shows promise in enabling and informing this acute decision-making to optimize the experiences and outcomes of exercise. While subjective experiences can be effectively assessed using psychometric scales and instruments, these are often developed and deployed using cross-sectional samples, with resulting structures that reflect a normative pattern (nomothetic). These patterns may fail to reflect individual differences in sensitivity, experience and saliency (idiographic). We conducted this research with the primary aim of comparing the nomothetical and idiographic approaches to modeling the relatively novel concept of readiness-to-exercise. Study 1 (nomothetic) therefore analyzed data collected from 572 participants who completed a one-time survey using R-technique factor analysis. Results indicated a four-factor structure that explained 60% of the variance: "health and fitness;" "fatigue;" "vitality" and "physical discomfort." Study 2 (idiographic) included a sample of 29 participants who completed the scale multiple times, between 42 and 56 times: permitting intra-individual analysis using separate P-technique factor analyses. Our analyses suggested that many individuals displayed personal signature, or "profiles" of readiness-to-exercise that differed in structure from the nomothetic form: only two participants' personal signatures contained four structures as modeled in Study 1, whereas the majority demonstrated either two or three factors. These findings raise important questions about how experiential data should be collected and modeled, for use in research (conceptual development and measurement) and applied practice (prescribing, monitoring)—as well as in more applied research (implementation, effectiveness).

Keywords: idiographic analysis, ecological momentary assessment, interpersonal signatures, subjective assessment, individualization

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INTRODUCTION

Exercise, which refers to planned, structured, and repetitive activity to improve fitness, is commonly promoted as a means of increasing total physical activity levels and eliciting numerous health benefits, such as reduced risk of cardiometabolic disease and certain cancers (Febbraio, 2017). Yet, like many complex health behaviors, poor long-term adherence to exercise represents a persistent problem (Martin et al., 2005; Middleton et al., 2013). To facilitate regular behavioral engagement, service providers should ensure that the structure of the programming components (mode, frequency, intensity, duration, volume, progression; i.e., the "prescription") are optimally designed (i.e., maximizing physiological adaptation and minimizing risk) and clearly communicated (American College of Sports Medicine, 2017). Additionally, the prescription components should be matched to each individual's health status, exercise responses, and stated goals (Garber et al., 2011) to provide a basic foundation for physiological adaptation and behavioral maintenance (King and Senn, 1996; Zubin Maslov et al., 2018; Weatherwax et al., 2019). That is, individuals are unlikely to adhere to a program that yields minimal salient benefits, or to a program they find too challenging to perform as directed. To further support long-term maintenance, Ekkekakis et al. (2011) proposed that prescription components, particularly intensity, should also be designed to minimize negative affective responses (i.e., displeasure) during exercise, as a such responses predict lower future activity levels (Brand and Ekkekakis, 2018).

Individuals will also continually adapt to training stimuli, meaning that exercise prescription is best approached as a dynamic process where programmatic modifications must be responsive to emerging information (Kraemer and Ratamess, 2004; Sasso et al., 2015). While the standard attributes upon which we develop exercise prescriptions (health status, fitness level, and long-term goals) may be less likely to undergo rapid, unpredictable fluctuations, they are also not inherently stable and require assessment and subsequent modification several times per year. Conversely, modifications to optimize exercise *experiences* should occur more acutely. Recent evidence has demonstrated that in-task affect is not solely influenced by intensity, but also by pre-exercise affective states (e.g., moods, emotions, energy/tiredness), physical condition (e.g., residual soreness, illness, pain) and cognitions (e.g., perceived self-efficacy, anticipated affect; Rose and Parfitt, 2007, 2010; Vazou-Ekkekakis and Ekkekakis, 2009; Sala et al., 2016; Zenko et al., 2016; Strohacker et al., 2017; Beaumont et al., 2021). These and other physical, psychological, cognitive, and contextual correlates of exercise behavior can fluctuate relatively frequently over time (Dunton and Atienza, 2009; Dunton, 2017), potentially due to change in other behaviors (sleeping, eating) or events (bad news). Citing the failure of current health-based models to promote sufficient physical activity Barreto (2013) proposed that exercise should be promoted "with the flexibility of being adaptable to a person's circumstances" (p. 390). Similarly, noting that poor behavioral outcomes following theory-driven interventions are likely due to "one-size-fits-all" approaches, Conroy et al. (2020) proposed that "the science of physical activity promotion will advance most rapidly if person-specific psychological, contextual, and behavioral dynamics can be leveraged to adapt or 'tune' interventions to the specific requirements of each individual" (pp. 171).

"Autoregulation" (i.e., the purposeful and frequent adjustment of programming that corresponds to measurable changes in an individual's response to training- and non-training-related stressors) is a recognized and continually developing concept within competitive sport contexts (Greig et al., 2020). The routine monitoring of stressors is purported to guide training in a way that maximizes performance outcomes, reduces risk of negative acute experiences (e.g., overtraining, injury, incompletion, and psychological distress), and minimizes training response variance (Kraemer and Fleck, 2007; Borresen and Lambert, 2009; Mann et al., 2014; Thorpe et al., 2017). Flexible Nonlinear Periodization (FNLP) is an autoregulation strategy where training workloads, which are goal-specific and range from low- to high-demand, are chosen each day based on each individual's "readiness-to-train" (pre-exercise mental and physical states; Kraemer and Fleck, 2007). While Greig et al. (2020) suggest that autoregulation strategies may be beneficial in health-promotion settings, the authors note that the implementation of these exercise frameworks is limited in the health domain.

A particularly glaring gap relates to the operationalization of "readiness." In their foundational text, Kraemer and Fleck (2007) provided a six-factor checklist (coach-trainee interactions; injury status; hydration; mental and physical fatigue; vertical jump power; initial workload performance), whereas Mann et al. (2014) suggested that training status, sleep, stress, and habitual physical activity would indicate readiness-to-train. While these indices make intuitive sense, neither source presented empirical evidence to support their use in training scenarios. Within the existing FNLP literature, conceptualizations of readiness-to-train have varied, such that participants had been instructed to consider their energy level alone (McNamara and Stearne, 2010), reflect upon a combination of factors (e.g., mood, preference, energy, diet, stress level; McNamara and Stearne, 2013), or were not explicitly provided with indices to consider (Colquhoun et al., 2017) before choosing their training bout each day. Rationales were not provided to support these approaches and no data were presented to explore whether or not the suggested indices of readiness-to-train were actually utilized or, in the case of the latter study, what factors ultimately influenced participants' day-to-day decisions. These omissions are problematic because, on one hand, identifying a single marker of readiness-to-exercise assumes that it holds equal importance to all participants. On the other hand, providing multiple indices of readiness-to-train (or none at all) removes the researchers' burden to identify each individual's most salient construct(s). But, this approach assumes that: (1) individuals are cognizant of what factors most impact their exercise performance; and (2) that individuals will act in good faith, in accordance with their level of readiness. Without evidence of these assumptions, we might alternatively propose that individuals left to their own volition may choose workloads that are actually incongruent with their current state of readiness,

which would compromise the fidelity of the novel FNLP training paradigm. Such ambiguity regarding target indices of readiness and participants' compliance (i.e., choosing lower-demand bouts when presenting with reduced readiness) severely limits researchers' ability to empirically test behavioral, psychological, and physiological effects of FNLP as a strategy for personally-adaptive exercise programming.

In an effort to address this gap, researchers have demonstrated initial, empirical evidence for target indices underlying perceptions of readiness in non-athlete sample populations, which we will herein refer to as "readiness-to-exercise" to denote a conceptual shift toward health promotion rather than sport-specific training. An initial study, conducted using survey data from university students, presented four dimensions of readiness-to-exercise labeled "vitality" (positive mood, energy), "fatigue," "discomfort" (illness, soreness), and "health/fitness" (Strohacker and Zakrajsek, 2016). These dimensions were similarly reflected in a subsequent study using thematic analyses, which demonstrated that adults with obesity indicated that their readiness-to-exercise is impacted by perceptions of affective valence and activation (accounting for mood/emotional states and feelings of energy/fatigue), body integrity (injury, sickness, and soreness), physical fitness, fuel (hydration and food intake), and motivation (Strohacker et al., 2019). These shared dimensions of readiness-to-exercise not only reflect the prior (though not empirically-based) conceptualizations of readiness-to-train from the strength and conditioning literature, but also demonstrate overlap with the aforementioned determinants of exercise-related affect. As such, these dimensions, which represent vitality (e.g., energetic valence, mood/emotional state), fatigue, physical discomfort, and perceptions of health and fitness, as well as their structure served as target factors for the current study. We note here that many of these indicators may be measured objectively, and yet subjective indicators have also been shown to outperform, or at least complement such objective measures (Saw et al., 2016).

However, an important limitation of this work is that these conceptualizations of readiness-to-exercise were determined by generalizing responses *across* individuals, potentially obscuring or ignoring the scope for individual differences. Researchers often deploy the "top-down" approach (i.e., inferring idiographic properties based on nomothetic analyses) for data interpretation and application. Contrasting the common assumption in research that idiographic properties can be inferred based on nomothetic analysis, Molenaar (2004) examined psychological variables using mathematical modeling procedures for both approaches. This work demonstrated that structural features of data derived by analyzing *inter*individual variation cannot be generalized to data derived by analyzing *intra*individual variation. Thus, at minimum, it is important to examine both between-person and within-person structures regarding readiness-to-exercise factors prior to developing and implementing FNLP-based exercise programming.

Examining the structural features of multivariate data is often accomplished through factor analysis, which assumes that patterns of covariation among measured variables can be explained using fewer latent constructs. The most widely applied approach, R-technique, is used to examine factor structure at a population level by modeling single-observation data collected from a large number of individuals (Cattell, 1952). Results provide insight into the number of factors, total variance in the data explained by each factor, correlations between factors, pattern of measured items loading on each factor, and magnitude and direction of each item's factor loading. These same procedures can also be applied to time series data to examine the structure of multivariate data *within an* individual, a process known as P-technique factor analysis (Cattell et al., 1947; Cattell, 1963). Molenaar and Nesselroade (2009) demonstrated that the ability of this approach to recover underlying factors is comparable to that of dynamic factor modeling regarding accuracy and robustness. Researchers applying P-technique factor analyses to psychometric data (generally relating to personality research) have also demonstrated that individual factor structures can be relatively diverse compared to results uncovered using R-technique (Lebo and Nesselroade, 1978; Borkenau and Ostendorf, 1998; Molenaar, 2004; Fournier et al., 2008, 2009; Wright et al., 2016), resulting in unique structural features, or, as coined by Fournier et al. (2009), "interpersonal signatures." Wright et al. (2016) surmised that the ability to evaluate such personal "signatures" may help practitioners and clinicians better individualize treatment plans. To date, the degree of diversity present within personalized factor structures pertaining to readiness-to-exercise is a novel research question that has yet to be examined.

The purpose of the current study was to examine nomothetic and idiographic structural features of factors underlying readiness-to-exercise. Two studies were conducted using two existing databases to answer the following research questions: "what is the structure of readiness-to-exercise factors measured in a pre-exercise context?" and "what level of heterogeneity is observed among interpersonal structures of readiness-to-exercise factors measured over time?" Both databases included the same 12 items chosen to represent four dimensions of readiness-to-exercise as previously operationalized by Strohacker and Zakrajsek (2016).

MATERIALS AND METHODS

All methods described herein were approved by the University Institutional Review Board (IRB): Study 1 IRB #14-01841, Study 2 IRB #16-03048-XP.

Study 1—R-Technique Factor Analysis to Determine a Reference Structure for Readiness-to-Exercise

Participants and Sample Size Considerations

We sought a convenience sample of participants (faculty, staff, and students at a large university in the Southeast region of the United States) between January and April 2015 at the university recreation center. We focused our sampling on individuals who were at least 18 years of age and were at the recreation center to exercise (as opposed to meeting friends, purchasing food and drinks, for work, etc.). Sampling is considered to be adequate

if the Kaiser-Meyer-Olkin (KMO) test >0.50 and Bartlett's test of sphericity reveals statistical significance ($p < 0.05$) (Field, 2005). Regarding sample size, the ratio of observations (572) to variables (12) was 47:1. This value is considered adequate for factor analysis (Myers et al., 2011).

Procedures

We approached individuals after entering the university recreation building, but before swiping their identification cards to access areas containing fitness equipment. Interested individuals were provided with a written study information sheet that outlined details regarding the purpose, expectations, and risks of participating in the research study. Individuals were not asked to provide any identifying information, thus assuring participant anonymity. Individuals were also informed that completion of the pen-and-paper survey served as their consent to participate. A research assistant reviewed each survey. In the event of a skipped question, the research assistant asked the respondent to address the error. However, in cases where whole sections were left unanswered, the research assistants interpreted this as withdrawn consent and discarded the survey. We also discarded surveys that indicated the participant was under the age of 18. Of the initial 602 returned surveys, there were 30 surveys discarded due to the above criteria. A total of 572 surveys were retained for statistical analyses.

Instrumentation

Indices of Readiness-to-Exercise

Using a "right now" prompt, participants were asked to rate 12 items using a seven-point Likert scale (0 = not at all, 3 = moderately, 6 = extremely). In the original scale development, these items (indicated in parentheses) were chosen to represent the four factors of readiness-to-exercise: "vitality" (energetic, happy, and lively), "fatigue" (worn out, exhausted, and drained), "discomfort" (pain, achy, and stiff), and "health/fitness" (healthy, fit, and strong) as determined by a previous study (Strohacker and Zakrajsek, 2016). The instrument was limited to three items per factor for brevity and avoid potential redundancy; items were chosen based on ease of understanding, in that items were thought to be most representative of the related factor (Burisch, 1984).

Habitual Exercise

Respondents were first asked to indicate how many days per week they currently exercised. Those indicating one or more days per week were further asked to indicate how many minutes per day they spend exercising, on average. These values were multiplied to calculate total minutes per week of exercise.

Demographics

Participants were asked to indicate their age, current position at the university (undergraduate student, graduate student, staff member, and faculty member), gender, race, and ethnicity.

Statistical Analyses

Statistical procedures were conducted using the Statistical Package for the Social Sciences (SPSS; IBM, Armonk, NY). Means, standard deviations, and ranges were computed for all items. Raw data were not transformed or standardized prior to performing the factor analysis. The factor analysis was conducted using the principal axis method, as a number of variables demonstrated non-normal patterns of distribution (Fabrigar et al., 1999), and oblique (promax) rotation was applied, as we expected a degree of correlation between factors (Costello and Osborne, 2005). We conducted an initial analysis retaining factors based on eigenvalues (factors with values ≥1.0 were retained) to determine suitability for conducting factor analysis using the KMO and Bartlett's test of sphericity. Using available syntax (O'Connor, 2000), we then conducted a parallel analysis of the data to statistically determine the number of factors to retain. Raw data eigenvalues were considered significant (and thus, retained as factors) if they were larger than the 95th percentile eigenvalues and larger than the mean random data eigenvalues. We then examined the structural features of the resultant model (number of factors, proportion of variance explained, between-factor correlation, and item loading).

Study 2—P-Technique Factor Analysis to Examine Heterogeneity in Interpersonal Structures of Readiness-to-Exercise

Participants and Sample Size Considerations

A separate sample of participants from the same southeastern university were recruited *via* flier advertisements, listservs, and word of mouth between June and November 2016 to undergo ecological momentary assessment of exercise behavior and hypothesized correlates. Regardless of current exercise behavior, individuals were eligible to participate if they: (1) were at least 18 years old; (2) were not varsity athletes; and (3) owned a smartphone with text messaging and internet capabilities. Overall, 29 participants consented and completed all study procedures. Participants in this study provided 42–56 points of observation per person (Mean ± SD = 50 ± 4) for 12 items (mean observation-to-item ratio = 4:1). Molenaar and Nesselroade (2009) previously assessed the robustness of the P-technique using sample sizes (i.e., number of data points observed within a person) of 300 observations, 100 observations (considered a general rule of thumb), and 50 observations (a more realistic number of observations in longitudinal research studies). Similar results were found regarding factor loading pattern and strength (but with larger standard deviations) when comparing 50 observations and 300 observations relative to the true loading structure.

Procedures

Interested individuals were invited to an in-person session with a member of the research team. Eligible individuals who provided voluntary consent to participate underwent objective measures of height and weight to calculate body mass index (BMI) using standard procedures and then completed a baseline survey to assess demographic characteristics.

Participants were then familiarized with the primary survey designed to assess exercise behavior and correlates thereof. This survey was built and distributed using Qualtrics Research Suite (Provo, UT). In line with the accepted definition of

"exercise" (Caspersen et al., 1985), participants were explicitly asked to only report activities as exercise if they were planned, structured, and performed with the purpose of maintaining and improving one or more component of physical fitness. Additionally, we explicitly asked participants to avoid reporting non-exercise activity (e.g., transportation, chores, and work). For 14 consecutive days, participants received short-code text messages to their smartphone that contained an Internet link to open and complete the survey. Text prompts were sent four times per day at 9:30 am, 1:30 pm, 5:30 pm, and 9:30 pm. All participants who completed the study received $20 in grocery store gift cards.

Instrumentation

Indices of Readiness-to-Exercise

Using a "right now" prompt, participants were asked to rate 12 items using a seven-point Likert scale (0 = not at all, 3 = moderately, 6 = extremely). The items and rating format used here were identical to those in Study 1 and based on a previous dimensionality of readiness-to-exercise (Strohacker and Zakrajsek, 2016) to address "vitality" (energetic, happy, and lively), "fatigue" (worn out, exhausted, and drained), "discomfort" (pain, achy, and stiff), and "health/fitness" (healthy, fit, and strong), These items were included in each electronic survey.

Exercise Behavior

In response to the prompt "in the past 4 h, did you perform any of the following exercises?" participants were able to select one or more of the following modes: biking outdoors, jogging or running, brisk walking, group fitness class (aerobic), group fitness class (muscle strengthening), swimming, hiking, and weight lifting (free weights or machines). If a participant engaged in an unlisted activity, they were able to select the "other" option and specify the activity using a text box. For each mode selected, participants were asked to indicate how many minutes they spent engaging in each exercise. Estimates of exercise volume (MET-minutes) were calculated by multiplying self-reported duration by metabolic equivalent of task (MET) values provided in the Compendium of Physical Activities (Ainsworth et al., 2011). These items were included in each electronic survey.

Demographics

In the baseline survey, participants reported age, level of education, gender, race, and ethnicity.

Statistical Analyses

Using SPSS, we isolated each participants' time series data to describe item characteristics (mean, standard deviation, and range) and repeated the procedures described for the R-technique analysis: (1) preliminary factor analyses (principle axis method with promax rotation applied to raw scores; factors retained based on eigenvalues $\geq$1.0) were conducted to determine initial sampling adequacy; (2) parallel analyses were conducted to statistically determine the number of factors to retain; and (3) final factor analyses were conducted with the number of factors constrained based on each individuals' parallel analysis. The use of parallel analysis has been previously determined to be an acceptable approach for P-technique factor analysis, as serial dependency of data does not negatively impact performance of the test (Lo et al., 2017). In three cases (participants 021, 022, and 029), the number of factors designated by the parallel analysis could not be extracted using participant's data. As we considered this work exploratory in nature, we chose to conduct the final factor analyses with one fewer factor than originally identified. In two cases (participants 024 and 015), a single item in each participant's data demonstrated zero variance ("achy" or "fit"). These variables were removed, respectively, from each participants' dataset prior to statistical analyses. Extracted communality plots were created to graphically visualize the person-specific structures (compared to the reference structure) in terms of how well each variable in the dataset is explained by the retained factors.

Personalized factor scores were estimated at each measurement time point by summing raw scores corresponding to item loading pattern and direction (i.e., negatively loaded items were subtracted from the total score) (DiStefano et al., 2009). In cases where data were missing, the participant's most recent estimated factor score was carried over. We then examined the intraindividual consistency of "factor 1" scores using a two-way random-effects model to compute the intraclass correlation coefficient (ICC) for absolute agreement. A higher ICC value (range 0.0–1.0) is indicative of greater consistency. In order to interpret the degree of consistency, values are classified as follows: <0.5 (poor), 0.5–0.75 (moderate), 0.75–0.9 (good), and >0.9 (excellent). The interpretation of these values was also considered in the context of 95% confidence intervals (Koo and Li, 2016).

RESULTS

Study 1—R-Technique Factor Analysis

Participants ($N = 572$), on average (mean $\pm$ standard deviation), were comprised primarily of young adults (22 $\pm$ 6 years of age, 43.8% women) who reported exercising 4 $\pm$ 1 days per week. The racial make-up of the study sample reflected that of the university in general, such that 80.7% self-identified as non-Hispanic white (3.9% Asian, 8.8% African-American/Black, 3.5% Hispanic/Latino, 0.9% Native American, 0.9% Native Hawaiian/Pacific Islander and 1.2% indicating "other"). Although the student recreation center is open to any individual with a membership, the majority (81%) of respondents identified as undergraduate students.

The results of Study 1 provided the reference factor structure to which individual factor structures were compared. Participants' self-reported pre-exercise ratings for the 12 items were determined to be suitable for conducting factor analysis, as the KMO = 0.796 and Bartlett's test was statistically significant (chi square = 2720.256 (df 66), $p < 0.001$). The parallel analysis indicated four distinct factors (**Table 1**).

The four factors explained nearly 60% of the rotated variance in the dataset and were identified as representing "health and fitness," "fatigue," "vitality," and 'physical discomfort" (**Table 2**). All items demonstrated sufficient loading magnitudes (0.585–0.891) with low cross-loading onto other factors (maximum absolute cross-loading = 0.106). These observations indicate that

TABLE 1 | Results of the parallel analysis to determine factor retention for R-technique exploratory factor analysis (EFA; Study 1).

Initial factors	Initial eigenvalues from EFA	Parallel analysis raw data eigenvalues	Parallel analysis mean eigenvalue	Parallel analysis 95th percentile eigenvalue
1*	3.843	3.341	0.264	0.326
2*	2.439	1.903	0.200	0.246
3*	1.385	0.851	0.150	0.188
4*	1.063	0.537	0.106	0.143
5	0.648	0.024	0.067	0.101
6	0.496	−0.073	0.029	0.057

Asterisks denote factors that are statistically significant (raw eigenvalues > computed mean and 95th percentile eigenvalues).

TABLE 2 | Descriptive statistics and R-technique exploratory factor analysis—pattern matrix (Study 1; $N = 572$).

Item	Initial communalities	Mean ± SD (min-max)	Factor 1	Factor 2	Factor 3	Factor 4
Strong	0.522	4 ± 1 (0-6)	**0.857**	−0.056	−0.057	0.080
Fit	0.474	4 ± 1 (0–6)	**0.751**	0.072	0.049	−0.019
Healthy	0.469	4 ± 1 (1–6)	**0.736**	−0.001	0.045	−0.076
Worn out	0.531	2 ± 1 (0–6)	−0.009	**0.849**	0.106	0.010
Drained	0.579	2 ± 1 (0–6)	−0.019	**0.808**	−0.063	0.016
Exhausted	0.469	1 ± 1 (0–6)	0.039	**0.724**	−0.072	−0.013
Lively	0.545	4 ± 1 (0–6)	−0.015	0.047	**0.891**	0.000
Energetic	0.535	4 ± 1 (1–6)	0.048	−0.063	**0.747**	0.028
Happy	0.356	4 ± 1 (0–6)	0.008	−0.006	**0.630**	−0.038
Achy	0.465	2 ± 1 (0–6)	0.020	0.026	0.028	**0.832**
Pain	0.383	1 ± 1 (0–6)	−0.050	−0.023	0.052	**0.708**
Stiff	0.310	2 ± 1 (0–6)	0.027	0.011	−0.102	**0.585**
Initial values		% Variance Eigenvalue	32.027	20.325	11.545	8.855
Rotated values		% Variance Eigenvalue	28.900	17.052	8.207	5.596

Bold values meant to visually highlight which items strongly and uniquely loaded onto each factor.

factors were distinct from one another, which allowed relative ease regarding interpretation.

Study 2—P-Technique Factor Analyses

Participants ($N = 29$) consisted primarily of young adults (24 ± 6y, BMI = 25.3 ± 3.3 kg/m^2, 76% non-Hispanic White, 55% women). On average, participants self-reported engaging in 1240 ± 662 MET-Minutes per week of exercise.

We first assessed the degree of within-person variance in item ratings over time to determine if items described stable traits (i.e., minimal variance) or varying states. In many cases, participants responded using much of the 0–6 range. On average, the minimum rating across all items was 0.53 ± 0.96 and the maximum rating across all items was 4.94 ± 1.26. This indicates that item ratings demonstrated observable variance in affective and perceptual states across the 2-week monitoring period. However, the degree of discrimination between items differed across individuals. For example, participant 007 demonstrated the smallest difference between their highest item mean ("happy" = 3.36) and their lowest item mean ("pain" = 1.96), suggesting a higher degree of uniformity in ratings across all 12 items. In contrast, participant 028 demonstrated the largest difference between their highest ("healthy" = 5.93) and lowest ("pain" = 0.23) item mean. Of note, in 25 of the 29 individuals, an item representing physical discomfort ("achy," "stiff," "pain") was observed to be the lowest item mean, of which "pain" was the lowest in 15 of these cases. Similarly, the highest item mean across individuals was often "happy" (16 cases); however, in four cases, an unfavorable item (e.g., "drained" or "exhausted") demonstrated the highest mean among the 12 items.

The degree of discrimination within items also differed across individuals. There were only two cases where no temporal variance was noted for an item, in that two participants provided the same score for "achy" or "fit" at every measurement point over time. Excluding these cases, participant 006 demonstrated the most variance, such that average standard deviation across items was 2.24 (range: 1.61 for "fit" and 2.66 for "lively"). Conversely, participant 011 demonstrated an average standard deviation of 0.60 across all 12 items (range: 0.33 for "drained" and 0.82 for "lively").

Sampling was determined to be adequate for all 29 individual factor analyses based on values pertaining to KMO (0.757 ± 0.062, min = 0.626, max = 0.892) and Bartlett's chi square (366.546 ± 112.038, min = 202.82, max = 679.65; all p's < 0.001). When examining separate parallel analyses fit to the individual multivariate time series data for each participant, a median of three retained factors was observed among participants. Across all items, the average factor loading was 0.733 ± 0.150 (min = 0.406, max = 1.09). On average, the percentage of variance explained by each individual's first factor was 38.01 ± 9.50% (min = 21.96%, max = 66.92%).

Only two participants' data were determined to have four factors, in line with the reference structure, according to the parallel analyses (**Figure 1**). In contrast to the reference structure, wherein the first factor was comprised of items pertaining to the "health and fitness" domain, the first factors in both person-specific structures were comprised of items relating to "fatigue."

A three-factor structure was determined for a larger subset of participants ($n = 11$). Through interpreting the structures among a larger group of individuals, shared structural patterns in item loadings emerged under which three to four participants could be grouped. One pattern was characterized by all positively-valenced items (e.g., those representing "vitality" and "health and fitness" domains) loading onto the first factor, followed by separate factors representing "fatigue" and then "physical discomfort" (**Figure 2**).

A second three-factor pattern was characterized by fatigue-specific first factors (**Figures 3A,C,E**). In the third pattern, items relating to "vitality" and "fatigue" domains loaded onto the first factor, with the second and third factors pertaining to "physical discomfort" and "health and fitness," respectively (**Figures 3B,D,F**).

A two-factor structure was determined for the majority of participants ($n = 14$), with shared patterns under which two to three participants could be grouped. **Figure 4** shows the pattern shared by three individuals, which is characterized by all items loading onto the first factor except those pertaining to the "physical discomfort" domain.

Figure 5 shows the remaining shared two-factor patterns. In these patterns, the first factors are comprised primarily of items pertaining to (1) all positively-valenced items (Panels A,B), (2) all domains except "fatigue" (Panels C,D), (3) to "fatigue" and "vitality" (Panels E,F), and (4) to all negatively-valenced items (Panels G,H).

Single factor structures are demonstrated in **Figure 6** (Panels A and B). Additionally, this figure highlights the four participants who, based on their resultant factor structure, could not be grouped under shared patterns. This includes individuals with three-factor structures (Panel C) and two-factor structures (Panels D,E).

The distribution of estimated "factor one" scores within each individual are demonstrated in **Table 3**. For 16 individuals, higher scores could be interpreted as representing a more favorable state (e.g., positive loadings of items pertaining to health/fitness and vitality with negative loadings of items pertaining to fatigue or physical discomfort). For the remaining 13 individuals, higher scores could be interpreted as less favorable (e.g., positive loadings for fatigue and physical discomfort). The ICC = 0.62, $p < 0.001$ (95% CI = 0.50–0.75), suggesting a moderate degree of consistency across estimated factor one scores. **Figure 7** presents three representative cases to demonstrate fluctuation in calculated factor scores over the two-week measurement period. In all cases, higher first factor scores are indicative of a more favorable state. In Participant 001, higher second and third factor scores indicate more unfavorable states (i.e., more fatigue, discomfort; both domains are similarly accounted for together in the second factor of Participant 026). In Participant 007, higher second factor scores indicate a more unfavorable state (i.e., discomfort), whereas higher third factor scores indicate a more favorable state (i.e., greater perceptions of health and fitness).

DISCUSSION

We conducted this research with the primary aim of comparing the nomothetical and idiographic approaches to modeling the relatively novel concept of readiness-to-exercise. Study 1 (nomothetic) therefore analyzed a cross-sectional data from 572 participants, suggesting a four-factor structure that explained 60% of the variance in readiness-to-exercise: "health and fitness;" "fatigue;" "vitality" and "physical discomfort." Study 2 (idiographic) included a sample of 29 participants who completed the readiness-to-exercise scale multiple times, between 42 and 56 times: permitting intra-individual analyses. Our analyses suggested that many individuals displayed personal signatures, or profiles' of readiness-to-exercise that differed in structure from the nomothetic form: only two participants' personal signatures contained four structures as modeled in Study 1, whereas the majority were observed to have either two or three factors that were considered statistically significant in accordance with the parallel analyses. These findings raise important questions about how experiential data should be collected and modeled, for use in research (conceptual development and measurement) and applied practice (prescribing, monitoring)—as well as in more applied research (implementation, effectiveness).

From a conceptual viewpoint, readiness-to-exercise encompasses a variety of independent and interrelated psychological, physiological, and behavioral factors. When appropriately measured and appraised, indices of readiness-to-exercise offer promise in guiding in-the-moment modifications to exercise goals in response to an individual's changing circumstances over time. The application of factor analyses serves to reduce the dimensionality of multivariate data to observe fewer latent variables and the degree to which they explain variance in the full dataset (Cattell, 1952). From a practical perspective, Cattell (1952) noted that, in order to test a given hypothesis using standard experimental procedures, the researcher must first identify the variable (or variables) of most importance, often from a large array of potential variables. According to the R-technique factor analysis conducted in the first study, variables conceptualized to represent the "health

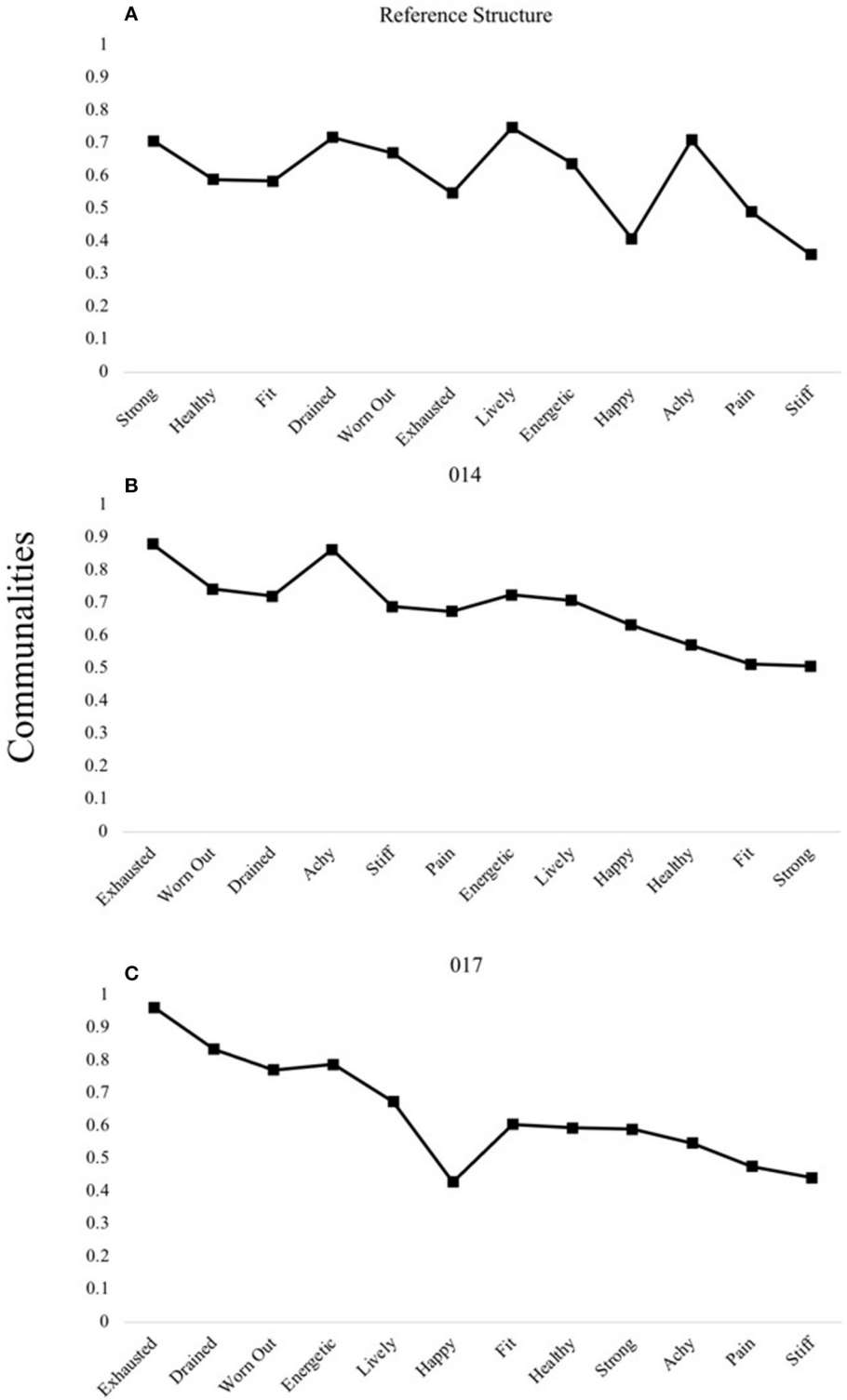

FIGURE 1 | R- and P-technique four-factor models demonstrating unique patterns. The reference structure derived from R-technique factor analysis in Study 1 **(A)** is compared to the four-factor structure of participants 014 **(B)** and 017 **(C)** uncovered using P-technique factor analyses in Study 2. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

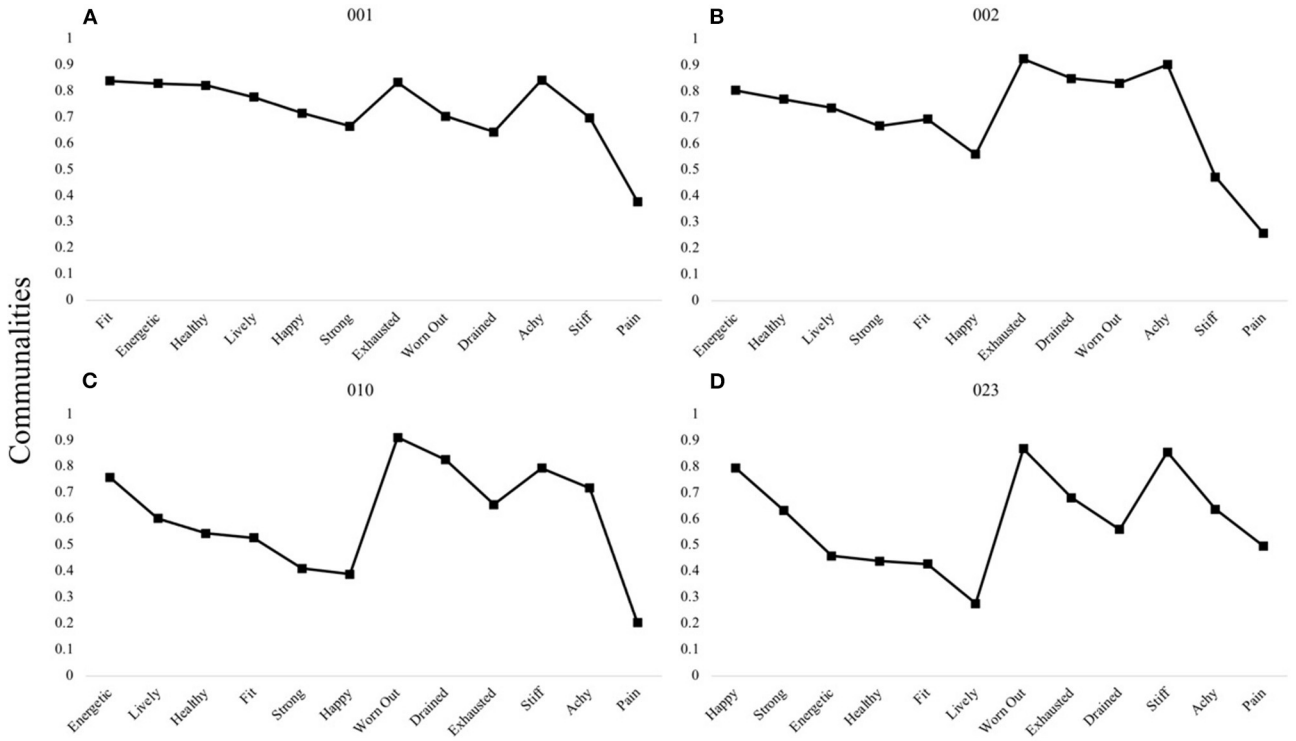

FIGURE 2 | P-technique three-factor models demonstrating a single shared pattern. Participants 001 **(A)**, 002 **(B)**, 010 **(C)**, and 023 **(D)** are shown to demonstrate the most common three-factor structure observed among individuals: VH-F-D. V, "Vitality" domain comprised of items happy, energetic, lively; H, "Health and Fitness" domain comprised of items health, fit, strong; F, "Fatigue" domain comprised of items exhausted, worn out, drained; D, "Discomfort" domain comprised of items achy, stiff, pain. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

and fitness" dimension ("strong," "fit," "healthy") collectively explained the most (29%) rotated variance in the dataset. Based on Cattell's reasoning, we might assume that, as it is considered the most important factor, differentiation in this factor score (i.e., high vs. low) would better discriminate which individuals should experience a standardized exercise session more favorably or unfavorably compared to "discomfort" factor scores, which explained the least variance. Additionally, items loading on this latter factor ("pain," "achy," "stiff") were scored lower compared to items that loaded on the other three factors. This finding is most likely explained by the young age and relatively high exercise level of the sample population, as physical inactivity is a predominant risk factor for chronic pain conditions (Landmark et al., 2011). Further, regular exercise has been demonstrated as an efficacious strategy for alleviating pain across various conditions (Biodonde et al., 2014; Fransen et al., 2015; Searle et al., 2015).

The R-technique structure observed in the current study contrasts with that demonstrated in the previous R-technique factor analysis of Strohacker and Zakrajsek (2016), wherein the analogous factor, comprised of just two items ("healthy" and "fit"), explained the least amount of rotated variance (2%) in their four-factor model. One likely explanation for these contrasting findings, given the similar student sample populations in both studies, is that variables relating to mood, emotional, and energetic arousal states were overrepresented in the earlier study. Through their systematic development of an item pool, Strohacker and Zakrajsek (2016) combined readiness-related words frequently listed by participants with items from commonly used psychometric instruments in exercise psychology research, which do not ascertain physiological states (e.g., sickness, hunger, and pain) or perceptions of fitness (e.g., endurance, strength, flexibility). Having fewer related items reduces the potential explanatory strength of a given factor. An alternative possibility is that differences in first factor item composition could be due to the context of data collection. For the current study, participants provided *integral* item ratings (i.e., in a pre-exercise context), as compared to the incidental ratings (i.e., in a classroom setting) provided by participants in the previously published work. Conceptually, readiness-to-exercise is not intended to be a predictor of future of exercise behavior, but rather, a predictor of an *impending* exercise experience (i.e., the decision to exercise is about to been enacted). In this regard, determining whether or not population-level structures hold across measurement contexts is particularly valuable. Contextual differences may also extend to the level of physical demand proposed. In their qualitative analysis of open-ended survey responses, Strohacker et al. (2019) noted that the

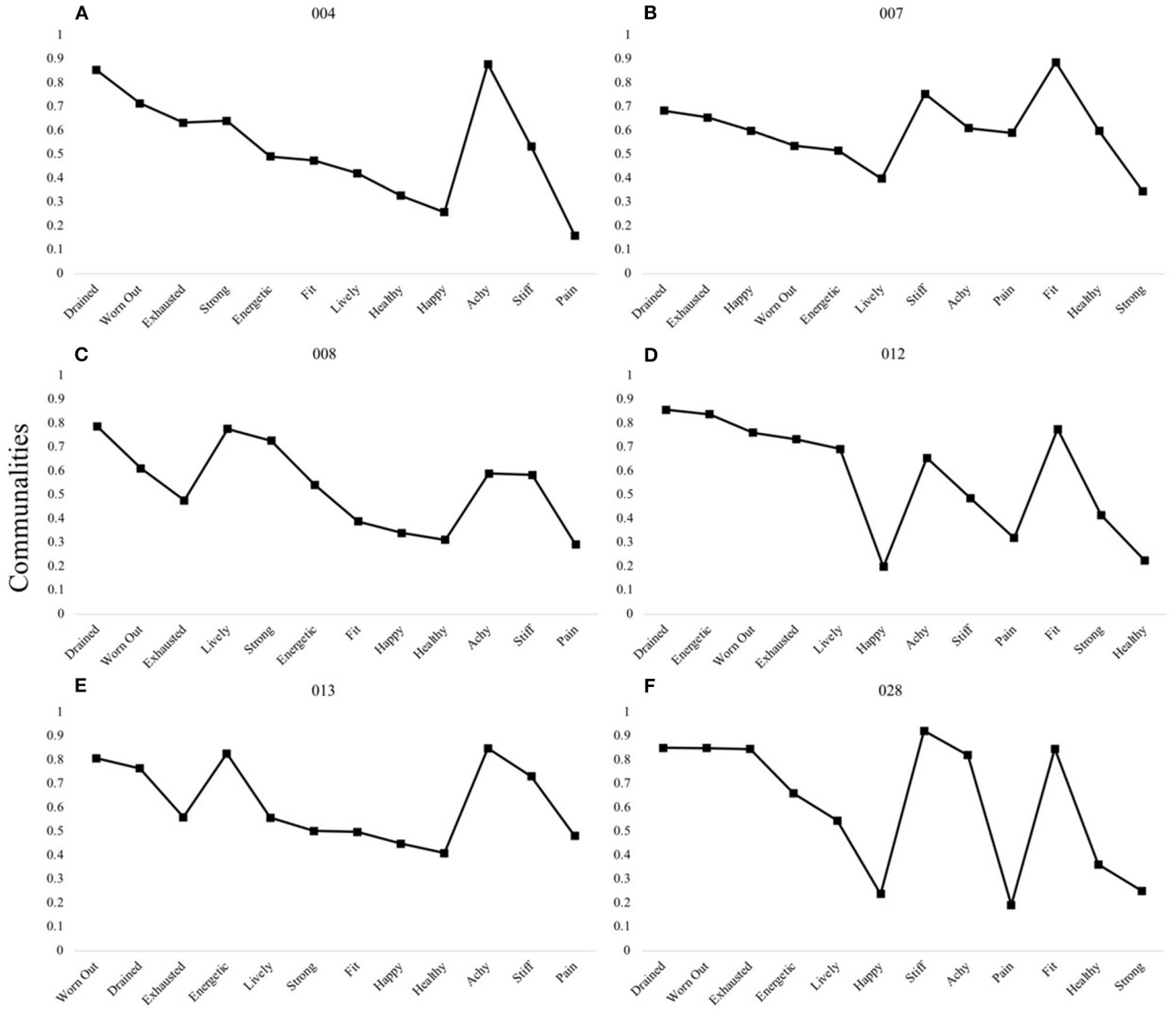

FIGURE 3 | P-technique three-factor models demonstrating two shared patterns. Participants 004 **(A)**, 008 **(C)**, and 013 **(E)** are shown to demonstrate the shared F-VH-D pattern, whereas participants 007 **(B)**, 012 **(D)**, and 028 **(F)** demonstrate the VF-D-H pattern. V, "Vitality" domain comprised of items happy, energetic, lively; H, "Health and Fitness" domain comprised of items health, fit, strong; F, "Fatigue" domain comprised of items exhausted, worn out, drained; D, "Discomfort" domain comprised of items achy, stiff, pain. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

theme pertaining to perceptions of fitness only emerged when respondents were asked to describe how they would need to feel to complete a 60-min jog, and not when asked to consider readiness to complete a 10-min slow stroll. The influence of context on resultant factor structures should be subsequently explored.

The results of the current study demonstrate that structural features of factors modeled using P-technique factor analysis display heterogeneity when compared to a reference structure achieved through the traditional R-Technique. This finding first suggests that the most important subjective variables (i.e., those that explain the most variance in the data) differ between individuals. Second, by modeling a set of factors using time-series data, researchers can uncover each individual's *dynamic structure* to reveal patterns of covariation that yields unique insight into a person's relevant preconditions, behaviors and resultant experiences (Wright, 2017). Our study provides proof-of-concept for the existence of numerous, distinctive patterns in structural features, occurring at least in regards to individuals' subjective precondition. In viewing the variability demonstrated in the communality plots, there is little doubt that "interpersonal signature" is a fitting term to apply. When mapping all factors scores over time, additional, person-specific information emerges. For example, in viewing the first factor scores (both

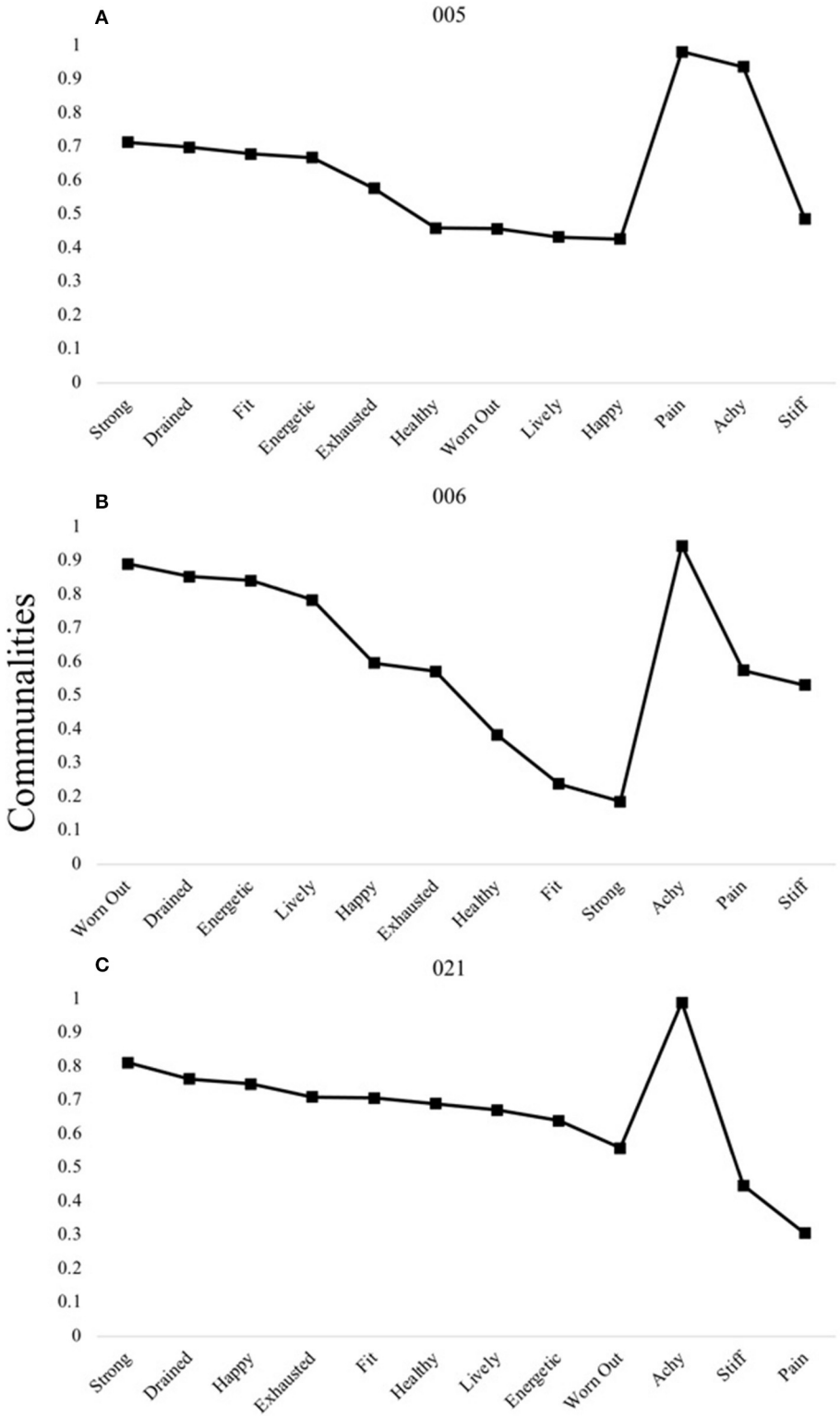

FIGURE 4 | P-technique two-factor models demonstrating a single shared pattern. Participants 005 **(A)**, 006 **(B)**, and 021**(C)** are shown to demonstrate the most common two-factor structure observed among individuals: VHF-D. V, "Vitality" domain comprised of items happy, energetic, lively; H, "Health and Fitness" domain comprised of items health, fit, strong; F, "Fatigue" domain comprised of items exhausted, worn out, drained; D, "Discomfort" domain comprised of items achy, stiff, pain. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

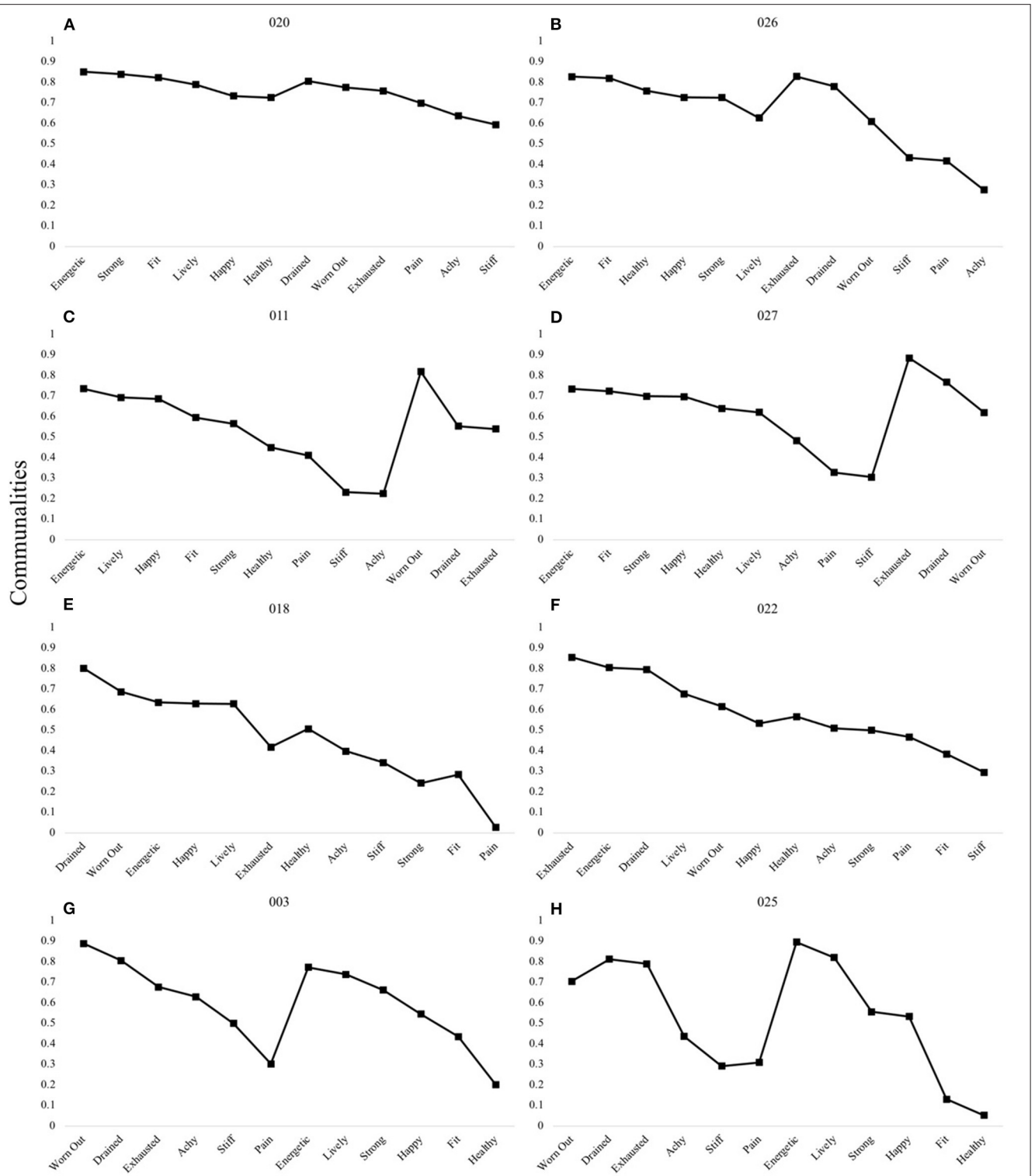

FIGURE 5 | P-technique two-factor models demonstrating four shared patterns. The VH-FD pattern was observed in participants 020 **(A)** and 026 **(B)**. The VHD-F pattern was observed in participants 011 **(C)** and 027 **(D)**. The VF-DH pattern was observed in participants 018 **(E)** and 022 **(F)**. The FD-VH pattern was observed in participants 003 **(G)** and 025 **(H)**. V, "Vitality" domain comprised of items happy, energetic, lively; H, "Health and Fitness" domain comprised of items health, fit, strong; F, "Fatigue" domain comprised of items exhausted, worn out, drained; D, "Discomfort" domain comprised of items achy, stiff, pain. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

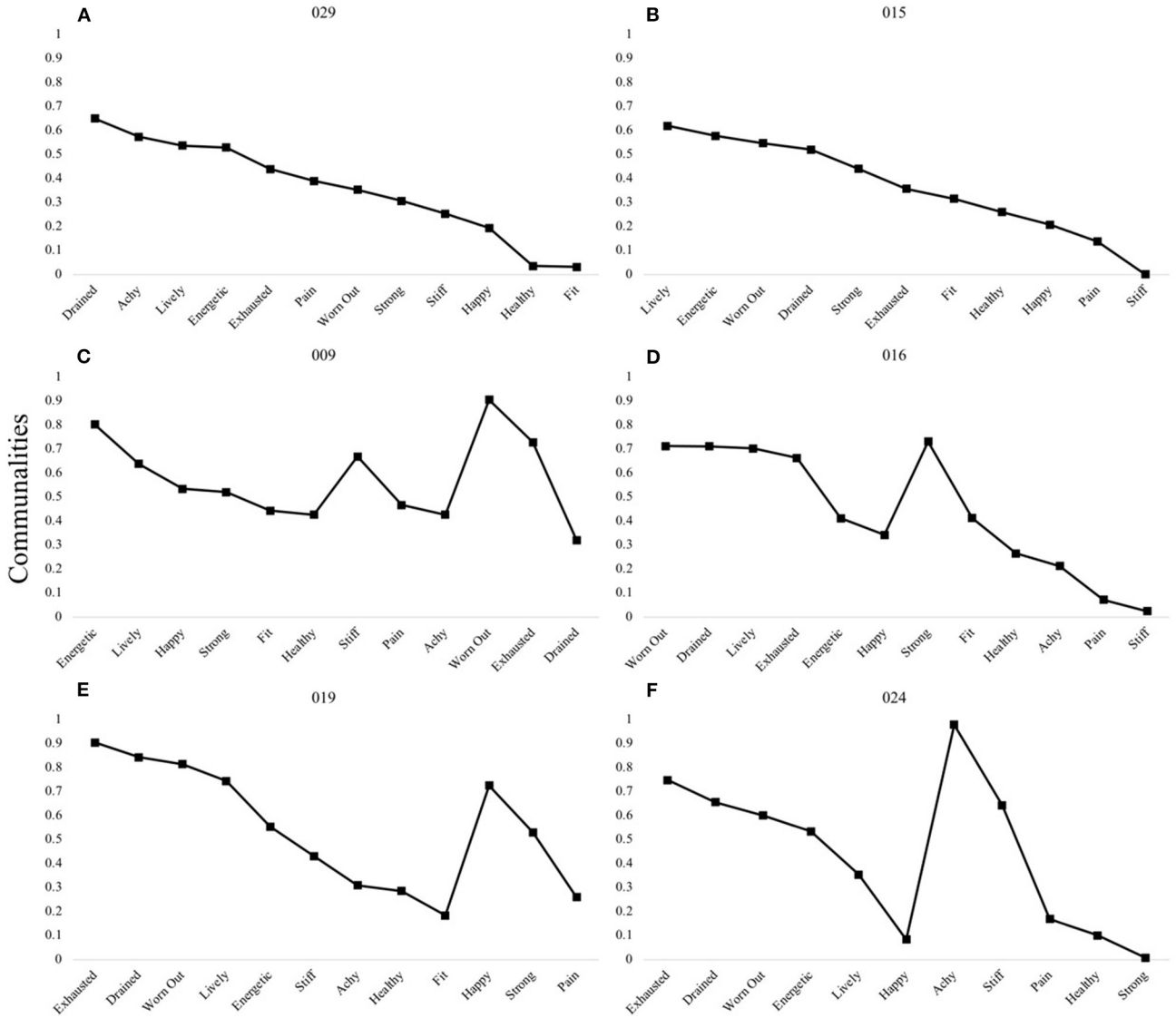

FIGURE 6 | P-technique single factor models and unique multi-factor patterns. Participants 029 **(A)** and 015 **(B)** demonstrated a one-factor model. Four individuals presented with unique three-factor **(C)** or two-factor models **(D–F)**. Communality scores ranging from 0 to 1 represent the degree to which each variable is explained by the resultant factors.

calculated by summing all six positively-valenced items) in Participants 001 and 026, we note that the former generally presented with higher scores (26 ± 9) compared to the latter (17 ± 6). Additionally, we also note that Participant 007 generally presented with higher scores for discomfort (second factor) than Participant 001 (third factor). Person-specific differences in central tendency and spread of factor scores should be accounted for, as it has previously been demonstrated that modeling trait-level patterns of instability as a construct improves physical activity prediction (Dunton, 2017).

The observation that multiple individuals could be represented by a particular structural pattern also aligns with the findings of Wright et al. (2016), who were able to discuss their results (which did not pertain to exercise or physical activity, however), using five "exemplar" cases to represent structures from 25 individuals. It is important, however, to consider these results from both studies in the context of the relatively small sample populations included (N's < 30). It is unlikely that this work was sufficiently powered to demonstrate either the full array of truly unique structural configurations or the number of representative configurations, under which numerous person-specific structures reasonably cluster. Further, as the sample was relatively homogenous regarding age, activity level, and race, we did not analyze the data to understand if those demonstrating similar interpersonal signatures also shared key demographic or habitual behavior features. To answer these

TABLE 3 | Description of within-person data distribution for estimated factor one scores for all participants ($N = 29$; Study 2).

Participant ID (factor score range)	Mean ± SD (min-max)	Participant ID (factor score range)	Mean ± SD (min-max)	Participant ID (factor score range)	Mean ± SD (min-max)
001 (0, 36)[a]	20 ± 7 (4, 36)	011 (−6, 36)[a]	22 ± 4 (15, 32)	021 (−18, 36)[a]	16 ± 9 (−5, 6)
002 (0, 36)[a]	16 ± 6 (3, 16)	012 (−18, 24)[a]	8 ± 7 (−5, 21)	022 (−18, 18)[b]	3 ± 9 (−17, 17)
003 (−6, 36)[b]	12 ± 11 (−6, 31)	013 (−6, 18)[b]	7 ± 4 (−1, 14)	023 (0, 30)[a]	11 ± 6 (0, 25)
004 (0, 18)[b]	8 ± 4 (1, 17)	014 (0, 18)[b]	11 ± 4 (3, 18)	024 (−12, 18)[b]	0 ± 4 (−8, 10)
005 (−18, 36)[a]	20 ± 8 (1, 33)	015 (−18, 36)[a]	19 ± 7 (3, 29)	025 (0, 36)[b]	14 ± 5 (3, 22)
006 (−18, 36)[a]	4 ± 16 (−18, 36)	016 (−18, 24)[b]	−3 ± 8 (−15, 12)	026 (0, 36)[a]	17 ± 6 (6, 22)
007 (−18, 18)[a]	1 ± 4 (−8, 8)	017 (0, 18)[b]	4 ± 3 (0, 12)	027 (0, 48)[a]	13 ± 6 (2, 15)
008 (−6, 18)[b]	5 ± 3 (−2, 15)	018 (−18, 24)[a]	10 ± 10 (−14, 24)	028 (−18, 18)[b]	−8 ± 6 (−17, 11)
009 (0, 36)[a]	20 ± 6 (6, 30)	019 (−12, 18)[b]	9 ± 5 (−6, 16)	029 (−24, 36)[b]	−16 ± 6 (−23, 14)
010 (0, 36)[a]	25 ± 4 (17, 31)	020 (0, 36)[a]	15 ± 9 (0, 36)		

[a] *Higher factor one score interpreted as more favorable state based on item loadings.*
[b] *Higher factor one score interpreted as a less favorable state based on item loadings.*

important questions, future work likely requires larger and more diverse sample populations. Nevertheless, given the theoretical possibility that individuals may not all experience the world in the same way—varying for example in interoceptive sensitivity and cultural reference-points—then our findings reinforce the argument that measuring and studying such experiences using nomothetic assumptions may be inappropriate for both researchers and practitioners alike. Findings may be unreliable, or invalid, in relation to the underlying reality, but participants may also feel alienated and poorly represented by the questions and resulting "insights." While, in the case of the current study, we are referring to subjective feelings and physical cues, researchers have previously surmised that individuals ascribe meanings to situations that can either be broadly shared by others or that are particularly idiosyncratic—the combination of which reveals person-specific dispositions and situation-behavior signatures (Fournier et al., 2008).

The demonstration of within-person variability, not only in singular item ratings, but also in estimated factor one scores further highlights that individuals in our study experienced and reported changing circumstances. Further, the ICC regarding estimated factor one scores within individuals fell below the threshold for "good" consistency (ICC $\geq$ 0.75), suggesting that individuals experience a degree of variance even over a relatively short time period. In other words, the factor that explains the most variance for each individuals' data better represents dynamic states, rather than static traits. This finding lends support for refining FNLP to account for individuals' changing circumstances. In particular, we propose that applying the P-technique should allow researchers to objectively identify individualized models of readiness-to-exercise in order to determine the smallest number of the most important variables to monitor over time, for each person. This proposed approach is in contrast to the varied and relatively unstructured approaches to operationalize readiness in the existing FNLP-based research. For example, in reviewing time-series data for Participant 001, time-point 35 likely represents a vulnerable period, wherein scores for positively-valenced items (i.e., energetic, happy, strong, and fit) are lower than normal and scores for fatigue-related items are higher than normal. It is possible that factor scores at time-points 3 and 23 for Participants 007 and 026, respectively, may similarly signal an increased vulnerability to negative acute responses to exercise. While such speculations need to be validated through experimental or observational data, the approach provided in the current study can serve as a feasible starting point for developing research designs to test such hypotheses.

Overall, the success of person-adaptive approaches for exercise programming hinges on participant "buy-in" to put forth sufficient efforts for data collection. That is, individuals must be willing to: (1) diligently self-monitor behavioral outcomes and/or routinely wear and care for physical activity trackers; (2) provide prompt and unbiased psychological and perceptual feedback consistently over time; and (3) be sufficiently responsive to inquiries and new directions. Ultimately, participants need to put forth mental effort above and beyond that of daily living, in essence, to allow a clinician or researcher to effectively guide dynamically personalized decisions in the best interest of participants' in-the-moment circumstances. Therefore, the experience of generating data (as well as the exercise itself) needs to feel relevant, worthwhile and rewarding. Thus, in appreciation of this potential burden, researchers must strive to use collected data appropriately to inform decisions based on individuals' most salient and informative constructs. Based on the results of the current study—and as argued in the supporting methodology papers that we used to design this study—P-technique factor analysis of data collected *via* ecological momentary assessment offers a powerful process that can be used in early-stage development to reduce multivariate data and view potentially meaningful factors through an idiographic lens.

In discussing the findings of the current study, it is important to consider a concern, raised by Borkenau and Ostendorf (1998), that heterogeneity derived from P-technique analyses that departs from a reference structure may simply

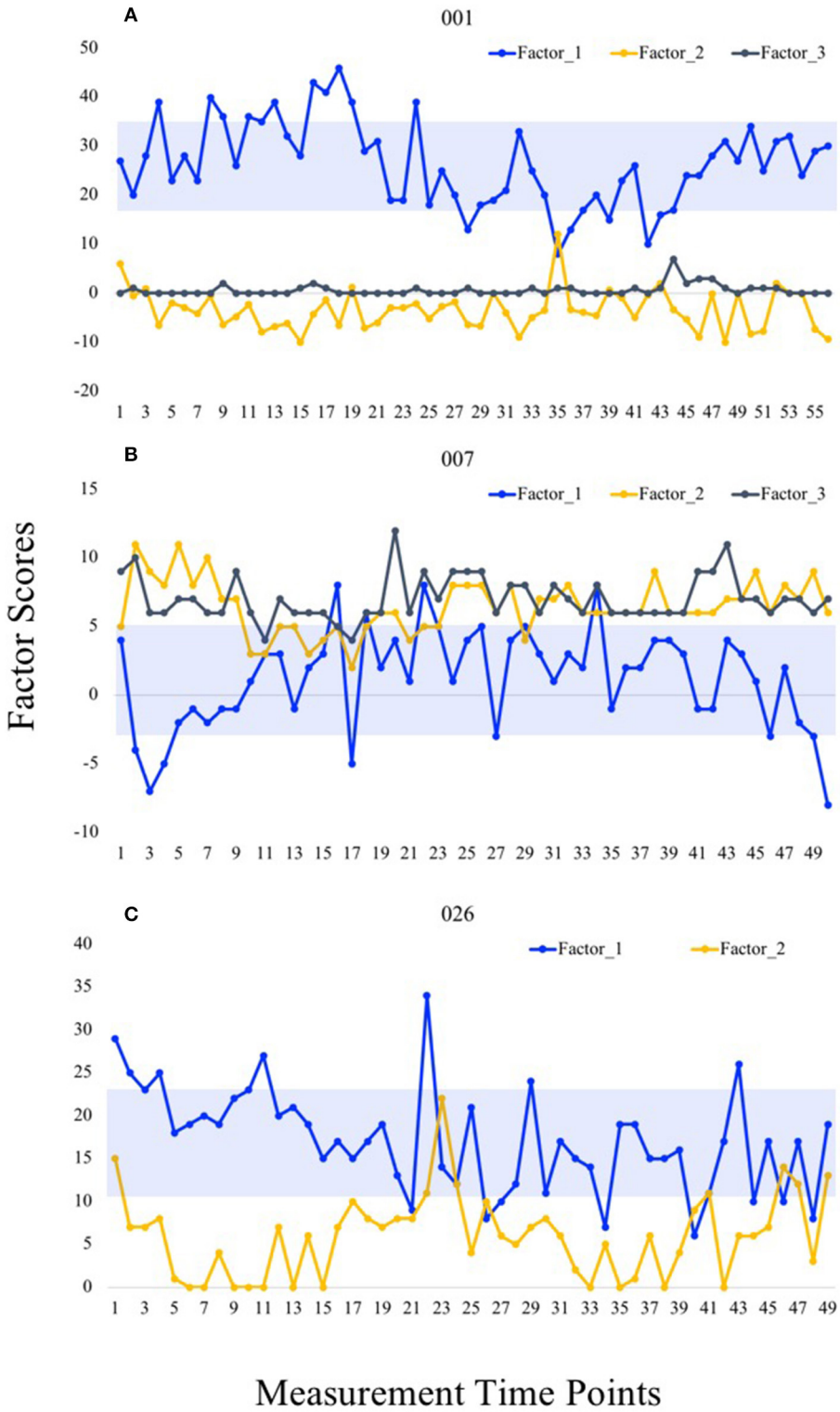

FIGURE 7 | Temporal fluctuation in factor scores in representative cases. Factor scores calculated at each measurement time point are shown for Participants 001 **(A)**, 007 **(B)**, and 026 **(C)**. Blue boxes demonstrate one standard deviation from the mean in both directions.

be an artifact of having fewer measurement points to analyze. The same authors nonetheless recognized that it would be exceptionally difficult to obtain sufficient time series data in a single person for robust comparisons to be made between R- and P-techniques. Alternatively, we propose that a more efficient approach for researchers is to direct efforts toward substantiating the utility of person-specific structures of readiness derived from P-technique factor analysis. For example, empirical modeling procedures could be applied to determine relationships between first factor scores and relevant outcomes (e.g., exercise-related effort, exertion, affect, and performance appraisals). As an example of this approach, using point-biserial correlations, Wright et al. (2016) observed that estimated first factor scores were associated with key behavioral outcomes in the target sample population. The informational utility of uncovered factor structures could also be explored through mixed methods designs. For example, individuals' interpersonal readiness signatures could be objectively constructed using P-technique factor analysis and presented to individuals in one-on-one interviews to gauge their perceptions regarding saliency as well as likely impact on exercise-related behavior and experiential outcomes. Systematic research efforts toward defining and testing key intervention components—in our case person-specific models of readiness-to-exercise—*via* experimental and qualitative designs are strongly promoted by experts in health psychology to more efficiently develop and refine promising, evidence-based behavioral treatments prior to examining efficacy in randomized controlled trials (Czajkowski et al., 2015). We also note the possibility of researching if-and-when participants' "personal-signature" factor structures may change, for example in response to learning or training: which seems both a plausible consequence of these findings and indeed a possibility suggested by researchers assessing interventions to develop interoception (Çöl et al., 2016; Navarro-Haro et al., 2019) and mindfulness (Farb et al., 2013; Haase et al., 2016).

The current research does present with several limitations. First, we do not propose that the original item pool for both studies represents all potential constructs underlying readiness-to-exercise, as these data had already been collected and, thus targeted for secondary analyses. The results should be interpreted more as proof-of-concept that idiographic factor structures can depart from those derived from nomothetic approaches: thus, requiring further research using purposefully collected and more recent data. Specifically, such data (or at least a portion thereof) should be integral (i.e., collected specifically within the pre-exercise context, as was accomplished in the first study), because the data analyzed in the second study better represent incidental measures of readiness-related constructs. Second, because the sample populations of both studies mainly consist of university students, it cannot be assumed that the uncovered structural features are representative of other populations who may perceive readiness-to-exercise differently, such as older adults, those diagnosed with chronic disease, or adults who must manage additional stress-producing life priorities (e.g., full-time employment, child or elder care). Further, as the participants primarily identified as non-Hispanic white, these findings cannot necessarily be extrapolated to individuals that identify with other (often minoritized) racial categories and ethnicities.

In conclusion, the current findings demonstrate that interpersonal signatures (and clusters of similarly-structured signatures among individuals) of readiness-to-exercise generated *via* P-technique factor analyses often depart from a generalized structure of readiness-to-exercise (i.e., differing in factor number, percentage of variance explained per factor, and item loadings within each factor). Uncovering dynamic state differences within an individual over time opens opportunities to more precisely identify important components to measure, which may be shared or unique across individuals, and used to guide personally-adaptive exercise programming. P-technique factor analysis offers a preliminary means of modeling idiographic structures and features of multivariate data that can be collected with relative ease using smartphone technology. Applying this process may help exercising individuals and practitioners begin to answer complex questions (i.e., which precondition—my energy level or my perception of physical discomfort—is more predictive of a subsequent exercise experience) that may otherwise be difficult to articulate "off the cuff," in absence of interpretable data. Such an approach would depart from current practices of utilizing a single, practitioner-chosen variable or relying on participants' personal (and potentially uninformed or uncritical) choices. Subsequent efforts to understand both the predictive and informational utility of individuals' uncovered factors aligns with recent calls by experts to progress toward person-specific interventions for both sport and general physical activity promotion.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

The collection of data utilized in Study 1 was designed and carried out by KS and RZ. The collection of data utilized in Study 2 was designed and carried out by KS. All authors contributed to data analysis and interpretation in the current study, as well as to all aspects of manuscript preparation.

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MINI REVIEW
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Fear of Movement/(Re)Injury: An Update to Descriptive Review of the Related Measures

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The prevalence of fear of movement (kinesiophobia) in persistent pain ranges from 50 to 70%, and it may hinder the subsequent rehabilitation interventions. Therefore, the evaluation of fear of movement/(re)injury plays a crucial role in making clinical treatment decisions conducive to the promotion of rehabilitation and prognosis. In the decision-making process of pain treatment, the assessment of fear of movement/(re)injury is mainly completed by scale/questionnaire. Scale/questionnaire is the most widely used instrument for measuring fear of movement/(re)injury in the decision-making process of pain treatment. At present, the most commonly used scale/questionnaire are the Tampa Scale for Kinesiophobia (TSK), the Fear-Avoidance Beliefs Questionnaire (FABQ), the Kinesiophobia Causes Scale (KCS), the Athlete Fear-Avoidance Questionnaire (AFAQ), and the Fear-Avoidance Components Scale (FACS). In order to provide necessary tools and references for related research and rehabilitation treatment, this descriptive review is designed as an introduction to the background and content, score system, available language versions, variants of the original questionnaire, and psychometric properties of these scales/questionnaries.

Keywords: fear of movement/(re)injury, kinesiophobia, scales, questionnaires, scoring system

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INTRODUCTION

In the past several decades, the relation between fear and pain has been described with various constructs. Fear of movement/(re)injury, pain-related fear, fear-avoidance beliefs, and kinesiophobia are the most commonly used constructs (Lundberg et al., 2011). In the 1980s, Lethem et al. (1983) developed the fear-avoidance model (FAM) to explain why some injuries transform from acute to chronic while others heal in normal time frames. In 1995, Vlaeyen et al. (1995) expanded the FAM into the cognitive-behavioral model of fear of movement/(re)injury. In that model, fear of movement/(re)injury was considered an important factor for disability, disuse syndrome, and depression in patients with musculoskeletal pain. If the patients misinterpret the pain and magnify the condition, in that case, they are likely to enter a maladaptive cycle of where fear of pain occurs, which leads to avoidance behavior and fear of movement/(re)injury. During the development of FAM, Kori (1990) proposed the concept of kinesiophobia that was defined for a patient who has "an excessive, irrational, and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to painful injury or reinjury." The prevalence of kinesiophobia in persistent pain ranges from 50 to 70% (Luque-Suarez et al., 2019). A considerable number of longitudinal studies have found that a high level of kinesophobia at baseline can be used

to predict the decreased quality of life, increased pain, and disability (Wong et al., 2015; Helminen et al., 2016; Maaike et al., 2017). Initially, the concept of "fear of movement/(re)injury" was applied to patients with chronic musculoskeletal pain (Vlaeyen et al., 1995). However, with the continuous exploration of researchers worldwide, research on other consequences accompanied by fear of movement/(re)injury gradually increased. In the clinical setting, fear of movement/(re)injury is an essential factor affecting the surgery (Doménech et al., 2014) and prognosis of physical therapy (Verwoerd et al., 2015), and it also can hinder the subsequent recovery of physical activity (Boutevillain et al., 2017). Assessing the fear of movement/(re)injury of the patients is helpful for researchers to explore the mechanism of chronic musculoskeletal pain more deeply and is useful for clinicians to make better clinical decisions.

Extensive research has shown that fear of movement/(re)injury is usually assessed with scales/questionnaires. The Tampa Scale for Kinesiophobia (TSK) (Miller et al., 1991) and the Fear-Avoidance Beliefs Questionnaire (FABQ) (Waddell et al., 1993) were designed in the early years. Some new measures like the Kinesiophobia Causes Scale (KCS) (Knapik et al., 2011), Athlete Fear-avoidance Questionnaire (AFAQ) (Dover and Amar, 2015), and Fear-Avoidance Components Scale (FACS) (Neblett et al., 2016) have been developed in recent years. Thus, renewing the information of these instruments is necessary for researchers and clinicians. The purpose of this article is to provide a descriptive review of each measure regarding the background and content, score system, available language versions, variants of the original questionnaire, and psychometric properties, which can offer the basis of scale selection and application reference for the research and clinical treatment of fear of movement/(re)injury.

METHODOLOGY

A search procedure, which involved searching electronic databases such as PubMed (https://pubmed.ncbi.nlm.nih.gov/), Web of Science (http://isiknowledge.com/), and Google Scholar (https://scholar.google.com/), was developed. The databases were searched from 1980 to 2021. Searches were carried out for the terms "kinesiophobia," "fear of movement/(re)injury," "scales," "questionnaires," "sports," and "fear-avoidance." All references were downloaded into the Zotero (version 5.0.96.2), which facilitated the large number of publications obtained. The aim of this review was to ensure that all the essential published papers were identified; nevertheless, some may have been missed out from the present review.

THE TAMPA SCALE FOR KINESIOPHOBIA

Background and Content

Miller et al. (1991) designed the TSK in 1991, but it was not published until 1995 (Acar et al., 2016). The TSK is one of the most well-known instruments for measuring fear of movement/(re)injury. Different models were proposed based on exploratory factor analysis (EFA) and confirmatory factor analysis (CFA): the generally accepted 2-factor model labeled somatic focus (TSK-SF; beliefs in underlying and serious medical problems) and activity avoidance (TSK-AA; beliefs that activity may result in [re]injury or increased pain) (Roelofs et al., 2004). Item response on a 5-point Likert scale range from 0 (strongly agree) to 4 (strongly disagree), including statements such as "I'm afraid that I might injure myself if I exercise (item 1)" and "If I were to try to overcome it, my pain would increase (item 2)."

Score System

The original TSK includes 17 items, among which 4 items (i.e., items 4, 8, 12, and 16) are reverse-scored. The test's total score is the sum of the points marked by the patient, ranging from 17 to 68. The higher the score, the higher the fear of movement/(re)injury of the patient. If the score is >37, the patient is considered to suffer from kinesiophobia.

Available Language Versions

As far as we know, it has been translated into Italian (Monticone et al., 2010), Japanese (Huang et al., 2019), Swedish (Larsson et al., 2014), Turkish (Acar et al., 2016), Dutch (Visscher et al., 2010), Chinese (Cai et al., 2019), Spanish (Aguiar et al., 2017), and Norwegian (Haugen et al., 2008).

Variants of the Original Questionnaire

Except low back pain, for which it was originally applied, the TSK was adapted for ACL injuries (Luc-Harkey et al., 2018; Huang et al., 2019), heart failure and pulmonary arterial hypertension (Acar et al., 2016), and temporomandibular disorders (Garrigós-Pedrón et al., 2018). The shortened versions of the TSK are TSK-13 (Jørgensen et al., 2015), TSK-12 (Visscher et al., 2010), TSK-11 (Kikuchi et al., 2015; Goldberg et al., 2018), and TSK-4 (Gregg et al., 2015), among which TSK-11 is the most widely used.

Psychometric Properties

The Cronbach's α of each version of the TSK scale is generally between 0.7 and 0.92, and the test-retest reliability is generally above 0.8 (Swinkels-Meewisse et al., 2003; Woby et al., 2005; Huang et al., 2019). Moderate correlation coefficients supported the construct validity with pain-related fear, pain catastrophizing, and disability in patients with chronic low back pain. Correlation coefficients supported a moderate predictive validity with performance on physical performance tests in patients with chronic low back pain. Concurrent validity is moderate, supported by Pearson's rho between TSK and FABQ in patients with acute low back pain, ranging from $r = 0.33$ to 0.59 ($P < 0.01$; Swinkels-Meewisse et al., 2003).

FEAR-AVOIDANCE BELIEFS QUESTIONNAIRE

Background and Content

The FABQ is a patient-reported questionnaire specially designed to measure fear-avoidance beliefs of patients about physical activity and work. It was developed by Waddell and published in 1993 (Waddell et al., 1993). The FABQ is a questionnaire based on the FAM, which was created to explain why some patients

with acute painful conditions can recover while others develop chronic pain from such conditions (Lethem et al., 1983; Fritz and George, 2002). The FABQ total (FABQ-T) includes two subscales, the work subscale (FABQ-W) and the physical activity subscale (FABQ-PA). The form of answer is a standardized option (7-point Likert fields), and each question is scored ranging from "completely disagree" (0) to "completely agree" (6). CFA showed that item 1 had low communality and had inconsistent factor loading while items 13, 14, and 16 were redundant (Waddell et al., 1993).

Score System

There are 16 items within the FABQ (maximum score of 66); FABQ-W with 7 questions (maximum score of 42) and FABQ-PA with 4 questions (maximum score of 24). Users should note that items 1, 8, 13, 14, and 16 are not scored (**Table 1**).

Available Language Versions

So far, in terms of the literature that we can be searched, the FABQ has been translated into Chinese (Pei et al., 2010), German (Pfingsten, 2004), Italian (Meroni et al., 2014), Brazilian (Abreu et al., 2008), Greek (Georgoudis et al., 2007), Thai (Wiangkham et al., 2020), Finnish (Pfingsten, 2016), and Hausa (Brox, 2019) d.

Variants of the Original Questionnaire

The FABQ has been adapted to assess fear-avoidance beliefs of patients in multiple areas, including low back pain (Fujii et al., 2013), chronic headache (Nash et al., 2006), fibromyalgia (Roelofs et al., 2004), neck pain (Lee et al., 2006), knee pain (Ross, 2010), shoulder pain (Mintken et al., 2010), osteoarthritis (Heuts et al., 2004), and even extended to burning pain (Sgroi et al., 2005) and complex regional pain syndrome type I (Jong et al., 2005).

Psychometric Properties

Most studies have verified the excellent reliability of the FABQ. A study showed that the test-retest reliability of FABQ-T, FABQ-W, and FABQ-PA are 0.97, 0.72 ∼ 0.90, and 0.80 ∼ 0.91, respectively (Williamson, 2006). Abreu et al. (2008) validated the Portuguese version of the FABQ the reliability of patients with low back pain, which showed that FABQ-P (ICC = 0.84, Cronbach's α = 0.80) and FABQ-W (ICC = 0.91, Cronbach's α = 0.90). The correlation coefficients of FABQ-T, FABQ-W, and FABQ-PA with Roland and Morris Disability Questionnaire (RMDQ) are 0.52, 0.63, and 0.51, respectively (Williamson, 2006). The correlation between TSK and FABQ-W and FABQ-PA was 0.33 and 0.39 (Swinkels-Meewisse et al., 2003). These pieces of evidence mentioned above supported that FABQ has good criterion validity. However, a study reported that the structural validity of FABQ was relatively low and that there was little evidence about the responsiveness before and after treatment (Lundberg et al., 2011).

TABLE 1 | The items, total possible points, and high score from the fear-avoidance beliefs questionnaire (FABQ) and its subscale.

Scale	Questions included	Total possible points	High score
FABQ-T	2–7, 9–12, 15	66	None
FABQ-W	6, 7, 9–12, 15	42	>34 Fritz and George, 2002
FABQ-PA	2–5	24	>15 Crombez et al., 1999

THE KINESIOPHOBIA CAUSES SCALE

Background and Content

The KCS is a relatively new patient-reported outcome measure used to identify the biological and psychological causes of kinesiophobia in people (Knapik et al., 2011).

Score System

This scale is composed of 20 closed questions. The domain score is the mean of the total factors that make up the domain, while the overall index of kinesiophobia (KCS) is the mean of two domains. According to Knapik's assumption, the total KCS score will range from 0 to 100 and can be interpreted as a percent of kinesiophobic behavior—a higher score indicating higher fear of movement (Knapik et al., 2011). The calculations of the biological domain, psychological domain, and total KCS score are performed as (A + B + C + D)/4, (E + F + G + H)/4, and (Biological Domain + Psychological Domain)/2, respectively (**Table 2**).

Available Language Versions

Currently, as far as the literature can be searched, English version (Knapik et al., 2011), Polish version (Brdak et al., 2015), Turkish version (Çayir et al., 2020), and Chinese version (Zhu et al., 2020) are available.

Variants of the Original Questionnaire

No other variants are available.

Psychometric Properties

The KCS was characterized with good internal consistency in a few studies. Saulicz et al. (2016) used the KCS to evaluate 105 women of perimenopausal age and verified that KCS had good internal consistency. Cronbach's α of the biological and psychological domain subscale were 0.79 and 0.77, respectively.

TABLE 2 | The domain, dimensions, and calculation of the kinesiophobia causes scale (KCS).

Domain	Dimension	Calculations
Biological domain	A. Morphologic (items 1–2)	A = items (1 + 2)/2
	B. Individual need for stimulation (items 3–5)	B = items (3 + 4+5)/3
	C. Energetic substrates (items 6-9)	C = items (6 + 7 + 8 + 9)/4
	D. Power of biological drives (items 10-11)	D = items (10 + 11)/2
Psychological domain	E. Self-Acceptance (items 12–14)	E = items (12 + 13 + 14)/3
	F. Self-Assessment of motor predispositions (items 15–16)	F = items (15 + 16)/2
	G. State of mind (items 17–18)	G = items (17 + 18)/2
	H. Susceptibility to social influence (items 19–20)	H = items (19 + 20)/2

The Cronbach's α of KCS total scale, biological domain, and psychological domain in the Turkish version are 0.86, 0.91, and 0.80, respectively (Çayir et al., 2020).

ATHLETE FEAR-AVOIDANCE QUESTIONNAIRE

Background and Content

In 2015, Dover developed the AFAQ, a sport-specific scale, to identify the high levels of fear-avoidance in athletes (Dover and Amar, 2015). Therapists and trainers can use it as a tool to address this psychological barrier early in rehabilitation and potentially reduce the time until they return to the game. As it is specially developed for athletes, the scale uses relevant terms that athletes can understand, including the expressions of "I will never be able to play as I did before the injury (item 1)" and "I believe that my current injury has jeopardized my future athletic abilities (item 5)." The AFAQ contains 10 items related to sports psychology, sports injury, and sports experience. The scale is measured on a 5-point Likert scale ranging from 1 (Not at all) to 5 (completely agree).

Score System

The total score ranged from 10 to 50, where the higher the score, the more fear-avoidance the athletes possess (Dover and Amar, 2015).

Available Language Versions

To our knowledge, the scale is available in three languages, English (Dover and Amar, 2015), Japanese (Fukano et al., 2019), and Portuguese (Leitão, 2019).

Variants of the Original Questionnaire

O'Keeffe et al. (2020) developed a modified AFAQ (mAFAQ) to make it a screening tool for fear-avoidance of athletes. Unlike the original version, the sentence "if I am injured" is added to each of the 10 statements to predict the degree of injury-related fear-avoidance that an athlete may occur after injury. The study showed that mAFAQ is a valid and reliable screening tool in predicting injury (O'Keeffe et al., 2020).

Psychometric Properties

The internal consistency of AFAQ was very high (Cronbach's $\alpha = 0.805$), and it was significantly correlated with FABQ and other assessment tools ($r = 0.352$, $P < 001$), which verified its concurrent validity (Dover and Amar, 2015). The results of the Portuguese version showed that the test-retest reliability of AFAQ is excellent (ICC = 0.969) (Leitão, 2019).

FEAR-AVOIDANCE COMPONENTS SCALE

Background and Content

The FACS is a newly developed scale developed by Neblett et al. (2016) in 2016, which combines the essential components of several well-studied scales (TSK, FABQ, Pain Anxiety Symptom Scale, and Pain Catastrophizing Scale), to evaluate the psychological characteristics of fear-avoidance in patients with painful medical conditions comprehensively. The items of the FACS are trying to correct the deficiencies of the above scales based on the latest fear-avoidance model. There were 20 items in the FACS, and each item was scored on a 6-point Likert scale ranging from 0 (completely disagree) to 5 (completely agree). The total score was 0–100, indicating subclinical (0–20), mild (21–40), moderate (41–60), severe (61–80), and extreme (81–100).

Score System

The final score is the sum of each item. Higher scores are intended to indicate higher levels of fear-avoidance (Neblett et al., 2016).

Available Language Versions

So far, there are four language versions available, including English (Neblett et al., 2016), Serbian (Knezevic et al., 2018), Gujarati (Bid et al., 2020), and Spanish (Cuesta-Vargas et al., 2020).

Variants of the Original Questionnaire

No other variants are available.

Psychometric Properties

Tested by Neblett et al. (2016), the English version of FACS has good internal consistency (Chronbach's $\alpha = 0.92$) and high test-retest reliability ($r = 0.90 \sim 0.94$, $P < 0.01$). In 2018, the Serbian version of FACS introduced by Knezevic et al. (2018) studied 322 patients with chronic musculoskeletal pain. In 2020, Cuesta-Vargas et al. (2020) selected 330 patients with chronic musculoskeletal pain and verified the adaptability of the Spanish version (FACS-Sp). Their Cronbach's α were 0.90 and 0.88, respectively. The convergent validity is supported by Pearson's correlation with Central Sensitization Inventory ($r = 0.414$).

DISCUSSION

The scales and questionnaires determine the severity of fear of movement/(re)injury in patients with different medical conditions. By presenting these five scales, it can be seen that the assessments of fear of movement/(re)injury tend to be more rigorously subdivided, such as special populations, causes, and components, and are becoming more comprehensive. From a perspective of use, the citations from high to low were FABQ (3268), TSK (493), KCS (61), AFAQ (29), and FACS (26). It is noted that researchers or clinicians need to be cautious in selecting the last three tables, due to which they were not well-studied as the former two. The TSK is the earliest instrument to measure fear of movement/(re)injury, and it has many language versions and a wide range of applications. A study showed that the TSK was sensitive in detecting clinical changes in subjects undergoing rehabilitation after lumbar fusion and chronic low back pain (Monticone et al., 2016). However, the validity of the TSK was low to moderate (Lundberg et al., 2011). Compared with the other shortened versions, the internal consistency of TSK-4 is insufficient (Archer et al., 2012). According to Japanese research on the TSK, the scale may not be the best tool for assessing psychological factors in patients with knee anterior

ligament injury (Huang et al., 2019). Currently, most studies believed the FABQ seems to be the best available measure to measure "fear-avoidance beliefs." Still, a recent study questioned this, suggesting that the FABQ questionnaire is most likely related to expectations rather than fear (Aasdahl et al., 2020). The FABQ can discriminate between patients with cervical radiculopathy and healthy subjects (Dedering and Börjesson, 2013). Compared with the TSK, a recognized cutoff score of the FABQ is still not available (Wertli et al., 2014). In addition, the construct validity of FABQ is relatively low, and there is little evidence of responsiveness before and after treatment (Lundberg et al., 2011). The KCS tries to identify and quantify the causes of kinesiophobia in patients from two domains: biology and psychology. Nevertheless, the research on KCS is dominated by Polish researchers, and the cross-cultural adaptation and validation of other versions need to be further studied. Moreover, the KCS scoring system is a little bit complicated and requires special attention when using it. The AFAQ is a sport-specific questionnaire used to evaluate the thoughts of athletes regarding injury and return to the competitions. However, there are few studies on the reliability and validity of AFAQ. Whether the questionnaire is still reliable in other languages/cultural backgrounds needs more studies to verify. The FACS is based on a developed FAM to improve the disadvantage of the well-studied measures. It has good psychometric characteristics and has five grades of severity range for clinical interpretation. It seems the most comprehensive scale so far. The application of FACS is still few, and its characteristics and limitations need to be further explored.

CONCLUSION

The present review has provided a general description of existing measures from 1991 (TSK) to 2016 (FACS). These scales/questionnaires mentioned above are useful tools for assessing the constructs related to fear of movement/(re)injury in several different types of studies. After comparison, it was found that no scale/questionnaire can evaluate all the characteristics of fear of movement/(re)injury. Still, the results of the measurements illustrate how much the different aspects of fear of movement/(re)injury limit the ability of the patient to perform the necessary life functions, thus giving an idea of how it affects the quality of life, pain, and disability. Considering that fear of movement/(re)injury has become a common factor of rehabilitation, using the scales presented allows clinicians to assess surgical/rehabilitation treatment results. Each questionnaire should be considered for its characteristics when using in research and clinical practice. If necessary, the combination of those scales can be considered. Therefore, with the help of adequately used fear of movement/(re)injury outcome measures, effective treatment methods can be selected and applied.

AUTHOR CONTRIBUTIONS

HLiu composed this study. LH designed the framework. ZY, HLi, and ZW revised the manuscript. LP provided supervision throughout the research and made critical revisions to this study. All authors contributed to the article and approved the submitted version.

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Relationship Between Cancer Related Fatigue, Physical Activity Related Health Competence, and Leisure Time Physical Activity in Cancer Patients and Survivors

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Background: A large body of evidence supports the positive effects of leisure time physical activity (LTPA) and exercise on cancer survivors. However, only a fraction of survivors manages to attain international PA recommendations. This can be attributed to several external and internal barriers toward PA those patients seem to encounter, with cancer related fatigue (CRF) being the most reported internal barrier. Nevertheless, self-efficacy and knowledge about the utilization of LTPA can serve as facilitators of PA, which also correspond to certain constituents of physical activity related health competence (PAHCO). Since PAHCO is not investigated in cancer survivors we investigated if PAHCO can mediate the negative relationship between CRF and LTPA.

Methods: We surveyed 398 cancer survivors with different cancer types and therapy status. The patients completed the EORTC QLQ-FA12 (EORTC FA12) to assess CRF, the PAHCO questionnaire to assess PAHCO and the SQUASH to assess LTPA. We followed a two-step structural equation modeling approach. The first step established the measurement model, in the second step we fitted the mediation model. Since 163 patients chose not to answer the SQUASH, the mediation model was only fitted to the data of the remaining 235 participants.

Results: The proposed measurement model of the PAHCO offered an excellent fit. We found small to moderate positive associations between the PAHCO dimensions and the LTPA, and negative moderate relationships between the PAHCO and the EORTC FA12 dimensions. We did not observe a relationship between the EORTC FA12 dimensions and the LTPA ($p > 0.05$). The hypothesized mediation models did not display an appropriate fit.

Conclusion: The PAHCO confirmed its factorial validity; furthermore, it appears to have a positive relationship to LTPA. Therefore, integrating psycho-educational aspects can be beneficial in order to increase the PAHCO in exercise interventions. Because of the cross-sectional character of this study, causal conclusions are not suitable, therefore the longitudinal relationships of LTPA, CRF, and PAHCO require further investigation.

Keywords: cancer, cancer related fatigue, physical activity, physical activity related health competence, physical activity promotion among women in difficult life situations

INTRODUCTION

A large body of evidence supports the positive effects of physical activity (PA) and exercise for cancer patients all along the cancer trajectory (Fong et al., 2012; Furmaniak et al., 2016; Christensen et al., 2018). Exercise has shown to increase physical fitness (Strasser et al., 2013; Scott et al., 2018; Sweegers et al., 2019), health related quality of life (Mishra et al., 2012; Buffart et al., 2017) and improvement in cancer-related fatigue (CRF; Mustian et al., 2017; Van Vulpen et al., 2020). Prior to initial treatment, exercise can improve the fitness of cancer patients and reduce the likelihood of certain complications (Vermillion et al., 2018). During treatment, exercise has shown preventive health effects on cardio- and neurotoxicity (Chen et al., 2017; Kleckner et al., 2018); furthermore, it is closely associated with reducing cancer mortality and the probability of recurrence (Cormie et al., 2017; Friedenreich et al., 2020). Despite the benefits of regular PA, cancer patients tend to reduce their PA-levels after their diagnosis (Mason et al., 2013; Pugh et al., 2020) and only a minority of cancer survivors meet the PA guidelines (Blanchard et al., 2008; Lin et al., 2019). This can be contributed to particular internal as well as external barriers (e.g., the availability of programs and qualified facilities) cancer patients have to overcome, such as the frequently reported internal barrier of CRF (Brunet et al., 2013; Hardcastle et al., 2018).

CRF is one of the most common and distressing symptoms reported by cancer patients, produced by the cancer as well as its treatment (Bower, 2014; Berger et al., 2015). It is defined as a feeling intensive physical, emotional and cognitive exhaustion, without getting relieve after resting or sleeping (Weis, 2011). By the time cancer is diagnosed, 40% of patients already report signs of CRF (Rüffer, 2019). This proportion goes up to 60–100% during cancer treatments like chemotherapy and radiotherapy (Weis, 2011). CRF may even continue to impact the lives of long-term survivors for up to 10 years, as noted in 25–33% of cases (Bower, 2014). As of right now, there is no promising pharmacological treatment for CRF (Bower, 2014), with the most effective approach to mitigate CRF being PA (Mustian et al., 2017). This means cancer patients are often trapped in a vicious circle, since CRF prevents PA and thus increases CRF symptoms.

Patients need certain skills, knowledge and motivation (Schmid et al., 2020), i.e., they need competence, in order to positively engage in an active lifestyle. Thus, Pfeifer et al. (2013) developed the model of domain-specific physical activity-related health competence (PAHCO), inspired by the health model of Lenartz (2012), which focuses on promoting person-oriented competencies that enable a person to integrate an effective PA level into daily life. It contains three sub-competences (movement competence, control competence, and PA-specific self-regulation competence). Movement competence is a necessary condition that enables a person to realize the health benefits of exercise and everyday PA. Basically, movement competence comprises of motor skills and abilities. Control competence describes the degree a person is capable of utilizing their knowledge, based on the positive effects of exercise, how to implement health enhancing PA in their daily life, and how to control physical load in regards to their body signals, such as breathing, perceived exertion or heart rate. The third sub-competence, PA-specific self-regulation competence, encompasses the motivational and volitional abilities of a person to engage in health enhancing PA and implementing it into daily life (Sudeck and Pfeifer, 2016). Each of these sub-competencies contributes to regular health-promoting activity behavior. Sudeck and Pfeifer proposed a questionnaire to operationalize PAHCO, which predicts the PA-levels of patients undergoing medical rehabilitation (Sudeck and Pfeifer, 2016; Carl et al., 2020a).

A typical characteristic of CRF is its impairing effect on motivation (Brunet et al., 2013; Hardcastle et al., 2018); furthermore, CRF shows a positive relationship with depression (Bower et al., 2000; Brown et al., 2013). Considering that motivation and volition help using PA as constituents of the PAHCO model, PAHCO can play an important role in the correlation between CRF and LTPA. Since physical fatigue (PF) shows a certain sensitivity to PA (Van Vulpen et al., 2016), we would expect the relationships to be the strongest for this fatigue dimension. Because we were interested in the voluntary engagement of PA and exercise, in the hypotheses we focused on leisure time physical activity (LTPA). We therefore derived following five hypotheses.

- H_1: The CRF dimensions display negative correlations with LTPA

Abbreviations: AVE, Average Variance Extracted; CRF, Cancer Related Fatigue; χ^2, chi-squared; χ^2/df, chi-square-degrees of freedom ratio; CF, Cognitive Cancer Related Fatigue; CFI, Comparative Fit Index; CFA, Confirmatory Factor Analysis; CC, Control Competence for Physical Training; df, degrees of freedom; EF, Emotional Cancer Related Fatigue; LTPA, Leisure Time Physical Activity; MET, Metabolic Equivalent Task; MR, Physical Activity Specific Mood Regulation; SC, Physical Activity Specific Self Control; PA, Physical Activity; PAHCO, Physical Activity Related Health Competence; PF, Physical Cancer Related Fatigue; RMSEA, Root Means Square Error of Approximation; SRMR, Standardized Root Mean Square Residual; TLI, Tucker Lewis Index.

- H_2: The PAHCO dimensions display positive correlations with LTPA
- H_3: The CRF dimensions display negative correlations with PAHCO dimensions
- H_4: The PAHCO dimensions mediate the impact of CRF on LTPA
- H_5: The relationships are strongest for PF.

We first investigated the factorial validity of the PAHCO questionnaire in an US based sample, since the PAHCO questionnaire has thus far only been investigated in German speaking populations (Sudeck and Pfeifer, 2016), afterwards we tested the hypotheses in a structural model.

MATERIALS AND METHODS

Participants

Patients with any kind of cancer who were meeting the following inclusion criteria were eligible to participate in the study: ≥18 years, mobile enough to conduct exercise, and able to follow the study instructions. Patients were approached and asked to participate when they came to their treatment or follow-up.

Procedure

The current study followed a cross-sectional design conducted at the Penn State Cancer Institute in Hershey PA, USA. The study protocol was approved by the Penn State College of Medicine Internal Review Board (Study ID: HRP-591-PEXO, Clinical Trials.gov: NCT04328038). All participants signed a written informed consent form before completing the survey. Patients were recruited in the waiting rooms of the hospital (Infusion Suite, Radiation Oncology, Surgery), where they received and completed the paper-and-pencil survey. In only a few cases the questionnaires were taken home and returned at the patient's next visit. The survey consisted of demographics and medical information, the PAHCO questionnaire (Sudeck and Pfeifer, 2016), the Emotion Thermometers (Mitchell et al., 2010), the Perception of Health Scale (Diamond et al., 2007), the BRIEF Health Literacy Screening Tool (Haun et al., 2009), the EORTC QLQ-C30 (Fayers et al., 2002), EORTC QLQ_FA12 (EORTC FA12) (Weis et al., 2017) and the short questionnaire to assess health-enhancing physical activity (SQUASH) (Wendel-Vos et al., 2003).

In this analysis, the PAHCO questionnaire, EORTC FA12 and SQUASH are reported for being of particular interest while the other questionnaires only served as material for missing data imputation. The time to complete the survey ranged between 15 and 20 min.

Measures and Materials

The EORTC QLQ-FA12

The EORTC FA12 is a multidimensional self-reporting screening tool for assessing the extend of cancer-related fatigue. The tool was developed by the EORTC quality of life group and is used in conjunction with the EORTC QLQ-C30 (Weis et al., 2017). The questionnaire divides the CRF into three subscales using a total of 12 items: physical CRF (PF) (five items), emotional CRF (EF) (three items), and cognitive CRF (CF) (two items). The remaining two items serve as global indicators for impairment in performing daily life activities as well as the social sequelae of CRF, but they do not belong to a single subscale. All items were answered according to a four-stage Likert scale [from "not at all" (1) to "very much" (4)]. Reported Cronbach's alpha were good for all three dimensions with 0.88–0.90 for PF, 0.87–0.88 for EF and 0.79–0.82 for CF (Weis et al., 2017).

The Physical Activity Related Health Competence Questionnaire

The questionnaire is based on the PAHCO-Model outlined above and supposed to assess specific facets of the PAHCO, specifically addressing an individual's aptitude to effectively utilize physical activity to optimize their overall health. The questionnaire consists of 13 items comprised of three latent factors: PA-specific mood regulation (MR) (four items), control competence for physical training (CC) (six items) and PA-specific self-control (SC) (three items) (Sudeck and Pfeifer, 2016). In contrast to the PAHCO-Model, the PAHCO Questionnaire has no items to assess movement competence but instead focuses on the implementation (SC) and utilization (MR) of health enhancing PA, the control of physical load *via* body signals, as well as knowledge about the effects (CC). All items were answered on a four-stage Likert scale with possible responses ranging from "disagree completely" (1) to "agree completely" (4). Cronbach's alpha was good for all three dimensions with 0.89 for MR, 0.84 for CC and 0.78 for SC in patients undergoing exercise therapy and 0.88 for MR, 0.80 for CC and 0.80 for SC in people participating in health sports (Sudeck and Pfeifer, 2016). The original PAHCO questionnaire was developed and validated on two German samples (Sudeck and Pfeifer, 2016). However, the authors provided a version translated into English in their original publication. We used this translation and had it back translated into German by a member of the Penn State College of Medicine Internal Review Board who is both an English and German native speaker.

The Short Questionnaire to Assess Health-Enhancing Physical Activity

The SQUASH, a commonly used instrument to assess PA behavior in adults compares the physical activity levels of individuals and evaluates compliance to physical activity guidelines (Nicolaou et al., 2016). The SQUASH was developed by the Dutch National Institute of Public Health and the Environment (Wendel-Vos et al., 2003). It relies on self-reports, assessing 4 main domains: (a) commuting activities, (b) leisure time activities, (c) household activities, and (d) activities at work and school, which are evaluated based on an average week. The participants rate the amount of time they spent on each domain using three main queries: days per week, average time per day, and intensity (effort). To quantify the intensity of the activity, a metabolic equivalent task (MET) value, based on Ainsworth's compendium of PA (Ainsworth et al., 2000) is assigned to the activities, depending on the effort reported, the activities receive an intensity score and total score.

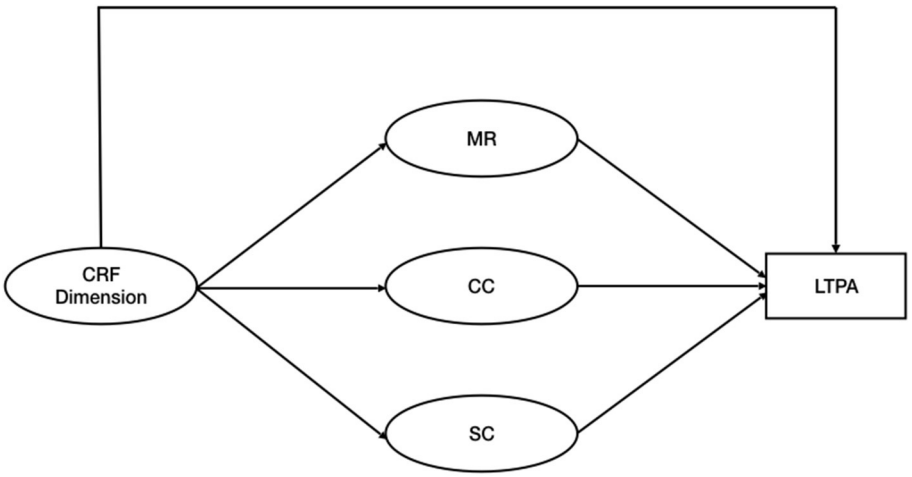

FIGURE 1 | Hypothesized mediation model. CRF, Cancer Related Fatigue; MR, Physical Activity Specific Mood Regulation; CC, Control Competence for Physical Training; SC, Physical Activity Specific Self Control; LTPA, Leisure Time Physical Activity.

Data Analysis

Descriptive statistics (i.e., means, standard deviations, inter quartile ranges, skewness, and kurtosis) were calculated. Linearity and collinearity between the single items were assessed by comparing bivariate Pearson-, Spearman-, and Kendall-tau-b correlation coefficients; in addition, optical bivariate scatter plots where we added to the Likert-scale items to increase interpretability (Gelman and Hill, 2007).

Questionnaires

The analysis of the hypothesized mediation model involved a two-step process. In the first step a confirmatory factor analysis (CFA) was conducted to investigate the factorial validity of the proposed measurement models. In the second step the structural model was established (Anderson and Gerbing, 1988).

Items from both questionnaires show a good agreement regarding the three correlation coefficients and therefore indicate linearity in their relationships, which is supported by the scatter plots. The normality assumption was tested *via* Shapiro–Wilk-Test for univariate normality and Mardia-Test for multidimensional normality. Univariate as well as multivariate normality was violated for all items in both questionnaires ($p < 0.001$).

Leisure Time Physical Activity

The univariate normality of the LTPA data was tested with the Shapiro–Wilk Test. For the outlier identification we conducted a qualitative approach by visually examining the LTPA distribution. Three values beyond 150 MET-h/week were identified which did not fit into the remaining distribution and thus were omitted from the data set. The remaining LTPA-data violated the assumption of normality ($p < 0.001$). Because of the violation of the normality assumption, we conducted a Box-Cox transformation by the power of 1/6 with the LTPA-data, resulting in an improved approximation of the normal distribution ($p = 0.055$). The raw data and the transformed data showed a Pearson-correlation of $r = 0.89$.

Missing Data

We excluded cases when the entire questionnaire was missing and acknowledged one missing entry for age and eight missing entries for gender. In the remaining data set 2–7 (0.5–1.7%) answers for the PAHCO items were missing and for the EORTC-FA 12 1–2 (0.25–0.5%) answers were missing. The data showed a general missing data pattern. We investigated the appropriateness of the variables for multiple imputations *via* influx and outflux diagrams (Van Buuren, 2018). All variables except of LTPA were appropriate for the imputation procedure. The comparison of the original and imputed variables *via* Mann–Whitney-*U*-Test found no evidence for differences between the original and the imputed data sets (Range of $p = [0.79, 1.0]$).

Measurement Model Estimation and Model Fit

The measurement models were estimated with the variance of the latent factors set to 1.0, this allowed us to compare the observed factor loadings to the ones reported in the original publications. Because of the violation of the normality assumption, we applied the maximum likelihood approach with a 10,000-replication bootstrap with 95% bias corrected confidence interval as well as the DWLS estimation, treating the items of the questionnaires as ordinal. Evaluation of the model fit was based on chi-squared (χ^2) tests, the chi-square-degrees of freedom ratio (χ^2/df), the Root Means Square Error of Approximation (RMSEA), the standardized Root Mean Square Residual (SRMR) as well as the Comparative Fit Index (CFI) and the Tucker Lewis Index (TLI). For the χ^2/df a value < 3 was considered as acceptable (Iacobucci, 2010). For CFI and TLI values >0.90 were considered acceptable and >0.95 considered as good, for RMSEA and SRMR values <0.06 were considered as good and <0.08 as acceptable (Hu and Bentler, 1999). The measurement model which displayed the better fit was

TABLE 1 | Patient characteristics.

Characteristics	*n*	%
Total	*398*	*100*
Demographics		
Age, mean ± SD, years	63.3 (± 12.5)	
Sex	221	55.5
Female		
Male	169	42.5
N/A	8	2
Marital status		
Married or living with a partner	265	66.6
Single	86	21.6
Widowed	37	9.3
N/A	10	2.5
Race		
White	364	91.5
Black or African American	13	3.2
Other	5	1.3
N/A	16	4
Education		
HS graduate or less	128	32.2
Some college	128	32.2
College graduate or more	133	33.4
N/A	9	2.2
Employment status		
Retired/Not working	193	48.7
Still working	194	48.5
N/A	11	2.8
Medical profile		
Primary cancer diagnosis		
Breast	116	29.1
Melanoma	49	12.3
Colon	38	9.5
Prostate	34	8.5
Other	105	26.5
N/A	56	14.1
Therapy		
Chemotherapy	190	47.7
Radiotherapy	195	49
Immunotherapy	82	20.6
Hormonetherapy	62	15.6
Surgery	277	69.6
Therapy completed	165	41.5
Therapy completed 2 years ago	46	11.6
Comorbidities		
≥1 cardiovascular/pulmonic disorder	156	39.2
≥1 orthopedic/rheumatologic disorder	129	34.4
Diabetes	62	15.6
Questionnaires		
EORTC FA12	26.7 (20, 46.7)	
PF, Median (IQR)		
EF, Median (IQR)	11.1 (0, 33.3)	
CF, Median (IQR)	0 (0, 33.3)	
PAHCO		
MR, Median (IQR)	75.0 (58.3, 100)	
CC, Median (IQR)	66.7 (44.4, 83.3)	
SC, Median (IQR)	44.4 (33.3, 66.7)	
Physical activity	$n = 235$	59%
LTPA, Median (IQR)	11.2 (0, 36.9)	

PF, Physical Cancer Related Fatigue; EF, Emotional Cancer Related Fatigue; CF, Cognitive Cancer Related Fatigue; PAHCO, Physical Activity Related Health Competence; MR, Physical Activity Specific Mood Regulation; CC, Control Competence for Physical Training; SC, Physical Activity Specific Self Control; LTPA, Leisure Time Physical Activity.

included into the structural model. Scale reliability was measured *via* McDonald's omega as an alternative to Cronbach's alpha, appreciating variability in factor loadings (Dunn et al., 2014). Discriminant validity between the factors was assessed using the Fornell–Larcker-Criterion. In this case the average variance extracted (AVE) should be larger than the highest squared inter-factor correlation corresponding to the variance shared by these two factors, i.e., the variance of the latent variable which can be attributed to its the indicators instead of measurement error (Fornell and Larcker, 1981; Rönkkö and Cho, 2020).

Structural Model

The three PAHCO dimensions as well as the three Fatigue dimensions were considered latent variables, as postulated in the literature (Sudeck and Pfeifer, 2016; Weis et al., 2017). The transformed LTPA was considered a manifest variable. To test the hypotheses we fitted three separate models for each CRF dimension where the relationship between CRF and LTPA is mediated by the three PAHCO (**Figure 1**).

We calculated direct, indirect and total effects. To evaluate the model fit the same parameters and criteria as outlined for the measurement models were applied.

All analysis were conducted in R (Team, 2013). Multiple Imputation was done *via* the R-package mice (Van Buuren and Groothuis-Oudshoorn, 2011), CFA and structural model were conducted *via* R-package lavaan (Rosseel, 2012).

RESULTS

Participants

In total a sample of 398 cancer patients (169 men and 221 women, 8 unknown) were surveyed. Initially 478 surveys were handed out, resulting in a return rate of 84%. The mean age of the participants was 63 years, with the age ranging from 22 to 89 years. The sample spanned over all levels of educational achievement. Approximately half of all participants reported treatment with chemotherapy, while half of the participants reported undergoing radiotherapy. Forty-two percent of participants have already finished their tumor

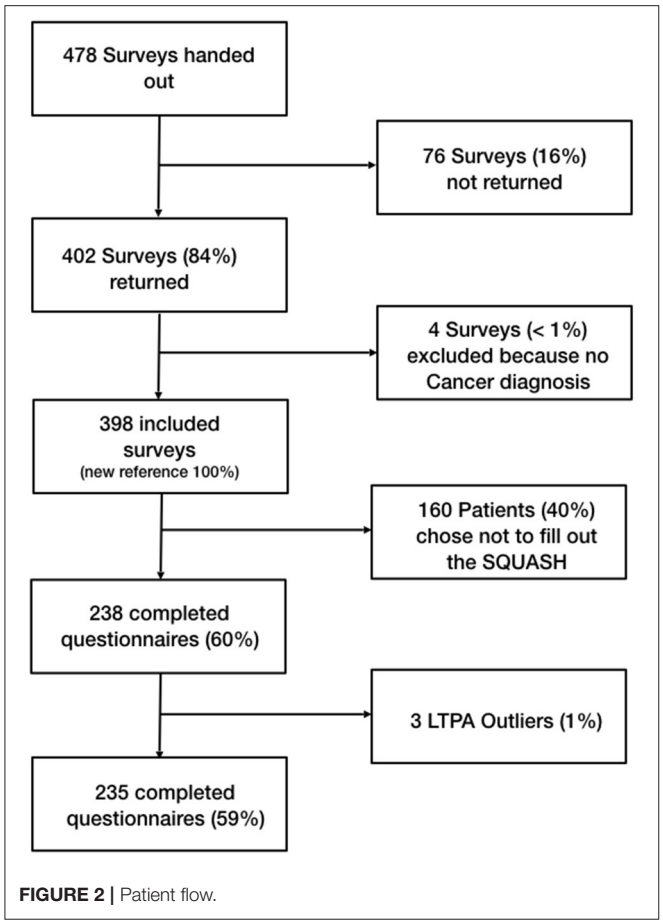

FIGURE 2 | Patient flow.

therapy, of which 28% finished their therapy more than 2 years ago. Twenty-two percent of participants were still undergoing therapy at the time the survey was completed. Twenty-six percent did not provide information about their treatment. Twenty-nine percent of the sample were breast cancer survivors, and 14% of participants did not provide information about their cancer site. Two participants were excluded for having no history of cancer (**Table 1**; **Figure 2**). One hundred and sixty-three participants chose not to answer the SQUASH questionnaire. These patients displayed significant differences ($p < 0.05$) in four of the 13 PAHCO items (Item 1–3, loading on MR and Item 11 loading on SC) as well as five items (Item 1–3 loading on PF and Item 9–10 loading on CF) of the EORTC FA12. In the case of the PAHCO items, the proportion who completed the SQUASH showed higher scores in each of the four items, indicating a higher PAHCO. Simultaneously, those ones who did not complete the SQUASH showed higher scores in each of the five concerned EORTC FA12 items, indicating higher levels of CRF.

Measurement Models

The confirmatory factor analysis measured three latent factors for the PAHCO (MR, CC, and SC) as well as the EORTC FA12 (PF, EF, and CF). All three PAHCO and EORTC factors showed good reliability with McDonald's omega of 0.94 for MR, 0.93 for CC and 0.92 for SC and 0.94 for PF, 0.89 for EF and 0.84 for CF. In order to assess discriminant validity we looked at the AVE from the indicators of 0.85 for MR, 0.67 for CC, and 0.87 for SC for the PAHCO as well as 0.79 for PF, 0.77 for EF, and 0.84 for CF for the EORTC FA12. In comparison the squared factor correlations between the latent variables is 0.23 for MR and SC, 0.33 for MR and CC, 0.55 for CC and SC, 0.56 for PF and EF, 0.41 for PF and CF and 0.60 for EF and CF in case of the EORTC FA12. Thus, the tallest shared variance between the factors appears to be smaller than the smallest AVE. Of the four different measurement models, the DWLS estimation treating the EORTC FA12 items as ordinal and the PAHCO items as continuous (Model 2) showed the best fit [$\chi^2_{(275)} = 196$, $p = 1.00$], with all fit criteria indicating good to excellent fit (**Table 2**). The second best fit is displayed by the model treating the PAHCO items as ordinal and the EORTC FA12 items as continuous (Model 3) [$\chi^2_{(275)} = 290$, $p = 0.251$] The model treating all items ordinal (Model 4)showed a slightly worse fit than Model 2 and 3. The least fitting model was Model 1 that treated all items continuous [$\chi^2_{(275)} = 536$, p =0.251]. Thus, for all following analyses we opted for Model 2.

Latent factors within the same questionnaire showed moderate to strong positive associations with each other [0.5–0.7].

Structural Models

No association between LTPA and the CRF dimensions was observed ($p > 0.05$) with respect to the borderline significant negative association of −0.15 ($p = 0.063$) between CF and LTPA (Rejection of H_1). The latent factors showed small to moderate negative correlations between the questionnaires [0.2–0.4], i.e., the CRF dimensions were negatively associated with the PAHCO dimensions (Confirmation of H_3) (**Figure 3**). Small to moderate positive correlations [0.18–0.27] for all PAHCO dimensions and LTPA were observed (**Table 3**) (Confirmation of H_2).

The hypothesized models displayed an insufficient fit of the data regarding the mediation in all three CRF dimensions (PF, EF, and CF). Although the CFI and TLI showed acceptable to good fits, RMSEA, SRMR, chi^2, and the chi/df-ratio did not meet any of the thresholds, therefore, the mediation models did not seem justified (Rejection of H_4 and H_5) (**Table 4**).

DISCUSSION

This analysis was able to confirm the factorial validity for the American-English version of the PAHCO, involving US-American cancer patients and survivors. The loadings and correlations between the latent PAHCO variables in our model roughly coincides with the correlational structure of the German original publication, reporting slightly lower loadings on MR and CC as well as slightly higher loadings on SC. Furthermore, we identified a moderate positive association between PAHCO-dimensions and LTPA, which conforms to observations made in other populations and also confirms H_2 (Sudeck and Pfeifer, 2016; Carl et al., 2020a). Of all three PAHCO dimensions, MR and LTPA showed the strongest association, while the association

TABLE 2 | Fit of the measurement models.

	χ^2	df	*p*-value	χ^2/df	CFI	TLI	RMSEA	RMSEA CI	SRMR
Model 1	536	*275*	<0.001	1.95	0.928	0.915	0.064	0.056–0.072	0.050
Model 2	*290*	*275*	*0.251*	*1.05*	*0.999*	*0.999*	*0.016*	*<0.001–<0.001*	*0.051*
Model 3	*196*	*275*	*1.00*	*0.71*	*1.00*	*1.006*	*< 0.001*	*<0.001–0.031*	*0.052*
Model 4	*347*	*275*	*0.002*	*1.26*	*0.998*	*0.997*	*0.034*	*0.021–0.044*	*0.057*

χ^2, chi-squared; df, degrees of freedom; χ^2/df, chi-square-degrees of freedom ratio; CFI, Comparative Fit Index; TLI, Tucker Lewis Index; RMSEA, Root Means Square Error of Approximation; SRMR, Standardized Root Mean Square Residual.

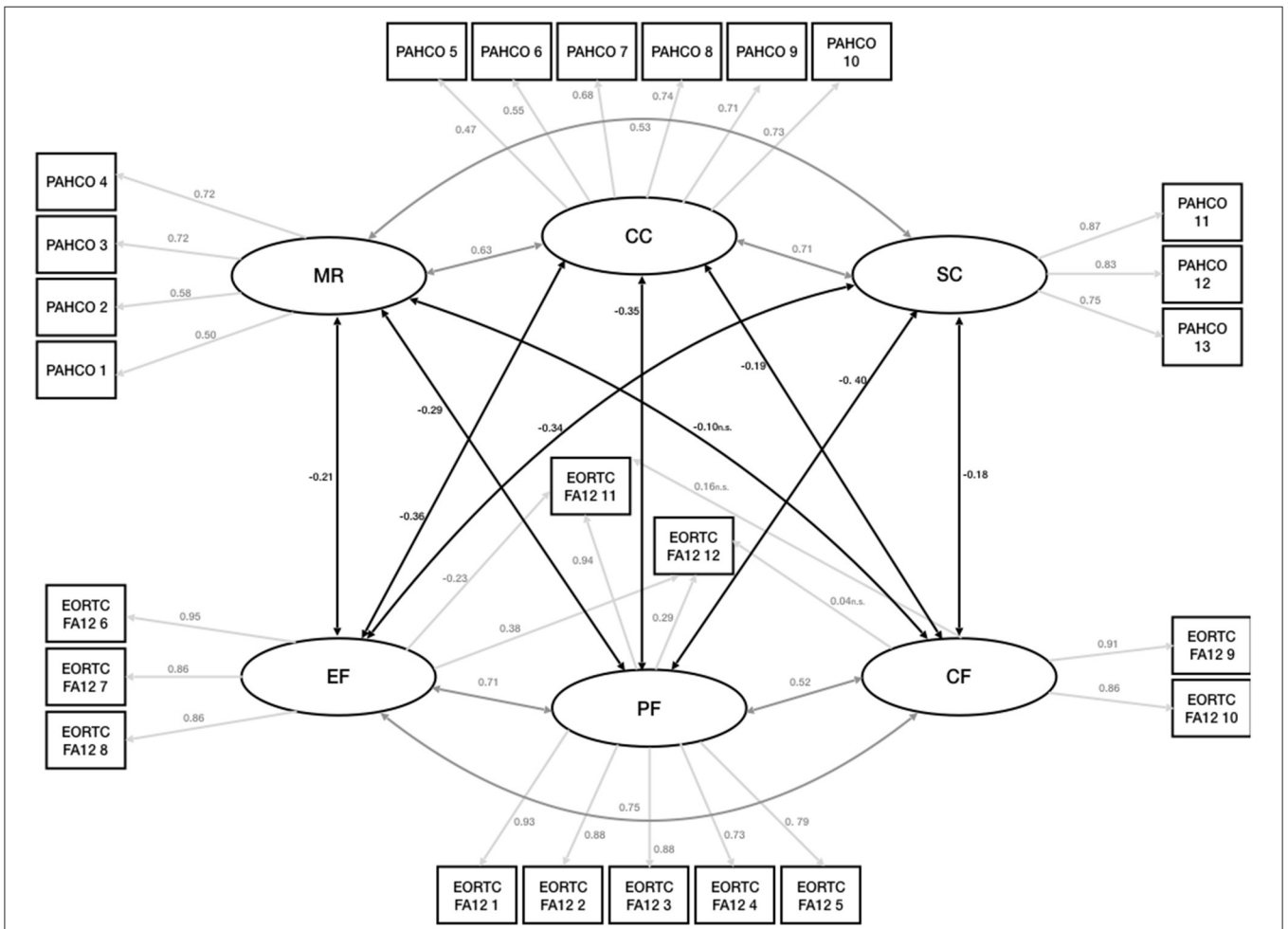

FIGURE 3 | Measurement model and structural components. EORTC FA12, EORTC QLQ-FA12; PF, Physical Cancer Related Fatigue; EF, Emotional Cancer Related Fatigue; CF, Cognitive Cancer Related Fatigue; PAHCO, Physical Activity Related Health Competence; MR, Physical Activity Specific Mood Regulation; CC, Control Competence for Physical Training; SC, Physical Activity Specific Self Control.

between LTPA and the other two remaining PAHCO dimensions had slightly smaller correlation coefficients. Ostensibly, the strong correlation between MR and LTPA can be attributed to the items loading on MR, addressing depression, stress and inner tension, which are elevated for cancer patients in comparison to the general public or even patients with other chronic diseases (Gil et al., 2012; Hartung et al., 2017; Rao et al., 2019). This may suggest that physical activity has an instrumental functionality when it comes to cancer patients since it helps them cope with psychological symptoms. It also goes in line with the recently published ACSM Roundtable on Physical Activity Guidelines for Cancer Patients (Campbell et al., 2019) which confirms a positive effect of exercise on depressive symptoms and anxiety. Nevertheless, the three correlation coefficients between LTPA and the PAHCO dimensions do not differ significantly from each other, considering their 95% confidence intervals, hence,

conclusions must be drawn with caution and can be premature. According to H_3, all PAHCO-dimensions displayed a negative relationship to the CRF-dimensions, however, MR showed the weakest correlation to either of the CRF dimensions, which are usually linked to mood disturbances and have a strong relation with depression (Bower et al., 2000; Brown et al., 2013).

A relationship between the CRF dimensions and LTPA has not been observed, which opposes the literature and H_1, that exhibits a small to moderate negative associations between CRF and PA levels (Kummer et al., 2013; Galiano-Castillo et al., 2014; Romero et al., 2018). This could be partially explained by a possible selection bias due to a lower response rate to the SQUASH compared to the other questionnaires (about 59%). Pertaining the questionnaires, participants who chose not to answer the SQUASH scored significantly lower in three of the four items loading on MR, significantly higher in three of seven items loading on PF, and significantly higher on two of four items loading on CF. Thus, the patients who completed the SQUASH and were investigated for the final analysis presented a higher PAHCO and lower CRF than the others. Bearing in mind that the SQUASH items are more arduous to answer than the Likert-scaled questions of the other questionnaires, it appeared that people with a positive attitude toward PA in general and LTPA in particular would invest more effort into completing the survey.

We could not observe a ceiling effect or lack of variance in the LTPA-Data; though, a plausible correlation between the PAHCO-dimensions and PA as well as between the PAHCO dimensions and EORTC FA12 were established. Accordingly, we should have been able to identify a relevant association, despite the likelihood of selection bias.

A conceivable mediation for the effect of CRF on LTPA *via* PAHCO renders obsolete (H_4 and H_5) given the lack of association between the two variables. Considering the cross-sectional character of the study, derived conclusions should not indicate causation, and further investigations need to examine relationship between CRF, LTPA and the role of PAHCO in a longitudinal manner. Subsequently, the time-lagged cross-correlations between CRF and LTPA would reveal further information about the relationship between these variables along the cancer trajectory. Due to the decline in PA-levels patients experience following cancer diagnosis and treatment, finding the causes as well as potential interventions are of great interests. Besides its explanatory value, increasing PAHCO in patients could potentially increase adherence to given exercise programs and an enhanced active lifestyle. One of the most common reported intrinsic barriers of cancer patients toward LTPA is the lack of self-efficacy (Brunet et al., 2013; Phillips and McAuley, 2013; Ungar et al., 2016; Hardcastle et al., 2018). In a systematic review the perception of control over ones well-being was one of the most common facilitators of exercise (Clifford et al., 2018). Another review has shown a strong prediction of instrumental attitude and planning on LTPA levels (Vallance et al., 2008). In fact, all these constructs can be considered constituents of PAHCO.

For patient care, PAHCO could be used to assess the level of support patients require to initiate an exercise routine and LTPA. By stratifying patients in accordance with their PAHCO levels, exercise therapists would be able to provide educational instructions tailored particularly to every patient's needs. By increasing PAHCO, patients would presumably feel empowered to engage in exercise and LTPA independently. In regards to health literacy, cancer patients with lower levels of knowledge seemed to necessitate expert support more than patients with higher levels, who were also more likely to perform research themselves (Morris et al., 2013). Additionally, the stratification process may prevent the misallocation of resources by providing especially patients in need with the highest level of guidance. Consequently, PAHCO is a promising concept to promote PA in cancer patients, which would result in vital lifestyle changes and increased participation in exercise programs.

TABLE 3 | Correlation matrix of the latent factors and LTPA.

	PF	EF	CF	MR	CC	SC	LTPA
PF	1	0.707**	0.524**	−0.288**	−0.350**	−0.395**	−0.026
EF		1	0.746**	−0.205*	−0.358**	−0.336**	−0.057
CF			1	−0.095	−0.193*	−0.183*	−0.150†
MR				1	0.626**	0.530**	0.268**
CC					1	0.706**	0.188*
SC						1	0.181*
LTPA							1

$^{**}p < 0.001$, $^{*}p < 0.05$, and $^{\dagger}p < 0.10$; PF, Physical Cancer Related Fatigue; EF, Emotional Cancer Related Fatigue; CF, Cognitive Cancer Related Fatigue; PAHCO, Physical Activity Related Health Competence; MR, Physical Activity Specific Mood Regulation; CC, Control Competence for Physical Training; SC, Physical Activity Specific Self Control; LTPA, Leisure Time Physical Activity.

Limitations

This study seems to have a couple of limitations. First, the cross-sectional character of the study does not allow for causal

TABLE 4 | Fit of the structural models.

	χ^2	df	χ^2/df	CFI	TLI	RMSEA	RMSEA CI	SRMR
PF	1,490	183	8.14	0.954	0.947	0.177	0.142–0.169	0.159
EF	957	146	6.55	0.964	0.958	0.156	0.147–0.166	0.142
CF	600	129	4.65	0.977	0.973	0.127	0.137–0.116	0.104

χ^2, chi-squared; df, degrees of freedom; χ^2/df, chi-square-degrees of freedom ratio; CFI, Comparative Fit Index; TLI, Tucker Lewis Index; RMSEA, Root Means Square Error of Approximation; SRMR, Standardized Root Mean Square Residual; PF, Physical Cancer Related Fatigue; EF, Emotional Cancer Related Fatigue; CF, Cognitive Cancer Related Fatigue.

conclusions. Therefore, the results from a mediation approach, which has an underlying causal preposition, will have to be interpreted with caution. An opposing relationship seems possible as well, meaning the therapeutic effect of LTPA on CRF can be utilized more efficiently by people with higher levels of PAHCO. Further research is necessary in order to investigate the relationship between LTPA, PAHCO and CRF with an experimental approach. Furthermore, movement competence, one of the three major sub-competences of the PAHCO model, was not assessed by the PAHCO questionnaire. Accordingly, the PAHCO has not been assessed in its entirety. More recent PAHCO instruments have already made suggestions to measure this dimension (Carl et al., 2020b) and should be applied to further research. Additionally, we encountered an immense loss of information due to incomplete PA-questionnaires, hence, less laborious but still reliable instruments, that assess physical activity in cancer patients, have been implemented without increasing study logistics and costs considerably, as it would be the case for accelerometers.

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 PennState College of Medicine internal review board (Study ID: HRP-591-PEXO, Clincial Trials.gov: NCT04328038). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MK: data collection, conducting the statistical analysis, and writing the manuscript. CK: data entry, descriptive statistics, and writing the manuscript. RW and KS: study design, coordination of data collection, and critical review of the manuscript. JW: study design, conducting the statistical analysis, and critical review of the manuscript. All authors contributed to the article and approved the submitted version.

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Different Endurance Exercise Modalities, Different Affective Response: A Within-Subject Study

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Affect experienced during an exercise session is supposed to predict future exercise behavior. However, empirical evidence reveals high variability in affective response to different exercise modalities. Thus, the purpose of the present study was to compare acute affective response and its variation during three different endurance exercise modalities: (a) moderate-intensity continuous exercise (MICE), (b) vigorous-intensity continuous exercise (VICE), and (c) high-intensity interval exercise (HIIE). Using the dual-mode theory as a theoretical framework, cognitive and interoceptive factors were considered as potential predictors of in-task affective response. In a within-subject design, 40 insufficiently active healthy participants (aged from 20 to 40 years) attended three sessions per exercise modality on a cycle ergometer. Affective valence (measured by the Feeling Scale), two cognitive factors (perceived competence and awareness of interoceptive cues), and one interoceptive factor (heart rate) were assessed before, during, and after each exercise session. Mixed models with three levels (*subject*, *exercise session*, and *time point*) revealed more positive affective valence during MICE compared with VICE ($p < 0.001$) and HIIE ($p < 0.01$), while there was no significant difference between the latter two. Levene's test results showed the highest variability of in-task affective valence during VICE ($ps < 0.01$). Regarding the course across the session, MICE was associated with a constant slight increase in affective valence from pre- to post-exercise ($p < 0.05$), whereas VICE and HIIE caused a decline in pleasure, followed by an affective rebound immediately after exercise termination ($ps < 0.01$). The highest importance of cognitive and interoceptive factors for in-task affective valence was observed in VICE ($ps < 0.05$). The current findings provide support for the tenets of the dual-mode theory, however, indicating that there may be differences in the affect-intensity relationship between continuous and interval exercise. In conclusion, the study results concerning previously insufficiently active individuals extend the knowledge of how exercise can positively shape affective well-being depending on exercise modality and psychophysiological influences. This knowledge enables public health practitioners to design more individualized activity recommendations, thereby improving the subjective experience of exercise.

Keywords: affect, physical activity, exercise, dual-mode theory, variability, within-subject, cognitive factors, interoceptive cues

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INTRODUCTION

In the context of theory-based interventions to enhance adoption and maintenance of exercise programs, affective response during an exercise session has been shown to predict future exercise behavior (Ekkekakis and Dafermos, 2012; Williams et al., 2012; Rhodes and Kates, 2015). However, substantial interindividual response variability has been demonstrated (Ekkekakis et al., 2011) and exercise characteristics (e.g., intensity, modality) seem to have a decisive influence (Stork et al., 2017). Affective response can be viewed as an umbrella term for numerous interrelated constructs, while current literature has highlighted *core affective valence* as the crucial component (Ekkekakis et al., 2020; Stevens et al., 2020), which is primitive and limited to basic appraisals of pleasure and displeasure (Russell and Barrett, 1999).

To date, research has not sufficiently clarified which specific factors influence the affective response and its variability during various exercise modalities. In order to prevent affective experiences that could obviate exercise adherence, this knowledge is of particular relevance. Thus, the purpose of the present study was to investigate affective response during three endurance exercise modalities considering different exercise intensities among insufficiently active adults. Providing explanations for variability in individuals' affective response will give insight into how exercise can be structured to achieve more positive affective states (i.e., how to make exercise more pleasant).

Affective Response Depending on Exercise Intensity

A broader conceptual framework that encompasses exercise intensity-dependent patterns of interindividual variability in affective response is the dual-mode theory (DMT; Ekkekakis, 2003, 2005). On the grounds of evolutionary arguments and adaptational implications, differences in affective response to exercise are explained by the continuous interplay between two general factors: (a) cognitive parameters (e.g., perceived competence, awareness of interoceptive cues), and (b) interoceptive stimuli (i.e., those emerging from the body such as increased heart rate and ventilation). The relative contribution of these two factors is hypothesized to shift systematically as a function of exercise intensity and the corresponding metabolic requirements (Ekkekakis and Acevedo, 2006; Ekkekakis, 2009). First, for exercise within the *moderate-intensity domain* (below the first ventilatory or lactate threshold [VT1/LT1]), it is assumed that affective responses are interindividually relatively homogeneous and mainly positive, with a small to moderate influence of cognitive factors (Ekkekakis et al., 2005a). Due to the low metabolic requirements, such intensities can be maintained over a long period of time and do not pose a threat to the homeostasis of the organism, consequently resulting in pleasant sensations (e.g., feelings of warmth; Ekkekakis and Acevedo, 2006). Second, in the *heavy-intensity domain* (extending from VT1/LT1 to the maximal lactate steady state [MLSS]), the highest variability of affective response is postulated, with some individuals reporting increases and others decreases in pleasure (Ekkekakis et al., 2005a). Rising blood lactate concentration and associated physiological processes to maintain the activity represent a challenge to the adaptive capacity of the body, without implying any concrete utility or danger. Given the ambiguous adaptational implications of exercise within this intensity range, cognitive factors are assumed to determine the affective response (Ekkekakis and Acevedo, 2006). Third, exercise within the *severe-intensity domain* (extending from MLSS to the level of maximal exercise capacity; above the VT2/LT2) is supposed to elicit again more interindividually homogeneous affective responses, but this time in the form of a decrease in pleasure (Ekkekakis et al., 2005a). Activities in this intensity range are based on limited energetic resources of the anaerobic metabolism and preclude the maintenance of a physiological steady state. A strong interoceptive influence (e.g., heart rate, blood lactate) is assumed here, which signals the approaching state of exhaustion to the body (i.e., adaptational risk) and provokes the timely termination of the exercise in order to prevent damage to the systems. Interoceptive stimuli thus act as a kind of protective mechanism, causing unpleasant sensations during exercise in this critical physiological range (Ekkekakis and Acevedo, 2006).

Exercise intensity-dependent patterns of affective response that are apparent during exercise tend to dissipate rather rapidly as soon as the activity is terminated (Ekkekakis et al., 2011). Accordingly, Backhouse et al. (2007) suggested that the "feel-better" effect of exercise may be an artifact of just measuring pre-post affective response, failing to account for affective fluctuations across an exercise session. While exercising within the moderate domain (i.e., intensities below VT1/LT1) should be accompanied by a constant or slightly increasing trend in affective valence, exercising at intensities at or above VT1/LT1 is supposed to cause a decline in pleasure, followed by a robust positive "affective rebound" once exercise is terminated. That is, a uniform shift toward pleasure after exercising in the heavy- or severe-intensity domain is predicted by DMT (Ekkekakis et al., 2005a). As a result, exercisers are supposed to return to or even exceed pre-exercise feeling states (Ekkekakis et al., 2011). Within the literature on DMT, this assumption is based on the "affect contrast" phenomenon described by Solomon (1980). Here, the opposing trend in the pattern of affective response is attributed to an adaptive benefit of terminating aversive stimuli and a concomitant restoration of homeostasis. As a result of an increased production of neuromodulators (e.g., endorphins, dopamine, serotonin), an increase in pleasure after intense exercise is assumed (Solomon, 1991; Basso and Suzuki, 2017).

Comparing Different Endurance Exercise Modalities: Empirical Evidence

Research on DMT provides broad support within the context of continuous exercise regarding the valence and variability of affective responses (e.g., Ekkekakis et al., 2011, 2018; Oliveira et al., 2015). Thus, empirical findings show less positive and more variable responses during vigorous-intensity continuous exercise (VICE; i.e., heavy domain) in comparison with moderate-intensity continuous exercise (MICE; i.e., moderate domain). In contrast, affective response during interval exercise is less

understood. Recently, high-intensity interval exercise (HIIE) has been gaining attention in the public health area as a time-efficient, less monotonous exercise strategy to improve cardiorespiratory and metabolic health (e.g., Batacan et al., 2017; Mattioni Maturana et al., 2021a). HIIE is characterized by relatively brief, repeated bouts at maximal or near-maximal effort, interspersed with recovery periods of low intensity or complete rest (Gillen and Gibala, 2014). The numerous benefits of HIIE on physiological outcomes are well-documented; however, concerns have been raised about the likelihood of HIIE (i.e., exercise in the severe-intensity domain) evoking a high degree of displeasure (Decker and Ekkekakis, 2017).

In recent years, an increasing number of studies have investigated differences in affective response between HIIE and continuous exercise, so review-based evidence is now available. Niven et al. (2020) performed a meta-analytic synthesis of the current research (HIIE vs. MICE: 15 studies; HIIE vs. VICE: 7 studies) and concluded that, while HIIE is associated with more negatively valenced affective responses during exercise when compared with MICE, there is no difference in in-task affective valence between HIIE and VICE. Importantly, a large degree of heterogeneity was evident in both comparisons. A detailed discussion on the apparent inconsistency regarding affective response to interval in comparison with continuous exercise can be found elsewhere (Decker and Ekkekakis, 2017).

Regarding the affective-rebound effect, the empirical data confirmed the assumptions of DMT for exercise at or above the VT1/LT1. Resembling the numerous findings on continuous exercise in the heavy domain (i.e., VICE; e.g., Ekkekakis et al., 2008, 2011), the affective valence decreased consistently during HIIE. However, as assumed, this decline in pleasure was followed by an affective rebound immediately after exercise termination or in the post-exercise period, returning to or even exceeding baseline values (Oliveira et al., 2013; Jung et al., 2014; Niven et al., 2018; Stork et al., 2018; Alicea et al., 2020; Box et al., 2020).

To date, not much is known about exercise modality-dependent factors of affective valence and its variation. However, among other cognitive factors, concepts relating to perceptions of ability (e.g., perceived competence) and attentional focus (e.g., awareness of interoceptive cues) have been shown to account for variation in the valenced (pleasure–displeasure) response to continuous exercise within the moderate and especially within the heavy domain (Rose and Parfitt, 2007; Ekkekakis et al., 2011). Recently, a narrative review found perceived competence to be a consistent explanatory variable for affective valence (Bourke et al., 2020). This is in line with the important role attributed to competency-related characteristics in prevalent theories of behavior change (e.g., Self-Determination Theory; Deci and Ryan, 1985, Social Learning Theory; Bandura, 1977). In contrast, mixed results were found for the concept of attentional focus (Bourke et al., 2020). Rose and Parfitt (2010) illuminate such mixed results in exercising around VT1, showing that some individuals interpret interoceptive cues positively and others negatively. Thus, the directional influence of the awareness of interoceptive cues on affective valence seems to be highly variable, depending on how the cues are interpreted (i.e., individual's cognitive appraisals of the stimuli). Still less studied is the negative influence of interoceptive stimuli (e.g., heart rate) on affective response in the severe domain postulated by DMT, although recent evidence supports the link between affective valence and homeostatic perturbations (Hartman et al., 2019).

Despite emerging trends, the comparison of affective response between continuous and interval-based exercise is still insufficiently elucidated. Due to the large number of existing endurance exercise modalities, barely any reliable predications can be made. In addition, the question arises as to which psychophysiological factors are relevant in which exercise modality, and to what extent these are related to the variability of affective response.

Study Rationale

This study aimed to investigate acute affective response to different endurance exercise modalities in previously insufficiently active individuals. Covering the exercise intensity domains described within DMT, the following three exercise modalities were compared: (a) MICE (i.e., moderate domain), (b) VICE (i.e., heavy domain), and (c) HIIE (i.e., severe domain).

Within this approach, we first wanted to explore differences in *valence and variation of in-task affective response* among the three different exercise modalities. With respect to the outlined theoretical arguments regarding continuous exercise (MICE and VICE) and review-based evidence on HIIE (in comparison with MICE and VICE), we hypothesized that MICE would result in more positive in-task affective valence compared with VICE and HIIE, while there would be similar affective responses between the latter two (MICE > VICE, HIIE [Hypothesis H1a]). We moreover assumed that, in line with the DMT postulate, VICE would be associated with a higher variability of in-task affective valence in comparison with MICE (VICE > MICE [Hypothesis H1b]).

Second, we examined whether the *course of affective response across the session* differs depending on the exercise modality. Considering the assumptions of DMT and the high consistency of research findings, we hypothesized that MICE would be on average accompanied by a constant or slightly increasing trend in affective valence from pre- to post-exercise, while VICE and HIIE (i.e., intensities above the VT1/LT1) would cause a decline in pleasure, followed by a positive affective rebound immediately after exercise termination (Hypothesis H2).

Lastly, we aimed to identify *psychophysiological predictors of in-task affective response*. As cognitive factors, we first considered perceived competence (PC) as an already highlighted important explanatory variable for affective valence. Second, within the concept of attentional focus, we examined the awareness of interoceptive cues (AOI) as a less consistent variable. Based on the DMT postulate and previous studies, we hypothesized that cognitive factors (PC and AOI) would be more strongly associated with in-task affective valence in VICE than in MICE (VICE > MICE; Hypothesis H3). Since evidence for interval exercise is particularly scarce in this regard, no directional hypothesis for HIIE was formulated. Third, we examined the

association of heart rate (HR), the interoceptive factor, with in-task affective valence on an exploratory basis.

MATERIALS AND METHODS

Study Design

This study was part of a larger research initiative entitled "Individual Response to Physical Activity—A Transdisciplinary Approach" (iReAct; Thiel et al., 2020). The iReAct project is an interdisciplinary research network, investigating individual physiological, affective, and cognitive responses based on a randomized, two-period sequential-training-intervention design. Over a period of ∼15-weeks, participants underwent two 6-week training periods starting with either HIIE or MICE (HIIE–MICE vs. MICE–HIIE). The training programs were of significantly different intensity, but matched for energy expenditure. Each training period consisted of three training sessions per week (on average). Participants underwent a physical fitness assessment before the start of training (week 1), between the two training periods (week 8), and at the end of the study (week 15), including an incremental step test for the standardization of exercise intensity and a VICE session (see **Figure 1**).

The present manuscript addressed a secondary research question of the iReAct project. As listed in detail above (Hypotheses H1–3), a comparison of acute affective response and potential influencing factors was made among three different endurance exercise modalities, which were linked to the intensity domains described within DMT (MICE $\triangleq$ moderate domain, VICE $\triangleq$ heavy domain, HIIE $\triangleq$ severe domain; Ekkekakis et al., 2005a). Our focus of interest was the *in situ* assessments, which were conducted at four time points (t_0-t_3) in three exercise sessions per exercise modality (Ses_{1-9}), resulting in a within-subject design with a total number of 36 observations per participant (see **Figure 1**). Therefore, it is important to note that the group comparison between training type effects across sequences (i.e., MICE–HIIE vs. HIIE–MICE) was not relevant for the current study, and that the following description refers to the relevant aspects for the present analysis. Further details on the clinical trial can be found in the study protocol (Thiel et al., 2020).

Eligibility and Recruitment

The targeted study group consisted of insufficiently active adults at the time of recruitment following the health-enhancing physical activity recommendations of the World Health Organization (WHO). That is, <150 min/week of moderate physical activity, <60 min/week of leisure-time exercise (including sports participation, endurance-oriented activities, and muscle strengthening), and no regular exercise engagement for several weeks during the last 6 months. Non-adherence to the WHO recommendations was assessed using the validated German version of the European Health Interview Survey—Physical Activity Questionnaire (EHIS-PAQ; Finger et al., 2015). Further inclusion criteria were (a) age from 20 to 40 years, (b) body mass index (BMI) from 18.5 to 30.0 kg/m^2, (c) non-smokers, (d) maximal oxygen uptake ($\dot{V}O_2max$) from 25 to 50 ml/min/kg, (e) no current or former eating disorder or obesity, (f) no severe internistic or neurological previous illness, (g) no pregnancy or breastfeeding period, and (h) German as a native language. Reasons for exclusion from the iReAct study included the following:

- Chronic diseases or findings that result in a decreased ability to exercise
- Medication or supplement intake within the previous 4-weeks
- Counter indication(s) for local anesthetics
- Clinically relevant deviations in the lab results
- Pathological indications in the resting electrocardiogram
- Vein conditions that do not allow for multiple blood sampling
- Participation in a medication study within the last 3 months
- History of drug use or alcohol abuse
- Current psychotherapy.

Recruitment occurred in six consecutive waves over a 2-year period (March 2018 to March 2020). Eligibility was assessed during a telephone screening, as well as a medical examination prior to final enrollment in the study. A total of 58 participants were assessed for eligibility, 49 of whom were included in the randomization process and nine were excluded during medical diagnosis. Out of these nine excluded participants, two were excluded due to time management issues and seven for not meeting the inclusion criteria (gastrointestinal issues [$n = 2$], iron deficiency anemia [$n = 2$], under psychological treatment [$n = 1$], drug consumption [$n = 1$], and BMI above the predetermined upper limit [$n = 1$]). One female, who exhibited a BMI below the specified range, was also included due to her normal percent body fat of 23.5 (normal range: 18–28%) as measured at baseline. The included participants ($N = 49$) were provided with detailed information about the study procedure and associated risks prior to giving written informed consent. During the baseline assessment, five participants dropped out for different reasons (migraine episode [$n = 1$], lung condition being discovered [$n = 1$], time management issues [$n = 1$], lack of willingness to continue participation [$n = 1$], and withdrawal during the VICE session due to discomfort with the exercise [$n = 1$]). Two other participants did not complete the first training period due to illness and thus not being able to complete the minimum adherence. Two non-native speakers included in deviation from study protocol were subsequently excluded from this data analysis because comprehension of the questionnaires could not be guaranteed. Thus, the final study sample comprised 40 insufficiently active healthy adults (men and women) from 20 to 40 years of age. An overview of participants' demographic and anthropometric characteristics can be found in **Table 1**.

Sample Size

We did not reach the sample size of $N = 60$ as originally projected in our power calculation and as documented in the study protocol (Thiel et al., 2020). This calculation, however, aimed at group comparisons between training type effects across the two training sequences (i.e., MICE–HIIE vs. HIIE–MICE), which was not the focus of the current study. No separate power analysis was performed for this secondary research question. A *post-hoc* sensitivity analysis (with the given sample size of $N = 40$) suggests that using a simple *t*-test for matched pairs and assuming a type I error of 0.05 (2-sided) and a power of 80% effect

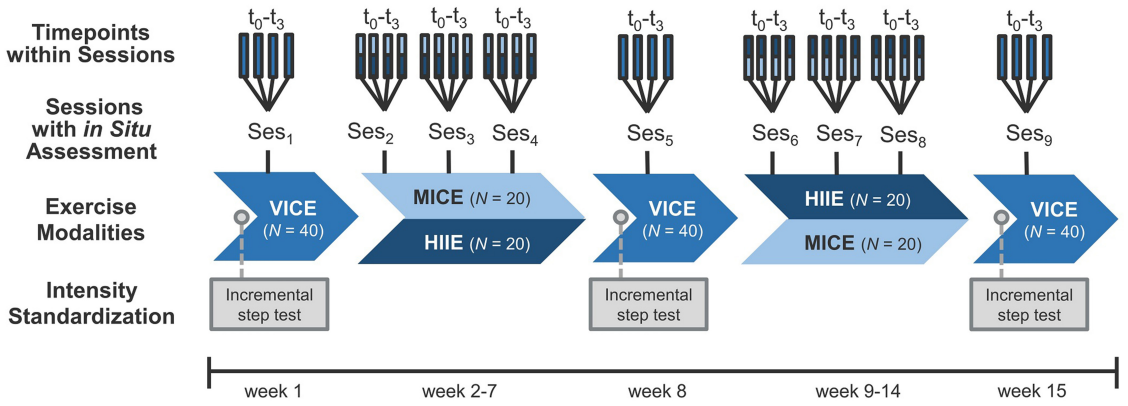

FIGURE 1 | Overview of the within-subject design. *In situ* assessments were conducted at 4 time points (t_0-t_3) within 3 exercise sessions per exercise modality (VICE, vigorous-intensity continuous exercise; MICE, moderate-intensity continuous exercise; HIIE, high-intensity interval exercise; Ses_{1-9}), resulting in a total number of 36 observations per participant ($N = 40$). In laboratory visits at weeks 1, 8, and 15, exercise intensities were standardized using an incremental step test with lactate diagnostics and spiroergometry.

TABLE 1 | Demographic and anthropometric characteristics of participants at baseline ($N = 40$).

Characteristic	*M* ± *SD*	Range
Age (years)	27 ± 6	20–40
Gender (female/male)	40[a]	29 (72%)/11 (28%)[b]
Height (cm)	171.2 ± 9.1	155.0–190.0
Weight (kg)	69.4 ± 11.1	45.0–101.4
BMI (kg m^{-2})	23.6 ± 2.6	17.6[c]–30.3[d]
$\dot{V}O_{2max}$ (ml kg^{-1} min^{-1})	31.4 ± 4.2	24.2–41.4
HR_{max} (b min^{-1})	191.3 ± 10.8	168.0–207.0
PO_{peak} (W)	162 ± 26	112–217
LTP1 (W)	68 ± 18	35–116
LTP2 (W)	122 ± 22	75–171

BMI, body mass index; $\dot{V}O_{2max}$, maximal oxygen uptake; HR_{max}, maximal heart rate; PO_{peak}, peak power output; LTP1, first lactate turning point; LTP2, second lactate turning point.
[a]Total number of participants. [b]number (percentage) of females/males. Minimum and maximum values of BMI are outside the specified range for one participant each but: [c]had a normal percentage of body fat (23.5%), and [d]had a BMI below 30 at inclusion.

sizes of $d = 0.45$ can be detected (no Bonferroni adjustment) (G*Power Version 3.1.9.6). We further discuss this issue in the limitations section.

Measures

Affective Response

Core affective valence, as the primary outcome variable, was assessed using the validated German version of the Feeling Scale (FS; Hardy and Rejeski, 1989; Maibach et al., 2020). The FS is a single-item, 11-point bipolar rating scale, ranging from −5 (*very bad*) through 0 (*neutral*) to +5 (*very good*) developed for the assessment of affective response during exercise along a displeasure-pleasure continuum.

Cognitive Factors

Two cognitive factors were examined in this study. First, *perceived competence* (PC) was operationalized via the level of agreement regarding the statement "*I feel like I am very competent for the physical activity.*" This single item has been formulated in context-specific variation by Sudeck and Conzelmann (2014). The version used in the present study was based on a 7-point bipolar rating scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Second, *awareness of interoceptive cues* (AOI) was assessed using a single-item designed on the basis of Rose and Parfitt's (2010) procedures. Participants were asked to rate the influence of interoceptive cues on their general affective state during exercise by completing the statement "*My physical reactions and sensations were...*" on a visual analog scale ranging from 0 to 100 with three verbal anchor points: *very disturbing* (0), *neutral* (50), and *very beneficial* (100).

Interoceptive Factor

The extent of interoceptive stimuli was operationalized by *heart rate* (HR), which was constantly monitored through a HR belt (further information follows in the next section). Minor artifacts in the HR data were cleaned using an anomaly detection algorithm to delete noisy data points (implausible spikes or gaps due to technical problems), which uses the interquartile method to find outliers (Upton and Cook, 1996). Each noisy data point was deleted, and the HR was then interpolated on a second-by-second basis.

Procedures

Standardization of Exercise Intensity

In the laboratory visits (weeks 1, 8, and 15; see **Figure 1**), participants undertook an incremental step test to volitional exhaustion on a cycle ergometer (Ergoselect 200; Ergoline GmbH, Bitz, Germany) for determination of the $\dot{V}O_{2max}$, peak power output (PO_{peak}), and lactate thresholds (first lactate turning point [LTP1] and second lactate turning point [LTP2]).

Before starting the test, baseline blood pressure and capillary blood lactate concentration ($[La^-]$) were measured. The test began with a 2-min resting period on the bike, followed by 25-watt (W) step increments every 3 min, starting at 50 W for males and at 25 W for females, until task failure. $[La^-]$ was analyzed (Biosen S-Line; EKF, Cardiff, UK) by collecting capillary blood samples (20 μL) from the right earlobe during the last 20 s of each stage and immediately after volitional exhaustion. HR and electrocardiogram (ECG) were constantly monitored throughout the test (12-channel PC ECG; custo med GmbH, Ottobrunn, Germany). Breath-by-breath pulmonary gas exchange and ventilation ($\dot{V}E$) were measured using a metabolic cart (MetaLyzer; CORTEX Biophysics, Leipzig, Germany). Calibration was performed before each test following the manufacturer's instructions. Lactate thresholds were analyzed using a segmented regression model at which two breakpoints were estimated from the $[La^-]$–power output relationship. LTP1 was determined as the first rise in $[La^-]$ above baseline levels (first breakpoint), which is accompanied by the first increase in $\dot{V}E$ as a function of $\dot{V}O_2$ (i.e., VT1). LTP2 was determined as the second abrupt increase in $[La^-]$ (second breakpoint), which is accompanied by the second sharp increase in $\dot{V}E$ as a function of $\dot{V}O_2$ (i.e., VT2; Binder et al., 2008; Hofmann and Tschakert, 2017).

Exercise Modalities

All exercise modalities were performed on calibrated bicycle ergometers (ec5000; custo med GmbH, Ottobrunn, Germany). Based on the results of spiroergometric and lactate measurements, the following exercise protocols were defined (for a graphical illustration, see **Figure 2**):

(a) *MICE* was prescribed as 60 min of continuous cycling at the power output (PO) corresponding to 90% of LTP1 ($\triangleq$ moderate-intensity domain).
(b) *VICE* was performed for 50 min at a constant PO corresponding to the midpoint between the first and the second lactate threshold (i.e., 50% of the difference between LTP1 and LTP2; $\triangleq$ heavy-intensity domain). The session was introduced by a 10-min warm-up at a PO corresponding to 90% of LTP1 ($\triangleq$ intensity of MICE), totaling 60 min of exercise.
(c) *HIIE* involved 4 x 4-min intervals at a PO corresponding to 90% of HR_{max}. This exercise intensity was chosen as such intensity would be within the severe-intensity domain for this population (i.e., all the exercise intensities were above LTP2). Each high-intensity load interval was interspersed with a 4-min active recovery at 30 W. The session was enclosed by a 10-min warm-up (at 70% of HR_{max}) and a 5-min cool-down at 30 W, totaling 43 min of exercise duration.

All exercise sessions were supervised by trained personnel. While VICE took place under standardized controlled laboratory conditions, MICE and HIIE were completed in a health and fitness orientated training environment. However, we considered a potential modality-dependent influence of environment-related characteristics on the affective response in preliminary analyses (see **Supplementary Table 1**).

Data Collection

An overview of measures used at the different survey time points can be seen in **Figure 2**. Within each survey session, affective valence (measured by FS) was recorded prior (t_0), at two time points in-task (t_1, t_2), and immediately after exercise (t_3) (i.e., four time points in total). In-task assessments for FS were performed after 14 and 30 min in HIIE (i.e., in the last 15 s of the first and third loading intervals). To achieve temporal alignment of the measurement time points, minutes 20 and 40 were set for the continuous exercise modalities (MICE and VICE). Cognitive factors were assessed during and after the exercise session. Data collection points for PC were minutes 22 and 38 in HIIE (i.e., in the last 15 s of the second and forth loading interval), minutes 20 and 40 in VICE, and minutes 31 and 53 in MICE. The time-lagged assessment in MICE and HIIE resulted from other study interests as well as the rationale of not overloading individual measurement time points. Consequently, PC values in MICE/HIIE were estimated using the next observation carried backward (NOCB) method (Engels and Diehr, 2003). AOI was collected in the form of a retrospective rating immediately after exercise cessation (see **Figure 2**).

In-task assessments were implemented by presenting the individual items on A3 posters as visual references so that the participants could concentrate on the exercise itself. The questions, including scale anchors, were read aloud by the investigator and the participant's response was recorded via smartphone (Google Nexus 5; LG Group, Seoul, South Korea) with the movisensXS application (movisens GmbH, Karlsruhe, Germany) after consultation. Pre- and post-surveys were conducted independently by the participants with smartphone in hand. HR was collected throughout all sessions using a HR belt (3-channel ECG; custo med GmbH, Ottobrunn, Germany). Based on this training monitoring, HR was adjusted to fitness changes over the weeks (for details, see Mattioni Maturana et al., 2021b). This ensured that participants were always exercising within the originally prescribed relative intensity of exercise.

Statistical Analyses

A manipulation check was carried out to verify whether the participants were exercising at different exercise intensities in the three exercise modalities as intended. Separate one-way analysis of variance (ANOVAs) were executed for the variables of $\%HR_{max}$ and %HRR.

Descriptive statistics using means (*M*) and standard deviations (*SD*) were generated for continuous variables according to the distribution; frequencies (*n*) and percentages (%) were generated for categorical variables. Intraclass correlation coefficients (ICCs) were calculated for the main outcome measures. Furthermore, estimates of the within-person variability across the FS measurements (9 sessions × 4 time points) and the PC, AOI, and HR measurements (9 sessions × 3 time points), as well as the between-person variability in these outcomes, were calculated.

For the first research question regarding in-task (t_1, t_2) affective valence in the three different exercise modalities (Hypothesis H1a), we fit a multilevel model for repeated measures with the levels *subject* (ID), *session* (s1, s2, s3), and

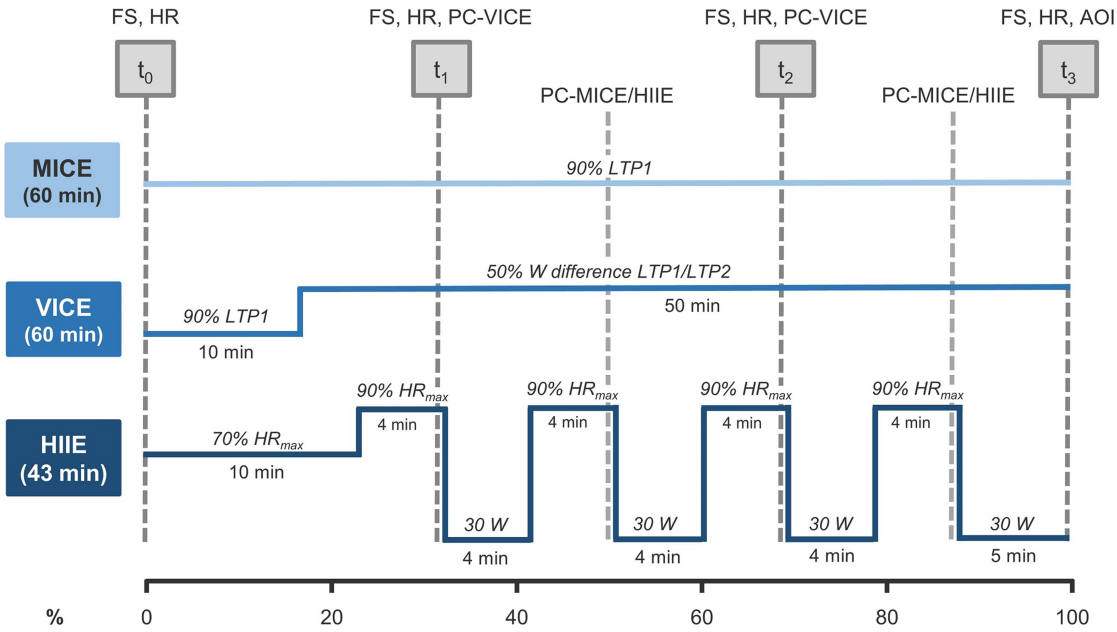

FIGURE 2 | Overview of exercise modalities and measures. Data was collected at 4 points in time: pre-exercise (t_0), in-task (t_1, t_2), and post-exercise (t_3). The x-axis describes the percentage of exercise completed (0–100%). FS, Feeling Scale; HR, heart rate; PC-VICE, perceived competence assessed in VICE; PC-MICE/HIIE, perceived competence assessed in MICE/HIIE; AOI, awareness of interoceptive cues; MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise; LTP1, first lactate turning point; LTP2, second lactate turning point.

the crossed factor *modality* (MICE, VICE, HIIE) to examine the effect of intensity conditions during the intervention on the FS (Model 1). A step-up model construction strategy was applied, retaining fixed effects in the model if they demonstrated statistical significance ($p < 0.05$) and successively adding random effects to account for the correlated structure of the data. Due to non-convergence caused by over-parameterization (the random effects structure exhibited a complexity not supported by the underlying data), we did not account for the nesting of individuals within group sequence (i.e., MICE-HIIE vs. HIIE-MICE). Thus, our final model included the fixed effect modality and a random intercept on the subject and session level, as well as allowing for a random slope for exercise modalities. To examine the in-task (t_1, t_2) variability of affective valence in the three different exercise modalities (Hypothesis H1b), equality of variances between exercise modalities was tested using the median-based Levene's test.

To address the second research question with regard to the course of the affective valence across a session within the three different exercise modalities (Hypothesis H2), data from the pre-exercise time point (t_0), the in-task time points (t_1, t_2), and the post-exercise time point (t_3) were examined in the model (Model 2). As fixed effects, we considered modality, time point, and the interaction term modality *x* time point. A random intercept on session and subject level, as well as a random slope, were included.

For the third research question concerning the identification of exercise modality-dependent predictors of in-task (t_1, t_2) affective response (Hypothesis H3), we extended Model 1 by separately introducing one of three factors (PC, AOI, or HR) and its interaction with modality as fixed effects (Model 3a, b, c, respectively).

Due to the low numbers of units on the subject level, simple covariance structures (scaled identity) had to be chosen to reach convergence in all the models. Significant effects were followed by pairwise *post hoc* comparisons applying Bonferroni adjustments. For significant interaction terms, *post hoc* probing was performed to describe the direction of the interaction effect. We contrasted effects with one *SD* below and above the mean value (± 1 *SD*) using two-way interaction plots.

Data preparation and statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS, version 26; IBM Corp., Armonk, NY, USA). All *p*-values were two-sided, and the statistical significance level was set at $p < 0.05$.

RESULTS

Descriptive Analyses

The manipulation check confirmed that participants were exercising at different intensities in the three exercise modalities based on mean in-task $\%HR_{max}$, $F_{(2,645)} = 701.53$, $p < 0.001$, $\eta^2 = 0.69$, and %HRR, $F_{(2,645)} = 643.92$, $p < 0.001$, $\eta^2 = 0.67$. In addition, comparison of the HR data with reference values proposed by Binder et al. (2008) indicated that the

TABLE 2 | Descriptive statistics for study variables.

Variable		Between-person variability				Within-person variability			
	ICC	*N*	*M*	*SD*	Range	*N*	mV	*SD*	Range
FS [−5 to +5]	0.35	40	2.70	0.96	−0.12 to 4.46	1360[a]	80	1.29	0.17 to 2.66
PC [1 to 7]	0.63	40	5.29	1.13	2.70 to 6.89	1020[b]	60	0.85	0.19 to 2.37
AOI [0 to 100]	0.47	40	56.10	12.83	33.11 to 85.11	1020[b]	60	13.14	3.03 to 27.41
HR	0.25	40	149.74	12.01	122.35 to 169.34	958[b]	122	19.48	13.03 to 26.49

ICC, intraclass correlation coefficient; mV, missing values; FS, Feeling Scale; PC, perceived competence; AOI, awareness of interoceptive cues; HR, heart rate.
[a]FS was measured at 4 points in time (pre-exercise [t_0], in-task [t_1, t_2], and post-exercise [t_3]). [b]PC, AOI, and HR were measured at 3 points in time (t_1, t_2, and t_3).

exercise modalities were within the targeted intensity domains (for descriptive statistics see **Supplementary Table 2**).

Descriptive statistics of the study variables can be found in **Table 2**. It is important to note that there are missing values due to disturbances in HR measurement as well as an early termination of the last survey wave due to the COVID-19 pandemic. The grand means of FS, PC, and AOI were in the upper third or upper half of the respective scales. The empirical range of person means varied from −0.12 to 4.46 for FS, from 2.70 to 6.89 for PC, and from 33.11 to 85.11 for AOI, indicating substantial between-person variability. The ICCs indicated that 35% (FS), 63% (PC), or 47% (AOI) referred to between-person differences. In contrast, the ICC of HR indicated that 75% could be attributed to within-person differences.

Main Analyses

Valence and Variation of In-task Affective Response

Figure 3 illustrates the differences of in-task (t_1, t_2) affective valence and its variation among the three different exercise modalities (the corresponding descriptive statistics are provided in **Supplementary Table 3**). Model 1 revealed a significant main effect for modality ($F = 14.56$, $p < 0.001$) on affective valence (FS). Pairwise *post hoc* comparisons (see **Table 3**) showed FS to be significantly higher in MICE than in VICE and HIIE. No significant difference was found between VICE and HIIE (confirmation of Hypothesis H1a). Levene's test results indicated significant variance differences among exercise modalities ($F = 8.57$, $p < 0.001$). Pairwise *post hoc* comparisons showed significantly higher variability of FS in VICE than in MICE ($F = 19.91$, $p < 0.001$; confirmation of Hypothesis H1b) and in HIIE ($F = 8.98$, $p = 0.003$). No differences in variability were found between MICE and HIIE ($F = 2.52$, $p = 0.113$).

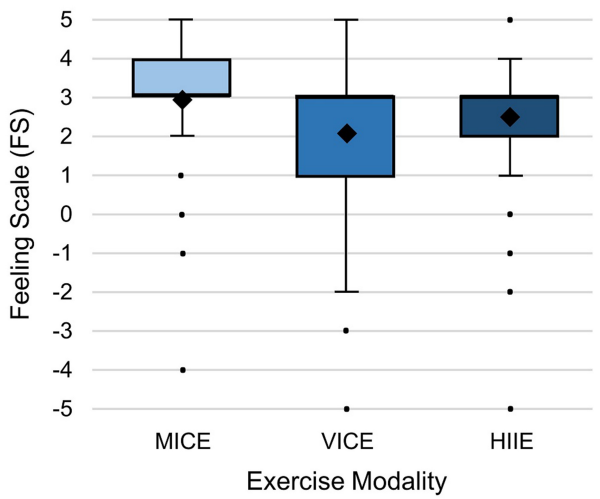

FIGURE 3 | Affective valence (Feeling Scale) and its variation within the three different exercise modalities: MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise. The diamonds represent the mean values. Raw data is presented for the in-task time points (t_1, t_2) of each of the three sessions (Ses_{1-3}) without adjustment for the dependencies within clusters.

Course of Affective Response Across the Session

Figure 4 shows that, while a slight increase of FS occurred in MICE, there was an affective rebound in VICE and HIIE. Model 2 revealed significant main effects for modality ($F = 6.08$, $p = 0.003$) and time point ($F = 24.22$, $p < 0.001$) on FS; however, they were qualified by the interaction modality *x* time point ($F = 13.33$, $p < 0.001$). In the pairwise *post hoc* analysis (see **Table 4**), we observed a significant increase of FS from pre- to post-exercise in MICE. In contrast, a significant decrease in FS from pre-exercise to t_1 and t_2 was evident for VICE and HIIE, followed by a significant increase from t_2 to post-exercise (confirmation of Hypothesis H2). While the FS post value for VICE remained below the pre-exercise value, the FS post value for HIIE increased above baseline.

Psychophysiological Predictors of In-task Affective Response

Figure 5 depicts the association of cognitive (PC, AOI) and interoceptive (HR) factors with FS as a function of exercise modality. Models 3a-c revealed significant main effects for all fixed factors and interaction terms.

For PC (Model 3a), we found significant main effects for modality ($F = 10.58$, $p < 0.001$) and PC ($F = 41.54$, $p < 0.001$) on FS; however, they were qualified by the interaction modality *x* PC ($F = 7.55$, $p = 0.001$). Pairwise *post hoc* comparisons (see **Table 3**) showed a significantly stronger association of PC with FS in VICE than in MICE (confirmation of Hypothesis H3) and in HIIE, while no significant difference was observed between MICE and HIIE. Contrasting the interaction effect with one *SD* higher

TABLE 3 | Associations of exercise modality and psychophysiological factors with affective valence.

		Fixed effect	B	SE	*p*
MODEL 1: in-task affective valence[a]					
	Exercise Modality	MICE vs. VICE	0.886	0.165	<0.001***
		MICE vs. HIIE	0.535	0.166	0.005**
		VICE vs. HIIE	−0.350	0.166	0.114
MODEL 3: Predictors of in-task affective valence[b]					
(a)	PC × Exercise Modality	VICE vs. MICE	0.342	0.107	0.006**
		MICE vs. HIIE	−0.051	0.108	>0.999
		VICE vs. HIIE	0.291	0.088	0.003**
(b)	AOI × Exercise Modality	VICE vs. MICE	0.013	0.007	0.186
		MICE vs. HIIE	0.006	0.007	>0.999
		VICE vs. HIIE	0.019	0.007	0.015*
(c)	HR × Exercise Modality	VICE vs. MICE	−0.023	0.009	0.033*
		MICE vs. HIIE	−0.009	0.011	>0.999
		VICE vs. HIIE	−0.032	0.010	0.003**

The results represent pairwise post hoc comparisons of Feeling Scale (FS) values. PC, perceived competence; AOI, awareness of interoceptive cues; HR, heart rate; x, interaction term; MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise.

[a]In Model 1, we examined in-task (t_1, t_2) affective valence by including the levels subject, exercise session, and the crossed factor exercise modality (MICE, VICE, HIIE). [b]For Model 3, we extended Model 1 by separately introducing the interaction term of one of three potential predictors (3a: PC, 3b: AOI, 3c: HR) with exercise modality (x exercise modality) as a fixed factor.

**p < 0.05. **p < 0.01. ***p < 0.001 (Bonferroni adjusted).*

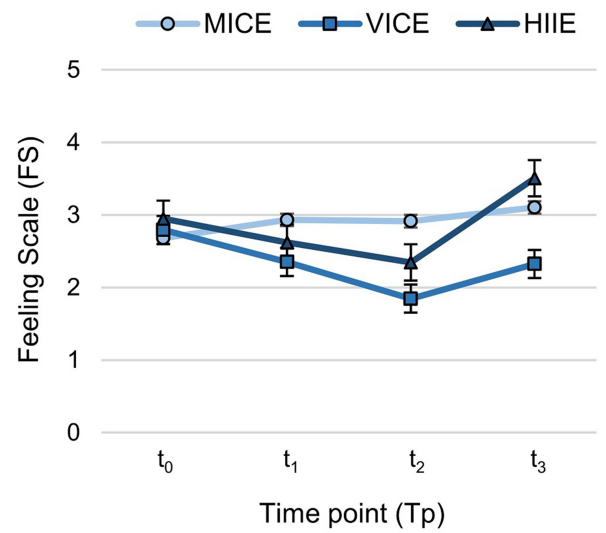

FIGURE 4 | Course of affective valence (Feeling Scale) across the session within the three different exercise modalities: MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise. The graphs represent estimated means and standard errors (Model 2) over 4 time points (pre-exercise [t_0], in-task [t_1, t_2], and post-exercise [t_3]).

and lower in PC resulted in an increase and decrease, respectively, on the FS by 0.80 in VICE vs. 0.31 in MICE and 0.38 in HIIE (see **Figure 5A**).

TABLE 4 | Comparisons of affective valence at four time points within exercise modalities.

	Tp	Δ_M	SE	*p*
MICE	t_1 vs. t_0	0.250	0.107	0.119
	t_2 vs. t_0	0.233	0.126	0.390
	t_3 vs. t_0	0.422	0.144	0.021*
	t_2 vs. t_1	−0.017	0.090	>0.999
	t_3 vs. t_1	0.172	0.114	0.791
	t_3 vs. t_2	0.190	0.132	0.913
VICE	t_1 vs. t_0	−0.441	0.109	<0.001***
	t_2 vs. t_0	−0.946	0.129	<0.001***
	t_3 vs. t_0	−0.468	0.147	0.009**
	t_2 vs. t_1	−0.505	0.092	<0.001***
	t_3 vs. t_1	−0.027	0.117	>0.999
	t_3 vs. t_2	0.477	0.135	0.003**
HIIE	t_1 vs. t_0	−0.327	0.108	0.016*
	t_2 vs. t_0	−0.602	0.128	<0.001***
	t_3 vs. t_0	0.558	0.146	0.001**
	t_2 vs. t_1	−0.274	0.092	0.018*
	t_3 vs. t_1	0.885	0.116	<0.001***
	t_3 vs. t_2	1.159	0.134	<0.001***

The results represent pairwise post-hoc comparisons of Feeling Scale (FS) values for the 4 points in time (Tp: pre-exercise [t_0], in-task [t_1, t_2], and post-exercise [t_3]; Model 2). MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise.

**p < 0.05. **p < 0.01. ***p <0.001 (Bonferroni adjusted).*

For AOI (Model 3b), we observed significant main effects for modality ($F = 8.40$, $p = 0.001$) and AOI ($F = 58.29$, $p < 0.001$) on FS; however, they were qualified by the interaction modality *x* AOI ($F = 4.29$, $p = 0.014$). Pairwise *post hoc* comparisons (see **Table 3**) revealed a significantly stronger association of AOI with FS in VICE than in HIIE. In contrast, no significant differences were found between VICE and MICE (rejection of Hypothesis H3) or between MICE and HIIE. Effect contrasting of AOI resulted in an FS change of 0.66 in VICE vs. 0.32 in HIIE (and 0.43 in MICE; see **Figure 5B**).

For HR (Model 3c), the model revealed significant main effects for modality ($F = 5.33$, $p = 0.006$) and HR ($F = 17.61$, $p < 0.001$) on FS; however, they were qualified by the interaction modality *x* HR ($F = 6.61$, $p = 0.002$). Pairwise *post hoc* comparisons (see **Table 3**) showed a significantly stronger association of HR with FS in VICE than in the two other modalities (MICE and HIIE), where no significant difference was observed. Effect contrasting of HR resulted in a FS change of 0.90 in VICE vs. 0.39 in MICE and 0.19 in HIIE (see **Figure 5C**). Importantly, the direction of the interaction effect here was opposite to that for the cognitive factors, such that an increase in HR rate was accompanied by a decrease in affective valence.

DISCUSSION

The present study was designed to investigate acute affective response associated with endurance exercise modalities

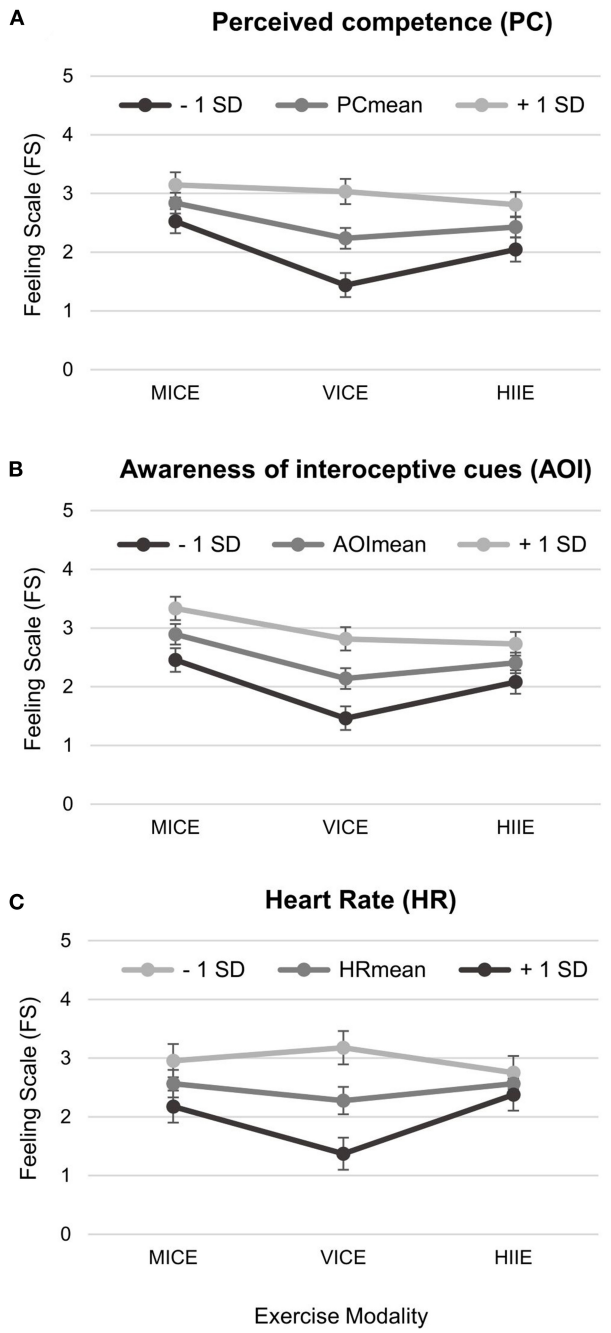

FIGURE 5 | Two-way interaction plots of psychophysiological predictors of in-task (t_1, t_2) affective valence (Models 3a-c): **(A)** Perceived competence, **(B)** Awareness of interoceptive cues, and **(C)** Heart rate. Shown is the respective expression of the Feeling Scale (FS) for the mean value of the predictor as well as for one standard deviation below the mean value (−1 SD) and for one standard deviation above the mean value (+1 SD) with error bars representing standard errors. MICE, moderate-intensity continuous exercise; VICE, vigorous-intensity continuous exercise; HIIE, high-intensity interval exercise.

considering different exercise intensities. Based on the lactate threshold concept proposed by DMT, two continuous exercise protocols within the moderate- (MICE) or heavy-intensity domain (VICE) and an interval exercise in the severe-intensity domain (HIIE) were compared in a within-subject study among insufficiently active adults. Basically, the current findings provide support for the tenets of DMT regarding continuous exercise, but suggest that these are not directly applicable to the intermittent nature of HIIE that allows periods of recovery between bouts of severe exercise.

Consistent with the hypotheses, in-task affective valence was more positive in MICE compared with VICE and HIIE, while there was no significant difference between the latter two. However, the descriptive statistics suggested that VICE was more negatively valenced in comparison with HIIE. Taken together, our results are in line with previous research, indicating similar (Martinez et al., 2015; Niven et al., 2018; Alicea et al., 2020) or even more positive affective responses (Jung et al., 2014; Kilpatrick et al., 2015; Martinez et al., 2015) in HIIE as opposed to VICE. On the basis of these results, it can be assumed that the short periods of severe intensity in HIIE are not of sufficient duration to disrupt homeostasis to such an extent that a more negative affective response is induced. Rather, the rest periods seem to mitigate the detrimental effect associated with the HIIE load intervals. Reduced monotony, the prospect of getting a break, and a feeling of pride after the completion of each interval could positively influence the affective response in contrast to continuous exercise in the heavy domain. In line with this assumption, studies showed that the specific characteristics of HIIE promote participants' self-efficacy beliefs (Jung et al., 2014) and result in more positively valenced post-exercise narrative responses (e.g., feelings of reward and reenergization associated with the rest interval) in comparison with continuous exercise (Alicea et al., 2020). Due to the fact that, in our study, we exclusively considered affective response at the very end of the load intervals, it seems plausible that the beneficial influence of the interval exercise modality in terms of affective valenced states was not only reflected in the overall picture but also within the specific severe-intensity exercise periods.

Further, a rebound to more positive affect was observed in this study following exercise in the heavy and severe domain, which aligns with the assumptions of DMT (Ekkekakis et al., 2005a) and empirical evidence (e.g., Stork et al., 2018; Alicea et al., 2020; Box et al., 2020). As hypothesized for the course across the session, MICE was associated with a slight increase in affective valence from pre- to post-exercise, whereas VICE and HIIE caused a decline in pleasure, followed by an affective rebound immediately after exercise termination. Regarding the amount of affective rebound, post values of affective valence in our study remained below baseline values in VICE, but exceeded baseline values in HIIE. Importantly, the post-value was collected in VICE directly following the exercise, whereas in HIIE, a 5-min cool-down was performed before the end of exercise. Results of previous studies suggested that the postulated affective rebound effect only develops (completely) in the post-exercise period (e.g., Decker and Ekkekakis, 2017; Stork et al., 2018; Box et al., 2020). Thus, it can be assumed that a cool-down phase or a later survey time point of post-exercise affective response (e.g., 5 min post-exercise) would also have revealed a rebound to more positive valenced states in VICE.

The current results revealed the heavy-intensity range (i.e., VICE) as the zone of the highest response variability. Furthermore, the study provided an explanation for this finding by showing a higher importance of psychophysiological factors within the heavy domain. Both cognitive factors (perceived competence and awareness of interoceptive cues) almost consistently had a greater association with affective response during VICE in contrast to MICE and HIIE (see **Figures 5A,B**). A one *SD* higher score on either cognitive factor resulted in twice the rate of change in affective valence in VICE compared with HIIE. Moreover, perceived competence was shown to be more relevant within continuous exercise in the heavy domain (i.e., VICE) compared with the moderate domain (i.e., MICE), associated with an even 2.5 times higher rate of change in affective valence. Such a tendency could also be seen for the awareness of interoceptive cues with a factor of 1.5 for the comparison of impact in VICE vs. MICE, although here the significance level was not achieved.

There was no difference in the association of cognitive factors on affective response in the moderate (i.e., MICE) and severe (i.e., HIIE) modalities considered here. While previous research based on a comparison of imposed and self-selected HIIE concluded that (reflecting the assumptions of DMT on continuous exercise) affective valence within the severe domain is mediated by exercise intensity rather than the feeling of autonomy (Kellogg et al., 2019), the present results suggest an influence of cognitive factors in HIIE. Thus, it is possible that the intermittent nature of HIIE prevents a switch to a mode of affect induction that relies primarily on interoceptive stimuli. Supporting this assumption, we found an analogous pattern for the modality-dependent association of the interoceptive factor with affective response to that of the cognitive factors studied (see **Figure 5C**). That is, heart rate had a greater importance in the heavy vs. the other two domains, with a two times (VICE vs. HIIE) or even five times (VICE vs. MICE) higher rate of negative change in affective valence. This finding does not support the proposition of DMT for continuous exercise, that interoceptive stimuli have the greatest (negative) influence in the severe domain. Importantly, the heart rate examined in this study represents only one physiological factor and may have a different influence on affective response in contrast to a neurophysiological (e.g., heart rate variability), cardiorespiratory (e.g., oxygen uptake), or metabolic marker (e.g., blood lactate). For example, a study by Roloff et al. (2020) demonstrated that valenced affective states closely track changes in oxygen uptake in four different HIIE protocols.

Taking a closer look at HIIE, the contradictory study results can potentially be explained by examining the exercise protocol variables, such as work-to-rest ratio, total session duration, and energy expenditure. Since these characteristics decisively determine the extent of reliance on limited energetic resources of the anaerobic metabolism, they are supposed to have a decisive influence on affective response to exercise (Ekkekakis et al., 2005a). Therefore, it is not surprising that the strenuous HIIE protocol in a study from Oliveira et al. (2013) with 2-min work intervals and <1-min recovery periods resulted in less pleasure compared with VICE. Likewise, the detrimental influence of HIIE observed in the study of Decker and Ekkekakis (2017) could have been due to their demanding protocol with a work-to-rest ratio of 1:0.66 and a comparatively high intensity within the recovery periods (85% of VT1). In contrast, the 1:1 work-to-rest ratio used in this and in other studies (e.g., Jung et al., 2014; Alicea et al., 2020), with comparatively lower dependence on anaerobic metabolism, resulted in equal or even more positive affective states in HIIE vs. VICE. Interestingly, the negative impact of longer interval duration of 120 s in HIIE on affective response in comparison with VICE that was found in the study by Martinez et al. (2015) was not evident for this study which had an interval duration of 240 s. However, due to an equation of energy expenditure in their study, HIIE was of longer duration than VICE (24 vs. 20 min), whereas in our study, we used a significantly shorter HIIE protocol compared with VICE (43 vs. 60 min), since the main argument for promoting HIIE in public health is its time efficiency. Nonetheless, there is increasing evidence that low-volume HIIE may diminish feelings of displeasure during exercise (e.g., Haines et al., 2020). Similarly, reducing the intensity of load intervals (from 100 to 85% of peak power) has been shown to be a successful strategy for obtaining more positive affective experiences in HIIE while maintaining a health-promoting heart rate stimulus (Malik et al., 2019).

Strengths and Limitations

Some strengths of the current study are noteworthy. First, responding to the call for psychophysiological perspectives in research examining the affective response to exercise (Acevedo and Ekkekakis, 2006), we standardized exercise intensities relative to metabolic landmarks with reference to a physiological framework. This allowed us to ensure accurate comparisons of affective response across the three different exercise intensity domains proposed by DMT. Second, in line with current recommendations, we assessed the valence component of basic affect (using FS) before, during, and after the exercise session to provide in-task as well as course-specific patterns of affective response. Third, we applied a mixed model approach to account for the nested data structure of the within-subject design (9 sessions with 4 time points per participant). Finally, by recruiting adults who did not achieve the recommendations for health-promoting physical activity, the current findings are of direct relevance to a segment of the population that is particularly in need of interventions for promoting exercise.

Although the current study produced novel and important findings, some potential limitations should be mentioned. As this study addressed a secondary research question of the iReAct project, no group comparison between training type effects across sequences (i.e., MICE–HIIE vs. HIIE–MICE) was made, thus neglecting potential carry over effects. In addition, it is important to consider that, because the participants completed a 15-week training program, strictly speaking, they were no longer physically inactive during the study. However, through training monitoring, we accounted for fitness changes over the weeks and ensured that participants were exercising within the originally prescribed relative intensities.

Other limitations relate to the *in situ* assessments. First, due to concerns about overloading the surveys, not all measures were

collected at each survey time point during exercise, so the PC scores had to be estimated using the NOCB method. Although we consider this missing data approach to be reasonable due to the assumption of a certain latency period of the competence experience, the shift in data may have been associated with an over- or underestimation of effects. Second, for HIIE, we considered only responses within the load intervals (as representants of the severe-intensity domain). However, looking at the whole, the intermittent nature of interval exercise seems to play an important role (Stork et al., 2018). Especially when it comes to predicting subsequent exercise behavior on the basis of in-task response, fluctuations in affect during both the rest and load intervals should be considered in future studies. Third, the 5-min cool-down period in HIIE compared with VICE made it difficult to compare the extent of the affective rebound. It would certainly have been worthwhile to have considered affective valence not only immediately after the end of exercise, but also at several time points in the post-exercise period (e.g., 10, 20, and 30 min post-exercise; Decker and Ekkekakis, 2017), but this was not possible due to other study interests. Last, *in situ* assessments were carried out in different environmental conditions with a rather sterile laboratory setting (VICE) on the one hand and a less standardized training area (MICE and HIIE) on the other. Although we took this potential confounder into account in preliminary analyses, a minor influence of environment-related characteristics on affective response to exercise cannot be completely ruled out.

Moreover, the three exercise modalities assessed in the present study should be considered as only a selection of a large pool of possible options. In particular, we solely examined one HIIE protocol, so no conclusions can be drawn about which specific variables of HIIE influenced acute affective response in our study. Because there is high variability in HIIE protocol configurations among studies that limits the generalizability of our and previous findings, future research should emphasize a more detailed comparison of different HIIE sessions to determine optimally configured protocols. A balanced work-to-rest ratio as well as shorter total duration compared with continuous exercise seems to be promising.

Lastly, only 40 participants could be recruited for the elaborate within-subject design with 15-weeks of training and three extensive diagnostic blocks that did not allow for extended absences. Due to this low sample size, observed effects have to be interpreted with caution. In future studies, accounting for interindividual differences, it should be tested how stable these effects are, in order to improve the generalizability of the results. In this context, due to the highly standardized ergometer training, the limited external validity should be mentioned as another limiting factor.

Practical Implications and Conclusion

The current findings provide us with a more comprehensive understanding of insufficiently active people's acute affective response to MICE, VICE, and HIIE. When it comes to aerobic exercise prescriptions, one size does not fit all due to interindividual differences. Thus, health promotion practitioners should offer beginners the opportunity to try different forms of endurance exercise in order to achieve more positive affective states. In addition to this acute experimental manipulation study of affective response to prescribed endurance exercise modalities, future studies should expand the scope of the present investigation to real-world settings (i.e., increase external validity) and long-term exercise adherence monitoring.

In the process of personalized exercise programming, trait differences (i.e., individuals' preference for and tolerance of exercise intensity or modality; Ekkekakis et al., 2005b) as well as state differences (i.e., individuals' pre-exercise physical and mental "readiness-to-exercise"; Strohacker and Zakrajsek, 2016) need to be considered. Thus, HIIE may be a viable, time-efficient strategy for some individuals and certain occasions in obtaining positive psychological responses and long-term health benefits. A combination of both HIIE and continuous exercise should be considered, in order to better utilize the advantages of each modality and to bring more variety and flexibility into the daily exercise routine.

Our results suggest that, in addition to bolstering one's self-perception of competence, changing individual interpretations of interoceptive cues (i.e., cognitive reframing) may be one avenue to increase pleasure during exercise, especially in the heavy intensity domain. Consequently, in addition to dissociative strategies of directing attention away from bodily symptoms (i.e., producing an external attentional focus by exercising with music/video; Karageorghis et al., 2021 or exercising in natural environments; Bourke et al., 2020), there is also potential for the use of associative strategies that consciously address the (unpleasant) bodily sensations themselves (e.g., mindfulness practices during exercise; Cox et al., 2020).

Collectively, this study provides insight into how exercise can be structured to elicit more positive affective states, and contributes to a theory-based foundation for the development and implementation of more individualized exercise promotion interventions, thereby improving the subjective experience of exercise.

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 Ethics Committee of the Medical Faculty, University of T(# 882/2017BO1) and was registered at the German Clinical Trials Register (# DRKS00017446). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KD, FM, AN, AT, and GS conceptualized the paper. KD and FM performed the measurements and prepared the data. AN, AT, and GS supervised the study. PM contributed to the planning of the statistical procedures. KD and IR analyzed the data. KD wrote the

first draft of the manuscript. FM provided the information for the procedures on the standardization of exercise intensity and IR for the model descriptions in the statistics section. All authors discussed and revised the manuscript before submission and read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.686661/full#supplementary-material

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The Natural Environment of Physical Activity and Perceived Stress: The Mediating Role of Specific Recovery Experiences

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Objective: The purpose of this study was to investigate a potential psychological mechanism of green exercise on perceived stress. More precisely, it was analyzed whether the relationship between the natural environment of physical activity and perceived stress was mediated by recovery experiences, namely by psychological detachment and relaxation. An ecological momentary assessment approach was used, meaning that specific recovery experiences were assessed directly in real-life situations and multiple times.

Materials and methods: Thirty five women and 27 men took part in the ecological momentary assessment study over seven days ($M_{age} = 32.30$ years, $SD = 10.23$, 53% had a degree from a university or a university of applied science). If participants were involved in PA lasting at least 10 min on a given day, they had to answer questionnaires on the smartphone both prior to the activity and immediately afterwards. Perceived naturalness, psychological detachment and relaxation were assessed after physical activity events, whereas perceived stress was measured before and after each physical activity event. A two-level mediation analysis was conducted. The direct and indirect effect of perceived naturalness on perceived stress after engagement in physical activity was analyzed on the within- and between-person levels.

Results and conclusion: Results showed that the relaxation as a recovery experience served as mediator between perceived naturalness and perceived stress after engagement in physical activity, but only on a within-person level. This means that the more natural a given individual appraised the physical activity environment, the more relaxed he or she felt during physical activity ($\beta = 0.322$, $p < 0.0005$). Furthermore the more relaxed the individual was, the less stress he or she perceived after exercising ($\beta = -0.221$, $p < 0.0005$). The psychological detachment as a recovery experience in contrast, did not serve as mediator, neither at the within- and the between-person level. Considering the indirect effect of perceived naturalness on perceived stress and the importance of relaxation experiences, current findings suggest that research should put greater emphasis on examining the specific psychological mechanisms of green exercise to make even better use of its beneficial effects in the future.

Keywords: green exercise, stress regulation, ecological momentary assessment, restorative experiences, natural environment

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INTRODUCTION

Work is consistently being reported to be one of the main sources of stress in daily life (American Psychological Association, 2019). In Switzerland, 29.6% of all employees felt stressed at work in the year 2020. Just like in other Western nations, this number has increased over the last six years (Galliker et al., 2020; Health Safety Executive, 2020). This development is worrying, as numerous meta-analyses and reviews show that a high number of job stressors (e.g., high workload, intrapersonal conflicts) often lead to illnesses and poor mental well-being, particularly when job stressors persist over longer periods of time (Crawford et al., 2010; Nixon et al., 2011; Law et al., 2020). These negative impacts of job stressors can be reduced with recovery activities during non-working time (Sonnentag, 2018a). Physical activity (PA) has been shown to be a very effective recovery activity (see for a summary Sonnentag, 2018b), with about 60% of adults reporting that they exercise and do sports to reduce stress (Schmid et al., 2018). However, little is known about which settings or what types of activities are particularly effective (Klaperski et al., 2019).

In the past decades, there has been growing research interest in PA in natural environment, so-called "green exercise." It is hypothesized that direct exposure to nature (e.g., in parks, forests or by lakes) increases the positive effects PA has on mental well-being (Pretty, 2004). While a narrative review from 2011 found that green exercise produced a more favorable impact on mental well-being when compared to indoor exercise (Thompson Coon et al., 2011), more recent reviews show little or no added value (Lahart et al., 2019; Mnich et al., 2019). Overall, existing evidence is still limited and characterized by the heterogeneity of studies. Authors have identified several research gaps that need to be addressed.

A first important issue that future research should investigate are the underlying mechanisms of green exercise (Mnich et al., 2019). If we know which factors may promote mental well-being, they can be better targeted in studies and health promotion programs. Various theories in the field of environmental psychology have been proposed to explain the potential effect of nature, with the Stress Recovery Theory (SRT; Ulrich, 1983) and the Attention Restoration Theory (ART; Kaplan and Kaplan, 1989) being particularly prominent. SRT assumes that humans are programmed to react emotionally positively to natural settings and elements because these settings and elements are evolutionarily associated with safety and survival. This in turn, should reduce or buffer stress. Whereas, SRT focusses on affective benefits that may derive from nature, ART focusses on cognitive benefits. ART assumes that nature provides stimuli that attract involuntary, automatic attention. This effortless mode of attention allows individuals to recover from mental fatigue which occurs after performing cognitive tasks that require directed attention. Both theories highlight the negative impact of stress and suggest that nature-rich places are more likely to facilitate restoration or recovery experiences than built or urban environment (Joye and Dewitte, 2018). However, the theories differ with regard to the specific experiences they consider to be key in positively affecting mental well-being. Kaplan and Kaplan (1989) suggest, as asserted by their ART, that natural environments need to create a sense of "being away" to have a recovery effect. Concerning the SRT, Ulrich et al. (1991, p. 226) assume that natural settings generate a "mild, eyes-open form of relaxation response or wakeful, meditation-like state," which leads to their stress reducing effect. While there is only limited evidence on the role of these specific experiences of "being away" and relaxation in green exercise research, there has been a lot of research examining these concepts in the field of occupational health psychology: Sonnentag and Fritz (2007) identified psychological detachment and relaxation as two crucial experiences during off-job time that promote recovery from daily stressors at work.

Psychological detachment refers to the experience of "switching off." It is characterized by being physically away from the workplace (i.e., one does not engage in any work-related activities) and by mentally disengaging from work during leisure time (i.e., one does not think about work in one's free time). In contrast, relaxation refers to the positively-toned state of low activation (Sonnentag and Fritz, 2007). Meta-analytic evidence shows that both recovery experiences are associated with better mental well-being on a day-to-day level (Bennett et al., 2018). Consequently, it seems reasonable to hypothesize that psychological detachment and relaxation mediate the potential effect of green exercise on mental well-being by reducing the effects of stress. Yet only a few studies provide insights into this research topic to this day. For instance, Feuerhahn et al. (2014) demonstrated that the relation between PA and positive affect in the evening was explained by psychological detachment. However, in this study the natural environment of PA was not considered. Furthermore, Korpela et al. (2014) showed that the link between nature-based outdoor activities and well-being was mediated by a global measure of recovery experiences. Yet again, these research findings have limited transferability, because the study did not focus specifically on PA and detachment or relaxation. To the best of our knowledge, no study has yet examined the relationship between PA in a natural environment, psychological detachment, relaxation and perceived stress.

A second issue in existing green exercise research is that studies on short-term effects and mechanisms often use only a single bout of exercise, mainly being walking or running, and mostly in artificial laboratory conditions (Lahart et al., 2019; Mnich et al., 2019). Here, an ecological momentary assessment approach (EMA) may offer promising new insights. In EMA studies, features are measured immediately and multiple times in real-life situations, often by using smartphones (Dunton, 2017). Measuring features in real-life situations has the advantage that recovery experiences can be recorded as close as possible to the actual activity under natural conditions. The repeated measurements furthermore allow for the study of both intra-individual variations (within-person level) and inter-individual variations (between-person level). This is important, as the mechanisms of green exercise on mental well-being can be different depending on which level is being examined. For example, a negative association between psychological detachment and perceived stress after PA on the within-person level would mean that a given individual in different PA bouts experienced less stress if the activity allowed for

distance from work. In contrast, the same negative link on the between-level would indicate that individuals who experienced a higher level of psychological detachment during PA on average would report lower stress levels afterwards. If the decomposition of within-person and between-person effects were ignored and only between-person effects were considered, an improper generalization of between-person effects could occur. The between-person relationship would be inappropriately generalized to intra-individual relationships between natural environment of PA, recovery experiences and perceived stress. Thus, if both levels of analysis are taken into account, the risk of results being misinterpreted can be minimized. The fact that this has rarely been done in existing studies might be one reason for the inconsistent findings in green exercise research (Thompson Coon et al., 2011; Lahart et al., 2019; Mnich et al., 2019).

Thus, the aim of this study is to examine whether the potential relationship between PA in a natural environment and perceived stress is mediated by recovery experiences, specifically by psychological detachment and relaxation. While recovery experiences in previous studies in this area were recorded retrospectively (e.g., in the evening, Feuerhahn et al., 2014) or in a general manner (Korpela et al., 2014), the present research will use an EMA approach and assess specific recovery experiences directly in the scenario and across multiple bouts of PA in a sample of Swiss working adults. A working population will be examined because work is a main source of stress and to test the role of psychological detachment from work. The present findings have the potential to optimize exercise recommendations to achieve the most beneficial health effects.

METHODS

Sample

Inclusion criteria for the study were that participants worked at least 80%, were fluent in German, that they were between 20 and 59 years of age and that they engaged in exercise and sport activities sporadically or regularly (at least once a week). Furthermore, individuals were excluded if they were obese (BMI $\geq$ 30), because body weight might influence (recovery) experiences during PA and should consequently be controlled for (Toft and Uhrenfeldt, 2015). Finally, top athletes were excluded from the study, because the study focused on non-competitive PA behavior. Participant recruitment took place via the health management of more than 20 different service companies in the sectors credit/insurance or information/communication and through personal contacts of study assistants. The final sample consists of 62 individuals, of which 56.5% were female. The average age was $M = 32.30$ years ($SD = 10.23$, range: 22–59 years). Fifty Three percent of participants indicated having a degree from a university or a university of applied science as their highest level of education. The average full-time equivalent participants worked was 95.4%. 35.5% of the participants held a leadership position. Eighty percent of the participants did not have children. 8.1% of the participants reported at the beginning of the study that they habitually exercised <75 min per week and 91.9% exercised 75 min per week or more.

Study Design and Procedure

Participants who met the inclusion criteria and who were interested in participating in the study were individually invited to a face-to-face meeting or a phone call. There, they received information about the study goals and procedure. All participants gave their written informed consent and were free to decline participation. Afterwards, study assistants handed out a smartphone (Motorola Moto G5) on which the app "movisensXS" (Movisens GmbH, Karlsruhe, Germany) was installed. With this app, questionnaires can be implemented offline and from anywhere. All participants received detailed verbal instructions on how to answer the questionnaires in the app and answered sample items to become familiar with the app.

Basic sociodemographic information (e.g., age) was gathered via questionnaires before starting the EMA procedure. The EMA procedure for each participant lasted 7 days and took place sometime between the beginning of August and the end of October 2020. If participants were involved in PA lasting at least 10 min on a given day, they had to answer questionnaires on the smartphone both prior to the activity and afterwards (see **Figure 1**). It was emphasized that they needed to fill in the questionnaires as close in time to the PA session as possible (e.g., before showering or changing) and that they should not change their PA behavior because of the study. All participants received a definition of leisure-time PA to make clear when they had to complete the questionnaires (Fuchs et al., 2015).

As compensation, participants received a voucher for a swiss supermarket worth 35 Swiss francs (20 CHF for participation and another 15 CHF for completing seven days). In addition, they received individual feedback on their PA behavior (a summary of their weekly exercise volume and estimated energy consumption) after finishing the study. The Ethics Committee of the University of Bern's Faculty of Human Sciences approved the study.

Measures

Mode and Type of Physical Activity

The mode of PA was assessed after PA using the classification schema of Strath et al. (2013). Participants were asked to indicate whether they had just engaged in (a) exercise or sport in leisure time, (b) physical activity for transport, (c) domestic physical activity, (d) occupational physical activity, or (e) others. Furthermore, individuals had to name the type of PA (e.g., jogging, cycling).

Perceived Naturalness

Naturalness was assessed after PA using a visual analog scale by Mackay and Neill (2010). In their quasi-experimental study, they found a negative association between perceived naturalness and post-exercise anxiety, which supports the validity of the scale (see also Klaperski et al., 2019). In the visual analog scale, participants had to indicate the PA environment's degree of naturalness. The scale ranged from 0 *"artificial/urban"* to 100 *"natural."* A skyline

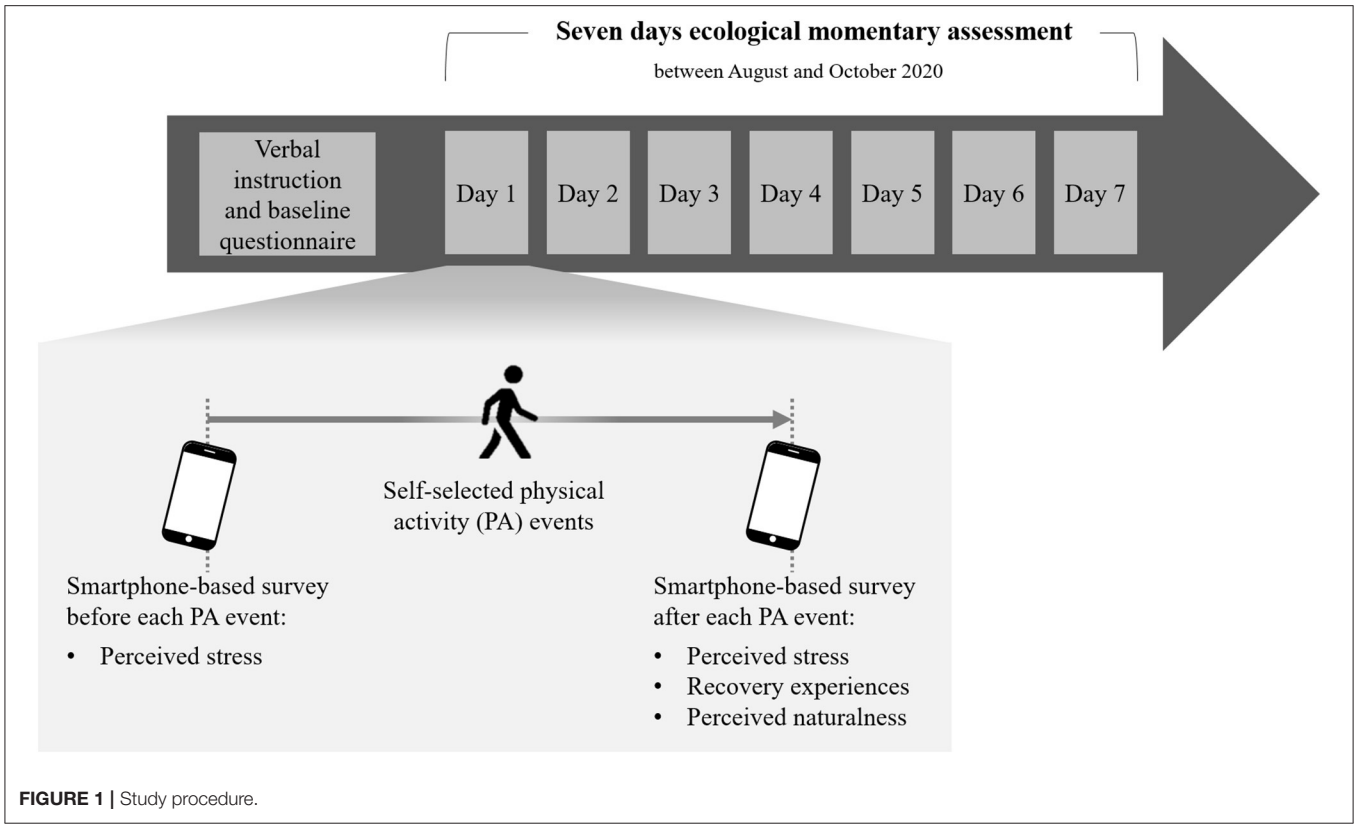

FIGURE 1 | Study procedure.

icon was shown at the artificial end of the scale and a forest icon was shown at the natural end of the scale.

Recovery Experiences During PA: Psychological Detachment and Relaxation

Psychological detachment and relaxation were assessed after PA with an adapted version of the recovery experience questionnaire (REQ) by Sonnentag and Fritz (2007). In the original REQ people are asked to rate recovery experiences in a general manner (item stem: "In my leisure-time…"). In order to capture recovery experiences situationally and with regard to PA, the original item stem was adapted to "During the PA event I have just carried out… " Of the original four items per subscale, those two were selected which had the highest loadings in the factor analysis (Sonnentag and Fritz, 2007; Chawla et al., 2020) and which simultaneously seemed appropriate in the PA context. Example items include "I forgot about work" (psychological detachment) and "I kicked back and relaxed" (relaxation). The response format was a 5-point scale from one *"I do not agree at all"* to 5 *"I fully agree."* The internal consistency of the subscales was rated satisfactory to good (psychological detachment: $r_{\text{within}-\text{person level}} = 0.77$; $r_{\text{between}-\text{person level}} = 0.98$; relaxation: $r_{\text{within}-\text{person level}} = 0.52$; $r_{\text{between}-\text{person level}} = 0.73$).

Perceived Stress

Perceived stress was assessed before and after PA with a visual analog scale widely used in research and clinical practice (Lesage et al., 2012). Existing studies have demonstrated its good reliability and sensitivity for assessing perceived stress caused by acutely distressing events. Furthermore, medium to high correlations with other stress questionnaires support the validity of the scale (Lesage et al., 2012). Participants had to indicate how stressed they felt at that moment. The response scale ranged from 0 *"not stressed"* to 100 *"very stressed."*

Data Preparation and Analysis

For the analyses, only sport and exercise activities in leisure time (e.g., hiking, soccer, yoga) and transportation related activities (e.g., walking or cycling to work) were considered. We excluded occupational PA, because the present study focuses on non-work PA experiences. Furthermore, we excluded physically demanding off-job duties, such as cleaning, as research shows that they often deplete resources and consequently should not be associated with recovery experiences (Ginoux et al., 2021). A two-level mediation analysis was applied, which allows for the consideration of the hierarchical structure of the data. The multiple measures of naturalness, recovery experiences during PA and perceived stress define the lower level of the hierarchy (level 1). These components were nested within the subjects that defined the higher level of the hierarchy (level 2). Based on theoretical considerations and empirical findings, the model was controlled for perceived stress before PA (Bennett et al., 2018; Sonnentag, 2018a). In total, 62 participants engaged in 423 PA events. The analysis was done with MLmed, a SPSS macro

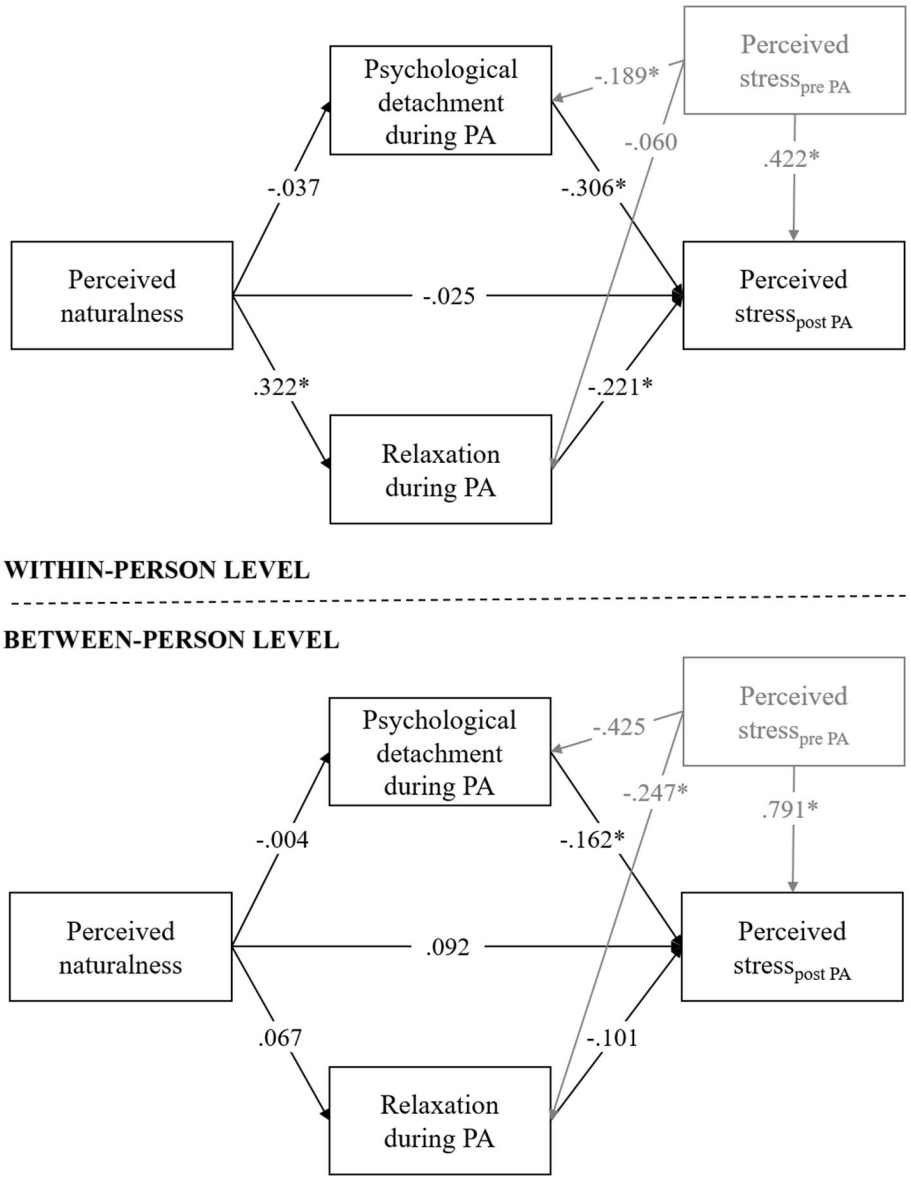

FIGURE 2 | Results of the two-level mediation analysis. All reported regression coefficients (*, $p < 0.05$) are standardized estimates. For a better overview, control variables are shown in gray.

by Hayes and Rockwood (2020). A random-intercept-random-slope model[1] was calculated and estimated using a full maximum likelihood method. Indirect effects were tested for significance using Monte Carlo confidence intervals. All variables were centered around the group mean. The alpha level of the tests was set to $p < 0.05$.

At the beginning, the entire data set was checked for multivariate outliers with Mahalonobis distance ($\chi 2$ at $p < 0.001$; Tabachnick and Fidell, 2013). This led to three PA events being removed from the dataset. The proportion of missing values was 15% (392 of total 2,569 data points). However, as Little's test (Little and Rubin, 2020) was not significant, it could be assumed that values are missing completely at random ($\chi 2$ (30) = 27.83, p = 0.580). Consequently, missing values were imputed using the expectation-maximation algorithm (Tabachnick and Fidell, 2013).

RESULTS

Descriptive Analysis

Data analyses are based on 420 PA events of 62 people. On average, 6.82 PA events per person were taken into account (SD = 3.99, range: 2–22). Fifty five percent were exercise

[1]Although slopes were principally specified as random effects in the model, four paths had to be fixed due to estimation problems. This applied to the following paths: relaxation → $\text{stress}_{\text{postPA}}$; naturalness → relaxation; $\text{stress}_{\text{prePA}}$ → relaxation (see **Figure 2**).

TABLE 1 | Descriptives of the study variables: Intraclass correlation coefficients (ICC), means *(M)*, variances (σ^2) and correlations (*$p < 0.05$).

Variables [range]	ICC	Between-person level						Within-person level				
		M	σ^2	Correlations				σ^2	Correlations			
				2.	3.	4.	5.		2.	3.	4.	5.
1. Perceived naturalness [1–100]	0.361	49.86	1412.26	−0.27	−0.14	0.17	0.07	718.80	−0.21*	−0.18*	−0.02	0.34*
2. Perceived $stress_{prePA}$ [1–100]	0.369	25.88	170.38	–	0.94*	−0.46*	−0.19	279.58	–	0.52*	−0.20*	−0.13*
3. Perceived $stress_{postPA}$ [1–100]	0.425	18.77	131.74	–	–	−0.57*	−0.34*	184.73	–	–	−0.48*	−0.39*
4. Psychological detachment during PA [1–5]	0.261	3.96	0.28	–	–	–	0.56*	0.78	–	–	–	0.38*
5. Relaxation during PA [1–5]	0.332	3.26	0.34	–	–	–	–	0.34	–	–	–	–

and sport activities, such as running or playing football. Fourty five percent were daily activities for transport, such as cycling to work or walking to the grocery store. The average duration of one PA event was 64.21 min ($SD = 59.76$, range: 10 min−420 min).

An overview of the descriptive statistics can be found in **Table 1**. To see whether study variables varied within individuals across recorded PA events, intra-class correlation coefficients needed to be subtracted from one. Values show that within-person variation of the recovery experiences and perceived naturalness were moderate to high (naturalness: 64%, relaxation: 67%, psychological detachment: 73%). Within-person variation of perceived stress after PA engagement (58%) was slightly lower than before engagement in PA (63%).

Two-Level Mediation Model

Figure 2 and **Table 2** show that the relationships between the study variables differed depending on the level of the model: At the within-person level, perceived naturalness was positively associated with relaxation ($\beta = 0.322$, $p < 0.0005$) but not with psychological detachment. This result indicates that the more natural a given person perceived the environment during multiple sessions of PA, the more he or she relaxed. In contrast, at the between-person level, perceived naturalness was not associated with either recovery experience. Additionally, at the within-person level, both psychological detachment ($\beta = -0.306$, $p < 0.0005$) and relaxation during PA ($\beta = -0.221$, $p < 0.0005$) were negatively linked with perceived stress after PA. This means that the more a given individual distanced from work or the more he/she relaxed during multiple sessions of PA, the less stress he or she perceived. On a between-person level, however, only psychological detachment was negatively associated with perceived stress after PA ($\beta = -0.162$, $p = 0.018$): Individuals who on average experienced a higher level of detachment during PA perceived less stress after PA.

Both on the within person- and the between person-levels, no evidence for direct effects were found from perceived naturalness on perceived stress after PA. However, the within person-level model revealed a small indirect effect between perceived naturalness and perceived stress after PA via relaxation. This indirect path reached statistical significance ($\beta = -0.07$, $B = -0.04$ [CI 95%: −0.059; −0.018]), while the other indirect pathway did not.

DISCUSSION

The present study aimed to investigate whether the relationship between perceived naturalness and perceived stress after PA was mediated by specific recovery experiences. This research expands upon previous studies by examining a potential psychological mechanism of green exercise. By investigating psychological detachment and relaxation, we focused on two recovery experiences that have previously only been vaguely addressed in prominent theories in the field of green exercise (Ulrich, 1983; Kaplan and Kaplan, 1989), but that have been intensively researched in occupational health psychology (Bennett et al., 2018). In the present research, self-reports were collected multiple times from individuals, proximal to the time and place PA occurred. Such an EMA approach has recently been identified as promising for future green exercise research (Mnich et al., 2019), because it more likely captures phenomena that vary over time or space compared to traditional cross-sectional, retrospective and summary methods.

As hypothesized, the relaxation as a recovery experience served as mediator in this study, but only on a within-person level. The more natural a given individual rated the PA setting, the more relaxed he or she felt during PA. In turn, the more relaxed the individual was, the less stress he or she perceived after PA. However, in contrast to our assumptions, psychological detachment did not serve as mediator, neither at the within- nor the between-person levels. Overall, the study shows that the associations between the study variables was different depending on which level of analysis was being considered. An indirect effect of perceived naturalness on perceived stress after PA via

TABLE 2 | Results of the two-level mediation analysis: unstandardized regression coefficients (*, $p < 0.05$), standard errors (SE) with lower and upper bounds of the convidence interval.

Paths	*B*	*SE*	*t*	*p*	*Lower bound*	*Upper bound*
Perceived $stress_{postPA}$ intercept	18.84*	6.13	3.07	<0.0005	6.56	31.11
Psychological detachment intercept	4.41*	0.25	17.54	<0.0005	3.91	4.91
Relaxation intercept	3.44*	0.17	20.67	<0.0005	3.12	3.77
Within-person level						
Perceived naturalness → Perceived $stress_{postPA}$	−0.01	0.02	−0.55	0.59	−0.06	0.03
Perceived naturalness → Psychological detachment	0.00	0.00	−0.57	0.57	−0.01	0.00
Psychological detachment → Perceived $stress_{postPA}$	−4.72*	0.77	−6.15	<0.0005	−6.27	−3.17
Perceived naturalness→ Relaxation	0.01*	0.00	5.08	<0.0005	0.01	0.01
Relaxation → Perceived $stress_{postPA}$	−3.61*	0.75	−4.82	<0.0005	−5.09	−2.14
Perceived $stress_{prePA}$ → Perceived $stress_{postPA}$	0.34*	0.04	8.43	<0.0005	0.26	0.43
Perceived $stress_{prePA}$ → Psychological detachment	−0.01*	0.00	−3.35	<0.0005	−0.02	0.00
Perceived $stress_{prePA}$ → Relaxation	0.00	0.00	−0.95	0.34	−0.01	0.00
Between-person level						
Perceived naturalness → Perceived $stress_{postPA}$	0.05	0.03	1.60	0.11	−0.01	0.12
Perceived naturalness → Psychological detachment	0.00	0.00	−0.03	0.97	−0.01	0.01
Psychological detachment → Perceived $stress_{postPA}$	−3.52*	1.38	−2.56	0.01	−6.27	−0.77
Perceived naturalness→ Relaxation	0.00	0.00	0.87	0.38	0.00	0.01
Relaxation → Perceived $stress_{postPA}$	−1.98	1.21	−1.64	0.11	−4.39	0.43
Perceived $stress_{prePA}$ → Perceived $stress_{postPA}$	0.70*	0.05	12.72	<0.0005	0.59	0.80
Perceived $stress_{prePA}$ → Psychological detachment	−0.02*	0.01	−3.29	<0.0005	−0.03	−0.01
Perceived $stress_{prePA}$ → Relaxation	−0.01*	0.00	−3.33	<0.0005	−0.02	0.00

relaxation could only be observed on a within-person level, where multiple PA events are considered as experienced within an individual. Thus, it seems to be a situational mechanism rather than a general one.

Our study results did not support Kaplan and Kaplan's (1989) assumption that vegetation-rich settings create a sense of "being away," which mediates the effect of naturalness on well-being. In line with the meta-analytic findings of Bennett et al. (2018), psychological detachment was associated with low stress after PA. However, psychological detachment was not linked to the naturalness of the environment of PA at either level of analysis. This finding might merely imply that the engagement in PA behavior is relevant to achieve detachment from work (Feuerhahn et al., 2014), and that there is no additional gain from a vegetation-rich environment. This would mean that taking an active "time-out" from work is in itself sufficient to recover from stress, a conclusion which has also been drawn in previous studies (Bahrke and Morgan, 1978). It is also possible that it is not necessarily the PA *setting* that influences psychological detachment, but rather more so the activity *type*. Fuchs and Klaperski (2018), for instance, suggest that activities which require being in the "here and now" as well as a deep involvement in the current action (e.g., climbing or game sports) prevent rumination or worry about hassles and therefore allow for mental distance from work. This assumption is supported by a recent quasi-experimental study in which it was demonstrated that bouldering facilitated mindfulness (e.g., being present) more when compared to a fitness training session (Wheatley, 2021).

Limitations and Future Directions

There are some limitations in this study that can lead to future research opportunities. Firstly, participants were mostly active, middle-aged and well-educated workers from the service sector. This relatively homogeneous sample limits the generalizability of the findings. Future research should explore whether the psychological mechanism observed in this study also appears in other occupational groups and professional contexts (Sonnentag et al., 2017). For instance, it can be assumed that people with physically demanding outdoor jobs (e.g., gardeners) experience less relaxation during leisure time PA in a natural environment than people with more cognitively demanding indoor jobs (e.g., administrative employees). Assessing different types of pre- and post-exercise recovery states and detachment (e.g., emotional, cognitive, or physical) could shed more light on these type of matching questions (see also Balk et al., 2017). Secondly, this study focused on perceived stress as an important determinant for well-being, yet well-being itself was not assessed. Although the amount of perceived stress seems to be particularly relevant in the work setting, future studies may assess affective well-being based on a dimensional approach (e.g., vigor and fatigue; Bennett et al., 2018). This would make it easier to compare the findings with existing research from the field of green exercise and occupational health psychology. Thirdly, the present research was limited to two specific recovery experiences as mediators. Psychological detachment and relaxation were chosen based on key assumptions of the ART, SRT (Ulrich, 1983; Kaplan and Kaplan, 1989) and on existing research in the field

of occupational health psychology (Sonnentag and Fritz, 2007; Bennett et al., 2018). However, future research should investigate the impact of further mediators, but also moderators. An additional mediator might be, for example, "mind wandering." Mind wandering is defined as thinking unrelated to the ongoing task (Smallwood and Schooler, 2015) and mentally moving hither and thither without a fixed course or certain aim (Christoff et al., 2016). One can hypothesize that subtly fascinating natural environments (e.g., clouds) support mind wandering (Kaplan and Kaplan, 1989; Williams et al., 2018) and this in turn reduces stress (Miś and Kowalczyk, 2020). Potential moderators may be an individual's habitual environment, and representations and expectations of green exercise. A person who lives and works in an urban neighborhood could experience physical exercise in green surroundings as well as the naturalness of an environment differently than a person living and working in a rural environment. Green exercise could be experienced as a strong contrast and therefore enhance the effect of PA on stress, possibly also based on neurological differences (e.g., Lederbogen et al., 2011). Furthermore, an individual's goals for PA (e.g., Schmid et al., 2018) could be considered as possible moderators, as studies showed that such motivational aspects influence the effect of PA on affective well-being (e.g., Jeckel and Sudeck, 2018). Fourthly, data collection in this study took place over three months. While some participants took part during more summer-like weather conditions in August, other participants had more fall-like conditions in October. These different seasons (different temperatures, colors) may have influenced the findings. In line with this, Bloom et al. (2017) found that the experience of detachment and relaxation during a park walk differed in spring and fall. Fifth, the present analyses are based solely on self-reported data. Ideally, future studies should assess leisure-time PA and its natural environment in an objective way (e.g., with accelerometers and portable global positioning system data). Such complementary analyses might help to get a deeper understanding of PA's impact on stress and recovery. Finally, it cannot be ruled out that the measure of perceived stress before PA was already influenced by natural settings. It is possible, for example, that people were already impacted by rich vegetation while being on their way to green space. Research shows that even a short view of natural elements can provide psychological benefits (Lee et al., 2015).

CONCLUSION

This study provides new insights into the psychological mechanisms which might underlie the positive effects green exercise has on stress levels and mental well-being. It shows that being active in natural settings further increases the benefits of PA on perceived stress, by altering relaxation on a within-person level. Thus, being active within a vegetation-rich environment may be an effective way to calm down. Overall, the current findings suggest that research should put greater emphasis on examining the specific psychological mechanisms of green exercise to make even better use of its beneficial effects in the future. Furthermore, result patterns highlight the importance of using a multilevel approach in green exercise research.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethics Committee of the University of Bern's Faculty of Human Sciences. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JS, SK, and GS contributed to the conception and design of the study. JS and LI acquired the data. JS and LI performed statistical analysis. JS wrote and drafted the manuscript. JS, LI, SK, and GS contributed to data analysis and interpretation. JS, LI, SK, and GS critically reviewed initial versions of the manuscript. All authors revised the manuscript critically for important intellectual content, as well as read and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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Does *Becoming* Fit Mean *Feeling* (f)it? A Comparison of Physiological and Experiential Fitness Data From the iReAct Study

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Regular exercise fosters fitness-enhancing benefits. We assume that exercise interventions become successful and sustainable if physiological benefits of exercise are also subjectively perceivable. The goal of this study was to examine how young inactive adults *physiologically respond* to an exercise intervention and how those responses are *subjectively experienced*. Furthermore, we aimed to assess whether the sequence of two distinct endurance-based exercise modes has an impact on physiological and subjectively experienced physical fitness. Thirty-one young inactive adults were assessed for this substudy of the larger iReAct study. Participants were randomly assigned to a high-intensity interval training (HIIT) or a moderate-intensity continuous training (MICT) group for 6 weeks and subsequently switched groups for a second training period. Physiological fitness data was collected at baseline, follow-up I, and follow-up II using a graded cardiopulmonary exercise test. Subjectively reconstructed (i.e., retrospective constructions) experiences relating to physical fitness were assessed at follow-up II using a biographical mapping method. A repeated-measures one-way ANOVA on each training group was performed to see whether physiological and subjectively experienced fitness differed across training periods. The rate of change between all variables was calculated for the first and the second training period in order to compare the agreement between physiological and subjective fitness improvements. Participants increased their fitness across the intervention period both physiologically and subjectively. However, the rate of change depended on the sequence of the two training modes. While VO_{2max} increased significantly in both training periods in the MICT-HIIT sequence, a significant increase in VO_{2max} in the HIIT-MICT sequence was only observed in the HIIT period. Participants similarly perceived those increases subjectively in their exercise-related physical fitness, although they experienced a significant decrease in the second period of the HIIT-MICT sequence. For subjectively perceived physical fitness relating to everyday activities, significant increases were only observed for the first period of the MICT-HIIT sequence. Young inactive adults can improve both their physiological and their subjectively perceived fitness through regular exercise. However, exercise

modes and their sequence can make a substantial difference regarding measured and perceived physical fitness. Additionally, despite a favorable tendency toward HIIT over MICT, inter- and intra-individual variability, particularly in the subjective experiences of fitness, reiterates the necessity of individualized approaches to exercise.

Keywords: exercise, high-intensity interval training, moderate-intensity continuous training, physical fitness, physiology, subjective experience, interdisciplinary, mixed-methods

INTRODUCTION

Researchers have described exercise as a "polypill" acknowledging its positive impact on biopsychosocial health and the decisive role it has come to play in both prevention and therapy (Fiuza-Luces et al., 2013; Rebelo-Marques et al., 2018). While dose-response-effects of exercise on health and fitness are well-established on a physiological level (Maturana et al., 2020), it is less clear whether and to which extent individuals who exercise also *subjectively experience* those changes in their physical fitness over time.

While the health-enhancing benefits of regular physical activity (PA) and exercise are vastly documented (Rhodes et al., 2017; Warburton and Bredin, 2017), even the largest public health initiatives have so far been insufficiently successful in motivating people to meet internationally recommended minimum levels of regular activity, as indicated by studies on the prevalence of physical (in)activity (Hallal et al., 2012; Guthold et al., 2018). One reason might be a lack of knowledge about how physiological training effects of exercise correlate with the subjective experience of exercise. We assume that a successful and sustainable structured exercise training requires that the physiological benefits of exercise must also be subjectively perceivable. While several studies that assessed the relationship between actual (i.e., "objectively" measured) and perceived (i.e., self-reported) physical fitness report significant correlations particularly for cardiorespiratory fitness measures and self-perceptions of endurance and fitness (Germain and Hausenblas, 2006; Monroe et al., 2010), there are no studies that examine how *physiological adaptations* to an exercise intervention relate to *subjective perceptions* of these adaptations over time.

Given the lack of studies on the relationship between objectively measurable physiological adaptations and the subjective experience of exercise outcomes across an intervention period, interdisciplinary biopsychosocial approaches, which integrate physiological and experiential factors over time, are needed (John et al., 2020). In this regard, it is interesting to examine the processual question of whether improvements in physiological fitness make individuals actually feel fitter. Answering this question is highly relevant, because we assume that even a high degree of physiological responsiveness to training has a larger effect on the individual if this response is also subjectively palpable. Eventually, if individuals do not *feel* the progress of becoming fitter, this lack of a subjectively beneficial response might jeopardize a long-term exercise engagement.

In the search for optimal strategies to counteract a prevailing trend toward more sedentary and inactive lifestyles, a controversial discussion on the use of different exercise modes has evolved. One of the focus points in this debate is the role of high-intensity interval training (HIIT) as a viable option for public health strategies (Biddle and Batterham, 2015) as opposed, for example, to moderate-continuous training (MICT). In this regard, the physiological benefits and the time efficacy of HIIT are well-documented (Gibala et al., 2014; Biddle and Batterham, 2015; Maturana et al., 2020). Moreover, research on psychological and affective responses to HIIT have indicated that interval training might be as (Stork et al., 2017, 2018) or even more enjoyable or preferable than MICT (Jung et al., 2014; Stork et al., 2017). We can therefore assume that HIIT might trigger different physiological and psychological effects than MICT.

The goal of our paper is to assess how individuals *physiologically respond* to HIIT in comparison to MICT and how those responses are *subjectively experienced and perceived* over time. In addition, we think that prescribing different sequences of training modes (i.e., HIIT first and MICT second or vice versa), might lead to different subjective experiences of the same training mode, because participants can comparatively evaluate, which training mode they perceive to be more beneficial.

Against this background, we aim to answer the following questions:

1. How do physiological fitness and subjective experiences of fitness develop over the time of an exercise intervention?
2. Does the sequence of two distinct endurance-based exercise programs (i.e., HIIT-MICT vs. MICT-HIIT) have an impact on how physiological fitness and subjective experiences of feeling fit develop?
3. How do physiological adaptations to exercise relate to subjective experiences of fitness?

MATERIALS AND METHODS

Study Design and Setting

Our study is part of the *Individual Response to Physical Activity (iReAct)* project, which is a transdisciplinary research program that aims to assess individual responses to exercise in physically inactive young adults from an integrated biopsychosocial perspective (Thiel et al., 2020a). The project includes researchers from the fields of sport sociology, psychology, and medicine, as well as from biochemistry and psychosomatics and thus follows a multi-method approach. In this regard, one of the primary goals of the research program is to mesh objective and subjective data and therefore to provide a new perspective on the effectiveness of

exercise programs and to contribute to the discussion about the necessity of individualized approaches.

After approval by the "Ethics Committee of the Medical Faculty University Tübingen" (reference number: 882/2017BO1), participants were recruited via several means including the university and the university clinics mailing lists, an experimental database, newspaper articles, and flyers. In order to participate, interested parties had to…

- …be physically inactive (i.e., currently not meeting the WHO's recommendations for moderate physical activity of at least 150 min/week and exercising for <60 min/week and not regularly exercising for several weeks during the last 6 months).
- …be non-smokers.
- …have a BMI between 18.5 and 30.0 kg/m^2.
- …have a maximum oxygen uptake (VO_{2max}) between 25 and 50 mL/min/kg.
- …have no current or former eating disorder.
- …have no severe internistic or neurological previous illness.
- …be not pregnant or being breastfeeding.
- …be German native-speakers.

Inclusion and exclusion criteria were chosen to ensure that inactive, yet only healthy, young adults were included. Young adults were selected as they find themselves in a period of their life were PA levels usually tend to drop due to various life events and transitions (Corder et al., 2020; Gropper et al., 2020; Winpenny et al., 2020) and therefore present a potentially "vulnerable" group for physical inactivity. Moreover, we opted for a healthy sample for two reasons: (1) PA and exercise are highly relevant in the prevention of non-communicable diseases. In order to have a preventive effect exercise should ideally be taken up while people are still healthy. (2) Participants should be able to sustain the study protocol. In addition, the inclusion and exclusion criteria accounted for the variety of biopsychosocial assessment tools (including various questionnaires and interviews that were in German) that were used [for more information and the detailed recruitment process, please see Thiel et al. (2020a)]. All participants were informed of the experimental protocol and all associated risks prior to giving written informed consent and being included in the study. The study was designed as a 15-week, two-period sequential-training intervention in order to compare adaptive responses to two training modes (HIIT vs. MICT) and their different sequential order (MICT-HIIT vs. HIIT-MICT). Biopsychosocial assessments took place on 3 days at baseline (week 1), after the first training period (week 8), and after the second training period (week 15). After the baseline assessment, participants were randomly assigned based on VO_{2max} and sex to either the HIIT or the MICT group in the first training period and switched groups for the second period. Each training period lasted 6 weeks with three training sessions per week. For a detailed overview of the study timeline, please see **Figure 1**.

A total of 58 participants were assessed for eligibility, 49 of whom were included in the randomization process. After baseline measurements, 44 participants engaged into the exercise training intervention (HIIT-MICT $n = 22$ and MICT-HIIT $n = 22$). One female, who exhibited a BMI below the specified range was also included due to her normal percent body fat of 23.5 (normal range: 18–28%) as measured at baseline. During the first training period, two participants (one from each group) dropped-out during the exercise training intervention due to illness and not being able to complete the minimum adherence (i.e., 15 out of 18 sessions in each training period). A total of 42 participants (21 in each group) completed the first follow-up. During the second training period, a total of 9 participants (4 from the HIIT-MICT group, and 5 from the MICT-HIIT group) dropped-out because they were unable to complete the minimum adherence due to the lockdown imposed by COVID-19. Two participants were excluded *post-hoc* due to language issues (one from each group). Therefore, a total of 31 participants completed the full protocol: 16 participants in the HIIT-MICT group, and 15 participants in the MICT-HIIT group.

Exercise Training Intervention

HIIT and MICT were designed with the goal that both interventions would be matched by energy expenditure (Andreato, 2020). After careful consideration, we prescribed the following exercise training programs:

HIIT: the HIIT group performed 10 min of warm-up at the power output corresponding to 70% of their maximal heart rate (HR_{max}), followed by four 4-min intervals at the power output corresponding to 90% of their HR_{max}. Each high-intensity interval was interspersed with a 4-min active recovery at 30 W. After the last high-intensity interval a 5-min cool-down at 30 W was performed, totaling 43 min of exercise. The power output at each percentage of HR_{max} was derived from the heart rate-power output-relationship during the step incremental test performed at baseline (first training period) or the first follow-up (second training period). To account for the delay in the heart rate response to the increase in work rate in each step, the average of the last 30 s of each step was taken, and then plotted against power output, deriving the linear model used for the calculation. All of the exercise intensities associated with 90% of HR_{max} were greater than the intensity associated with the second lactate threshold (LTP2), confirming that such intensity was in the severe-intensity domain.

MICT: the MICT group performed 60 min of continuous cycling at the power output corresponding to 90% of the first lactate threshold (LTP1). LTP1 was analyzed as the first systematic increase in blood lactate concentration above baseline levels, and such exercise intensity was prescribed for participants to cycle within the moderate-intensity domain.

Training monitoring: all exercise training sessions were performed on a cycle ergometer (ec5000, custo med GmbH, Ottobrunn, Germany) and participants' heart rate and ECG were constantly monitored (3-channel ECG, custo med GmbH, Ottobrunn, Germany). After every training session, the exercise training data (i.e., second-by-second power output, cadence, and heart rate) was exported and stored for further processing. The heart rate data was cleaned using an anomaly detection algorithm to delete noisy data points. Each noisy data point was deleted, and the heart rate was then interpolated in a second-by-second basis. Once the training sessions of every week were completed

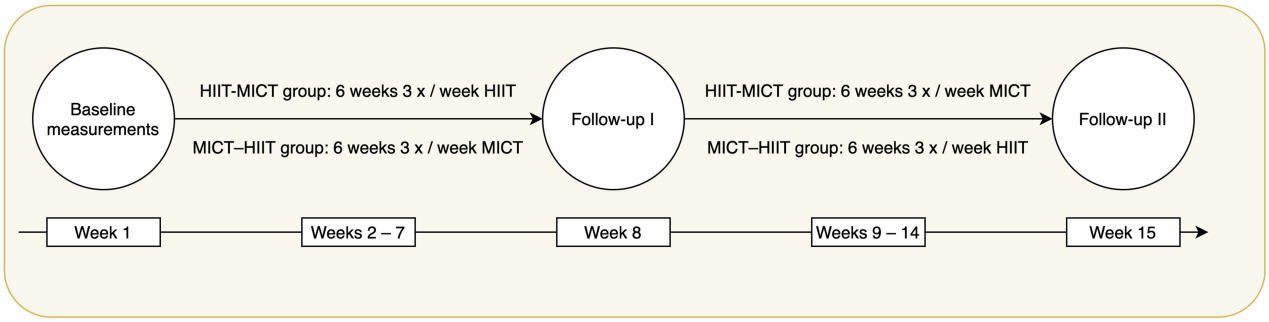

FIGURE 1 | Timeline and protocol of the iReAct study.

TABLE 1 | Participants' characteristics at baseline in each group.

	HIIT-MICT	MICT-HIIT	*p*-value
Age (yr)	26 ± 5	29 ± 6	$p = 0.127$
Height (cm)	171.0 ± 9.2	170.9 ± 8.6	$p = 0.991$
Weight (kg)	68.1 ± 12.2	71.0 ± 8.9	$p = 0.382$
Absolute VO_{2max} (L/min)	2.14 ± 0.48	2.15 ± 0.36	$p = 0.955$
Relative VO_{2max} (mL/kg/min)	31.5 ± 4.4	30.4 ± 4.3	$p = 0.417$
PO_{peak} (W)	162 ± 29	159 ± 21	$p = 0.685$
HR_{max} (bpm)	190 ± 10	191 ± 12	$p = 0.764$
SBP rest (mmHg)	117 ± 9	115 ± 9	$p = 0.645$
DBP rest (mmHg)	78 ± 6	77 ± 6	$p = 0.586$
SBP max (mmHg)	154 ± 14	150 ± 14	$p = 0.407$
DBP max (mmHg)	66 ± 9	65 ± 7	$p = 0.493$

VO_{2max}, maximal oxygen uptake; PO_{peak}, peak power output; HR_{max}, maximal heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure.

($n = 3$), the sessions were then ensembled-averaged and then averaged into 5-s bins. In this way, we retrieved one averaged dataset for each week. Thereafter, the weekly average response was compared with zones of smallest worthwhile difference around the prescribed heart rate [for further details, please see (Maturana et al., 2021)].

Minimum adherence: in order for participants to be included in the final analyses, a minimum of 15 out of the 18 prescribed exercise sessions in each training period had to be completed (minimum adherence = 83.3%).

Data Sources

In order to answer our research questions, mixed-method approaches are needed, as we aim to compare repeated measures of physiological and subjectively experienced fitness over time. The combination of physiological and experiential data allows painting a contextualized picture of an understudied phenomenon. In this regard, our analyses can reveal general biological developmental tendencies and relate them to subjective perceptions of this development.

Physiological Data

Physical fitness was tested at baseline, follow-up I, and follow-up II using a graded cardiopulmonary exercise test, where gas exchange and blood lactate concentration measures were taken. Fitness was defined via cardiorespiratory fitness (CRF) through VO_{2max}. After arrival in the laboratory, participants were directed to the room where anthropometrical measures were taken, which included height and weight (measured to the nearest 0.01 cm and 0.1 kg, respectively). Afterwards, participants undertook a step-incremental test to volitional exhaustion on a cycle ergometer (Ergoselect 200, Ergoline GmbH, Bitz, Germany) for determination of VO_{2max}, peak power output, and lactate thresholds (LTP1 and LTP2). Before starting the test, capillary blood lactate concentration ($[La^-]$) was measured. The test began with a 2-min resting period on the bike, followed by 25-W step increments every 3 min, starting at 50 W for males and at 25 W for females, until task failure. $[La^-]$ was analyzed (Biosen S-Line, EKF, Cardiff, UK) by collecting capillary blood samples (20 μL) from the right earlobe during the last 20 s of each stage and immediately after volitional exhaustion. Heart rate and ECG were constantly monitored throughout the test (12-channel PC ECG, custo med GmbH, Ottobrunn, Germany). Breath-by-breath pulmonary gas exchange and ventilation were measured using a metabolic cart (MetaLyzer, CORTEX Biophysics, Leipzig, Germany). Calibration was performed before each test following the manufacturer's instructions.

Experiential Data

At follow-up II, we assessed subjectively reconstructed (i.e., retrospective constructions) experiences of the intervention. This approach is rooted in constructivist biography-theoretical concepts (for an overview, please see Schubring et al., 2019). The basic assumption of these concepts is that an individual's judgement toward a given context or situation is informed by previous experiences and their reconstruction. In order to assess contextualized subjective experiences (e.g., in a specific exercise setting), we used a biographical mapping method. This method combines a narrative format with a drawing activity eliciting both qualitative and quantitative data on the subjectively reconstructed experiences and trajectories of 14 state and developmental variables that relate to physical activity,

exercise, and health (Schubring et al., 2019; Thiel et al., 2020b). For a detailed overview of the assessed variables, please see **Supplementary Table 1**.

The core feature of the biographical mapping is a two-dimensional coordinate system with a time axis (x-axis) that represents the time course of the intervention period and a perceived intensity scale (y-axis) from zero to ten. In a first step, participants were asked about any relevant life events that occurred over the 15 weeks of the training intervention. The interviewer wrote down those events on the time axis and encouraged participants to talk about everything they considered to be important with regard to the last weeks. To give the participants some temporal orientation all training sessions were already pre-registered (e.g., to see when trainings were missed or when the follow-up I diagnostic took place). Secondly, participants drew developmental curves for various variables including one for perceived exercise-related physical fitness (i.e., training status or athletic fitness) and one for perceived physical fitness in everyday life (i.e., general fitness for everyday activities). In this context, the y-scale of the coordinate system represented an intensity scale, where participants could indicate whether certain variables were experienced as very high (i.e., 10) or very low (i.e., zero) at different times over the last weeks. In a similar vein, participants could indicate how these experiences developed over time (e.g., stable trajectories, abrupt or gradual changes, linearity, etc.). The curves represent a quantified account of retrospective and subjective experiences and are complemented by verbal accounts. For the present study, however, we focused our analysis on the curve trajectories. For an exemplary biographical mapping, please see **Supplementary Figure 1**.

To collect data we used the bioMAP-software (Thiel et al., 2020c,d). During the mapping, the participants sat in front of a large touchscreen, on which they could draw the curve trajectories with a stylus. For each day of the intervention period, the software obtained one data point. The researcher sat right next to the participants with a separate monitor to follow up on what they were drawing. In addition, the participants gave their consent to audiotape the interviews. HG, who, afterwards, took field notes and filled in a protocol sheet, conducted all interviews.

Data Analysis

Analyzing Physiological Data

Breath-by-breath oxygen uptake (VO_2) data were edited as follows: breath data points that were outside the 95% of confidence interval from the local mean were considered outliers and then removed. Thereafter, the data was interpolated on a second-by-second basis and averaged into 30-s bins for VO_{2max} analysis (Mattioni Maturana et al., 2018; Martin-Rincon et al., 2019).

Maximal Values

VO_{2max} was considered as the highest 30-s VO_2 average. VO_{2max} attainment was confirmed if at least two of the following three criteria were met, as per the American College of Sports Medicine guidelines (American College of Sports Medicine et al., 2018): (i) maximal heart rate within 10 beats per minute (bpm) of the maximal predicted value (220–age); (ii) a respiratory exchange ratio (RER) higher than 1.10; or (iii) a maximal [La^-] of 8 $mmol \cdot L^{-1}$. Peak power output (PO_{peak}) was considered as the power output achieved at the moment of exhaustion and HR_{max} was considered as the maximal value achieved during the test.

LTP1 and LTP2

Lactate thresholds were analyzed using a segmented regression model at which two breakpoints were estimated from the [La^-]-power output relationship. LTP1 was determined as the first rise in [La^-] above baseline levels (first breakpoint), which is accompanied by the first systemic increase in the VE-VO_2 relationship (i.e., first ventilatory threshold). LTP2 was determined as the second abrupt increase in [La^-] (second breakpoint), which is accompanied by the second sharp increase in the VE-VO_2 relationship (i.e., second ventilatory threshold) (Binder et al., 2008; Hofmann and Tschakert, 2017). All these measures were analyzed as a function of power output, and then their corresponding VO_2 values were analyzed from the VO_2-power output relationship.

Statistical Analysis of Physiological and Experiential Fitness Trajectories

Normality (Shapiro-Wilk's test), homoscedasticy (Levene's test), and multicollinearity were checked when applicable. To calculate whether the continuous variables (i.e., VO_{2max}, perceived exercise-related physical fitness, and perceived physical fitness in everyday life) differed across training phases (i.e., baseline, follow-up I, and follow-up II), we performed a repeated-measures (within-subjects) one-way analysis of variance (ANOVA) on each training group (i.e., HIIT-MICT and MICT-HIIT). Effect sizes were calculated as the partial omega-squared, and multiple comparisons were adjusted by the Bonferroni correction. The alpha level was set at 0.05.

In order to compare and relate the changes in VO_{2max} to the changes in the subjective fitness levels (indicated by the biographical mapping curves for perceived exercise-related physical fitness and perceived physical fitness in everyday life), we calculated the slopes of the changes in each training period (i.e., from baseline to follow-up I and from follow-up I to follow-up II) and in each group (i.e., HIIT-MICT and MICT-HIIT). We then performed Pearson correlations, adjusted for multiple comparisons in each training phase. For the VO_{2max} slopes, a simple linear regression between two data points was performed (i.e., from baseline to follow-up I and from follow-up I to follow-up II). For the subjective fitness levels, since continuous data were obtained (i.e., one data point for each day during the training period), we performed a linear regression from the first until the last training day. Additionally, we performed a linear regression to calculate the rate of change in the subjectively perceived fitness levels in relation to the rate of change in VO_{2max}.

RESULTS

Data was collected from 31 participants (74% female) aged between 20 and 40 years ($M = 27$, $SD = 6$). For an overview of participants' characteristics at baseline in each group, please see **Table 1**. **Figures 2**, **3** display the inter- and intra-individual

variability in the subjectively perceived fitness measures over the course of each training period and group over the 6 weeks of training.

The repeated measures ANOVA for VO_{2max} (**Figure 4**) indicated a significant effect for both the HIIT-MICT $\{F_{(1.72, 25.75)} = 37.24, p < 0.001, \omega^2 = 0.07, 95\%\ CI = [0.00; 0.27]\}$ and MICT-HIIT groups $\{F_{(1.32, 18.45)} = 21.89, p < 0.001, \omega^2 = 0.09, 95\%\ CI = [0.00; 0.30]\}$. Pairwise *post-hoc* analyses showed a significant difference from baseline to follow-up I in the HIIT-MICT group after HIIT ($+ 16.0 \pm 7.3\%$, $p < 0.001$), but no significant differences were found from follow-up I to follow-up II (after MICT, $-0.02 \pm 7.3\%$). In the MICT-HIIT group, however, significant differences were found in both training phases—from baseline to follow-up I after MICT ($+7.7 \pm 8.8\%$, $p = 0.022$) and from follow-up I to follow-up II after HIIT ($+ 6.2 \pm 4.0\%$, $p < 0.001$).

The repeated measures ANOVA for perceived exercise-related physical fitness (**Figure 5**) showed similar results as VO_{2max}. The HIIT-MICT presented a significant main effect $\{F_{(1.50, 22.44)} = 31.27, p < 0.001, \omega^2 = 0.31, 95\%\ CI = [0.05; 0.52]\}$, with a significant increase from baseline to follow-up I after HIIT ($+ 204 \pm 505\%$, $p < 0.001$). Interestingly, a significant decrease from follow-up I to follow-up II after MICT was identified ($-10 \pm 16\%$, $p = 0.035$), while VO_{2max} did not change. The MICT-HIIT group also presented a significant main effect $\{F_{(1.55, 21.75)} = 31.27, p < 0.001, \omega^2 = 0.44, 95\%\ CI = [0.15; 0.63]\}$, with a significant increase in both training phases (MICT: $+ 154 \pm 283\%$, $p < 0.001$; HIIT: $+ 35 \pm 28\%$, $p < 0.001$).

For perceived physical fitness in everyday life (**Figure 6**), no significant effects were observed in the HIIT-MICT group $\{F_{(1.25, 18.72)} = 0.24, p = 0.68, \omega^2 = -0.02, 95\%\ CI = [0.00; 0.00]\}$. The MICT-HIIT group, however, showed a significant main effect $\{F_{(1.31, 18.41)} = 6.74, p = 0.013, \omega^2 = 0.08, 95\%\ CI = [0.00; 0.28]\}$. Pairwise *post-hoc* comparisons revealed a significant difference after MICT ($+ 59.7 \pm 158\%$, $p = 0.003$, from baseline to follow-up I), but not after HIIT ($+ 9.7 \pm 33.7\%$, $p > 0.05$, from follow-up I to follow-up II).

Figure 7 displays an integration of physiological and subjectively perceived fitness measures in two participants who are archetypical representatives of averaged developments.

A slope comparison between the values from baseline to follow-up I (first training period) and from follow-up I to follow-up II (second training period) was performed in order to analyze the association between VO_{2max} changes and changes in subjective fitness perceptions after training (**Figure 8**). A significant correlation was observed in the second training period for both the relationship between VO_{2max} and the perceived exercise-related physical fitness ($r = 0.5$, $p = 0.005$), and the relationship between VO_{2max} and the perceived physical fitness in everyday life ($r = 0.48$, $p = 0.01$). No significant correlations were observed during the first training period, indicating a different rate of change between the variables. However, the slope diagrams show a consistent pattern after the second training period, meaning that the correlation between VO_{2max} and subjective fitness (in both dimensions) was in most cases clearly higher in HIIT compared to MICT. Additionally, a slope comparison between the sequence of the training modes was performed (i.e., HIIT-MICT and MICT-HIIT) (**Figure 9**). A significant correlation was observed in the HIIT-MICT group for both the perceived exercise-related physical fitness ($r = 0.62$, $p < 0.001$) and perceived physical fitness in everyday life ($r = 0.37$, $p = 0.04$) with VO_{2max}. No significant correlations were observed in the MICT-HIIT group.

DISCUSSION

Dose-response effects of exercise on health and physical fitness are well-established on a physiological level (Fiuza-Luces et al., 2013, 2018; Milanović et al., 2015; Gomes-Neto et al., 2017; Maturana et al., 2020). What is less known is whether physiological adaptations to exercise that occur across the period of an intervention are subjectively experienced in a comparable way. PA (and hence exercise) has been deemed a "complex and multidimensional behavior" (Pettee Gabriel et al., 2012) that incorporates a multitude of correlates and determinants (Rhodes and Nigg, 2011; Bauman et al., 2012). In order to analyze the response to exercise appropriately, a more holistic, interdisciplinary, and biopsychosocial perspective is needed (John et al., 2020). In this sense, the aim of our study was to assess how individuals *physiologically respond* to exercise and how those responses are *subjectively experienced and perceived* over time. The underlying assumption of our study was that for exercise interventions to be successful and sustainable, physiological benefits, such as the improvement of physical fitness, must also be subjectively experienced as beneficial. By employing a mixed-methods approach, we set out to describe trends in the development of physiological and subjectively experienced fitness and to see how these two dimensions relate to each other.

Contributing to the ongoing discussion on the viability of HIIT for public health strategies from a different perspective (Biddle and Batterham, 2015), we compared the physiological and subjective fitness-related responses to two distinct endurance-based training programs (i.e., HIIT and MICT). In this regard, we also wanted to know whether the sequence of different training modes (i.e., HIIT-MICT and MICT-HIIT) has an impact on physiological and subjective fitness-related responses to training.

Our analyses have shown that VO_{2max} and perceived exercise-related physical fitness significantly improved both in the HIIT-MICT and the MICT-HIIT group indicating that inactive young adults can physiologically and subjectively benefit from a structured exercise intervention. In general, however, HIIT yielded greater effects for VO_{2max} than MICT, which is in line with recent research on healthy young to middle-aged adults (Milanović et al., 2015). The slope comparisons show that after the completion of the second training period, the correlation between subjective and physiological fitness is generally higher with regard to the HIIT mode. However, the sequence of training modes nevertheless had an impact on the physiological and subjective fitness outcomes. While the MICT-HIIT sequence was associated with continuous improvement in physiological fitness, the HIIT-MICT sequence was associated with increases only during the first training period. These results suggest that the

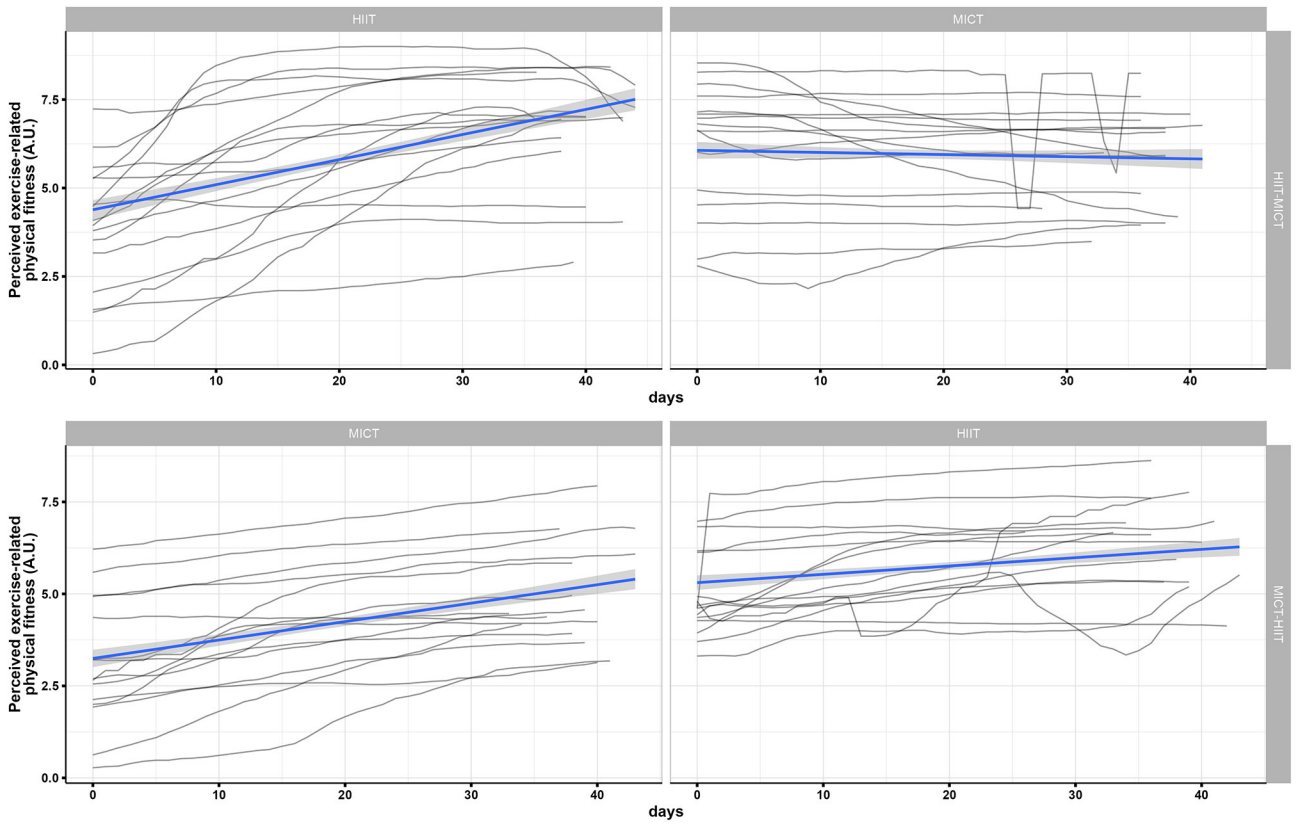

FIGURE 2 | Individual mapping trajectories and mean trajectory of perceived exercise-related physical fitness over the course of each training period and group.

sequence of training modes can have a substantial impact on the physiological response to exercise. MICT is a key training stimulus for long-term training (Bishop et al., 2019) and an important training mode in metabolic health (Maturana et al., 2020). However, the higher efficacy promoted by HIIT highlights the importance of controlling the exercise intensity for CRF improvements, at least in the short-term training (MacInnis et al., 2019). Similar tendencies were observed for perceived exercise-related fitness with a significant main effect for the HIIT-MICT group, as well as for the MICT-HIIT group. Interestingly, the MICT-HIIT group showed a significant increase in perceived exercise-related fitness across both training periods, while for the HIIT-MICT group we observed a significant increase only in the first training period. For the second training period in this group, we even found a statistically significant decrease in perceived exercise-related physical fitness. In our study, participants were not only physiologically untrained, but also the self-perceived levels of fitness tended to be in the lower half of the scale at the beginning of the exercise intervention. It is therefore not surprising that starting to exercise therefore yielded improvements in both physiological and perceived exercise-related physical fitness independent of exercise modality since for inactive or sedentary samples, even small increases in volume or intensity of PA can increase physical fitness (Maturana et al., 2021). The effects of HIIT were perceived as stronger, independent whether the group started with HIIT or MICT. For the group that started with MICT in the first training period, the subjectively perceived fitness-enhancing effects of the first training period increased further when they completed the physiologically more effective HIIT in the second training period. On the other hand, MICT is experienced as less effective regarding individual fitness enhancement, particularly if this training mode is performed after a physiologically and subjectively highly effective period of HIIT. Training moderately after having trained in orientation to a HIIT regime obviously has the effect that individual fitness is experienced even more negatively than the physiological situation actually has developed. Despite the reported developmental trends in VO_{2max} and perceived exercise-related physical fitness, regular exercise does not necessarily lead to a substantial increase in the subjective perception of physical fitness in everyday life. This may be because our sample consisted of inactive, yet young and healthy adults, who had no substantial physical impairments and thus were also able to participate in our exercise intervention. Accordingly, most participants rated their subjective fitness levels in everyday life in the upper half of the scale and generally showed little intra-individual variation over time.

In general, our results clearly show high degrees of variability within- and between-individuals in the subjective fitness parameters. Even though the metabolic stress imposed by each

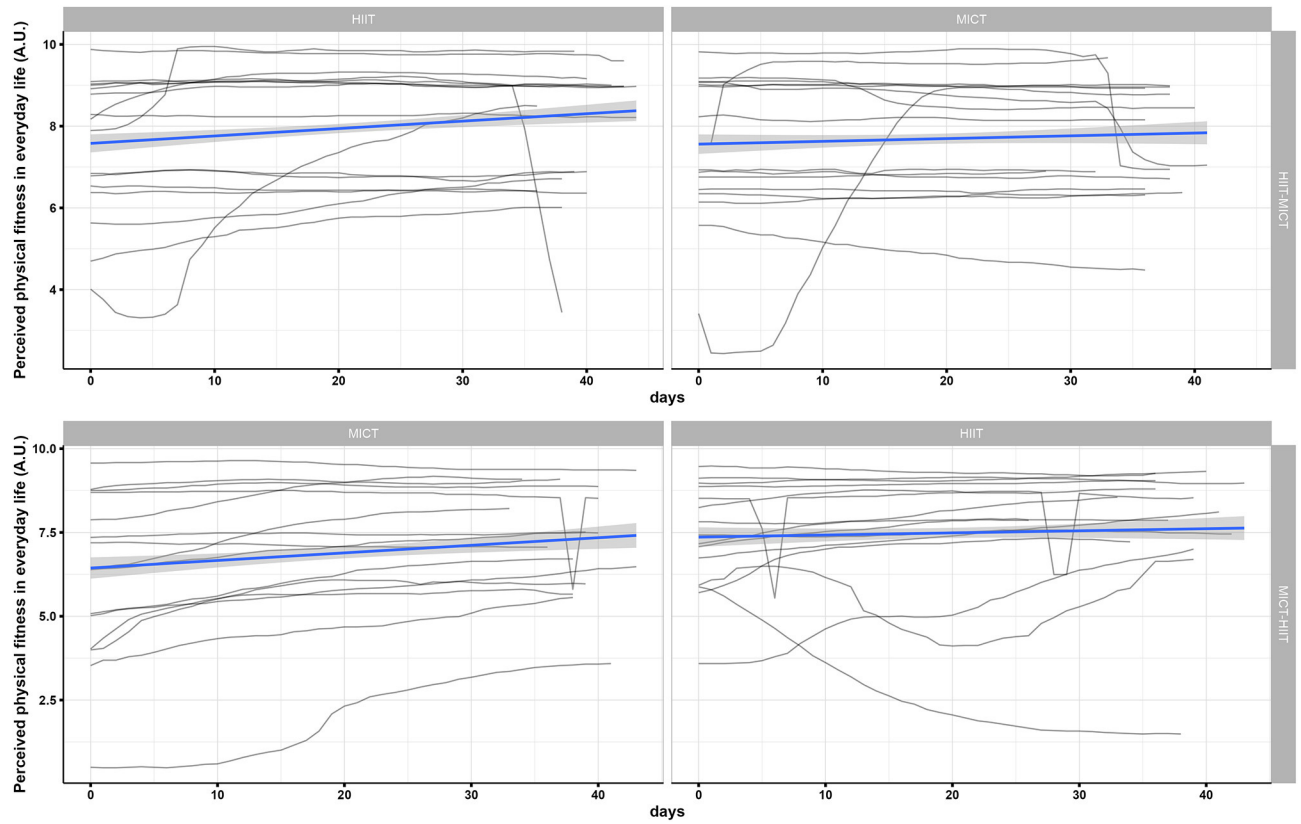

FIGURE 3 | Individual mapping trajectories and mean trajectory of perceived physical fitness in everyday life over the course of each training period and group.

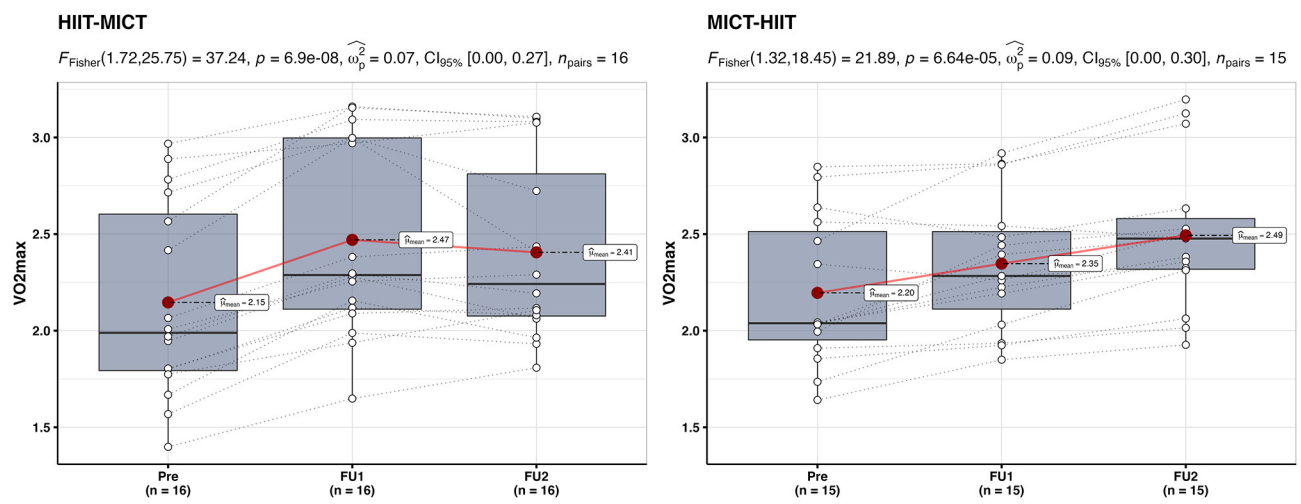

FIGURE 4 | Within-group between baseline (Pre), follow-up I (FU1), and follow-up II (FU2) in the HIIT-MICT and MICT-HIIT groups for VO_{2max}. Boxplots along with the individual data points are shown. The dotted lines connect the same participant, displaying the individual changes. The red dots display the average of each time point.

exercise training program was adjusted to be the same for all individuals (i.e., MICT was prescribed within the moderate-intensity domain and HIIT was prescribed within the severe-intensity domain), the perceived development of fitness showed to be heterogeneous.

When interpreting the results of our study, several strengths but also limitations should be considered. First, while there are intervention studies that use mixed-method approaches (with the qualitative assessments having a focus rather on attitudes toward PA and exercise than on physical fitness) this is, to our knowledge,

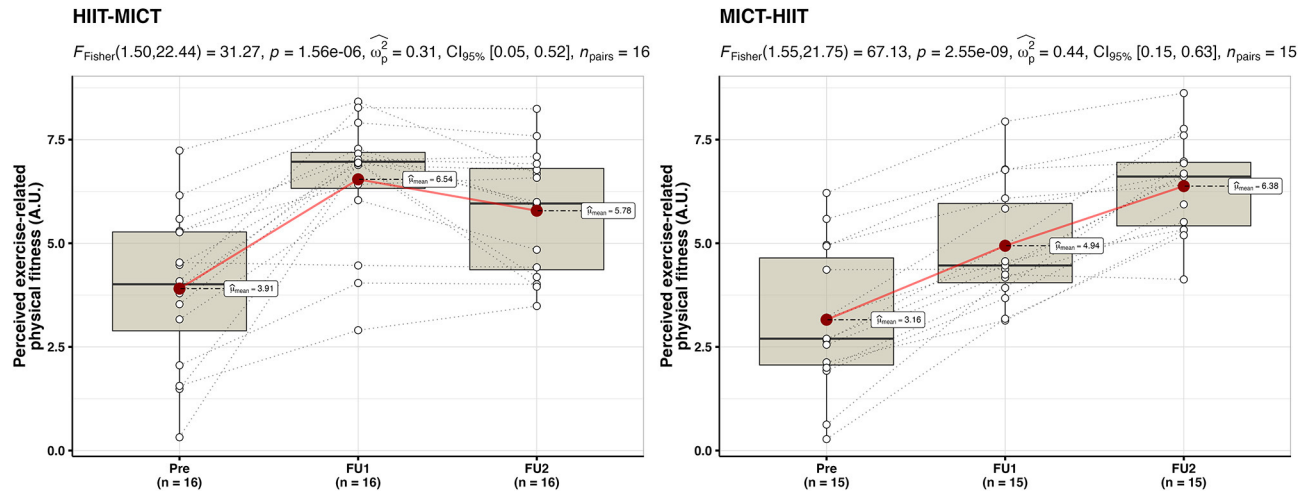

FIGURE 5 | Within-group between baseline (Pre), follow-up I (FU1), and follow-up II (FU2) in the HIIT-MICT and MICT-HIIT groups for perceived exercise-related physical fitness. Boxplots along with the individual data points are shown. The dotted lines connect the same participant, displaying the individual changes. The red dots display the average of each time point.

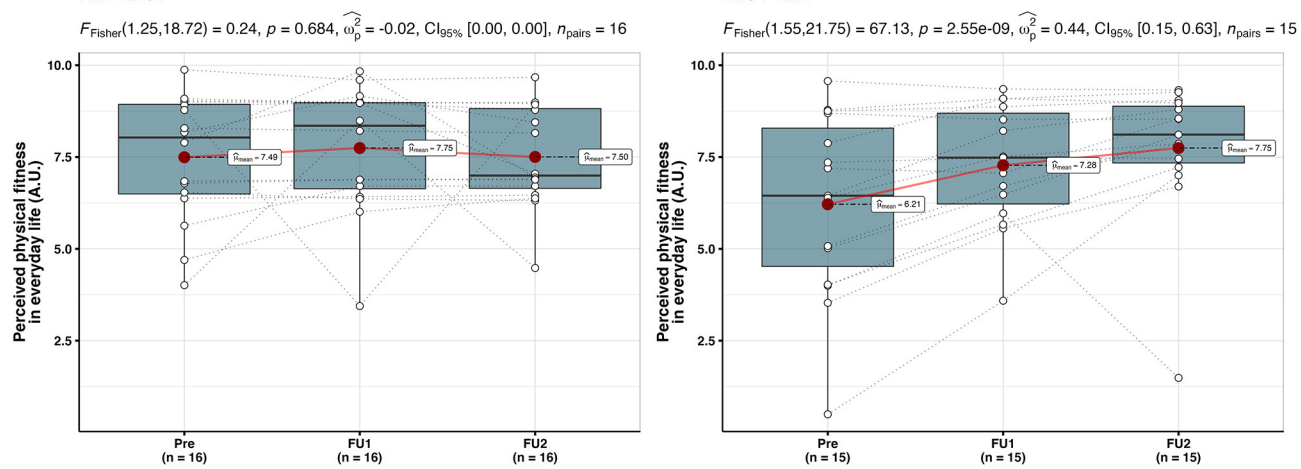

FIGURE 6 | Within-group between baseline (Pre), follow-up I (FU1), and follow-up II (FU2) in the HIIT-MICT and MICT-HIIT groups for perceived physical fitness in everyday life. Boxplots along with the individual data points are shown. The dotted lines connect the same participant, displaying the individual changes. The red dots display the average of each time point.

the first paper that focuses explicitly on the development of physical fitness as a response to exercise over time from both a physiological and a subjective-experiential perspective. By integrating "objectively" measurable fitness data and quantified constructions of retrospective and subjective experiences, our results may help better understand the relationship between exercise mode and individual responses to exercise. Second, by comparing HIIT to MICT and the respective sequences of the training modes, we aimed to contribute to the discussion on the viability of HIIT for public health measures. By focusing on the physiological and subjectively perceived development of physical fitness depending on different training modes, we hope to add another dimension to the discussion.

While we believe that our mixed-method approach might offer a more integrated perspective on and a broader understanding of the development of physical fitness in a structured exercise setting, our study is also associated with some shortcomings and limitations. First, with 31 participants and two experimental arms (HIIT-MICT and MICT-HIIT) our sample size is not particularly large. However, considering the explorative approach of the iReAct study and the fact that it was designed as a 15-week intervention (including 3 weeks of diagnostics and 12 weeks of training), time, economic, and personnel constraints limited the possible inclusion of further participants. Moreover, the last assessment wave (including nine more participants) had to be terminated early due restrictions

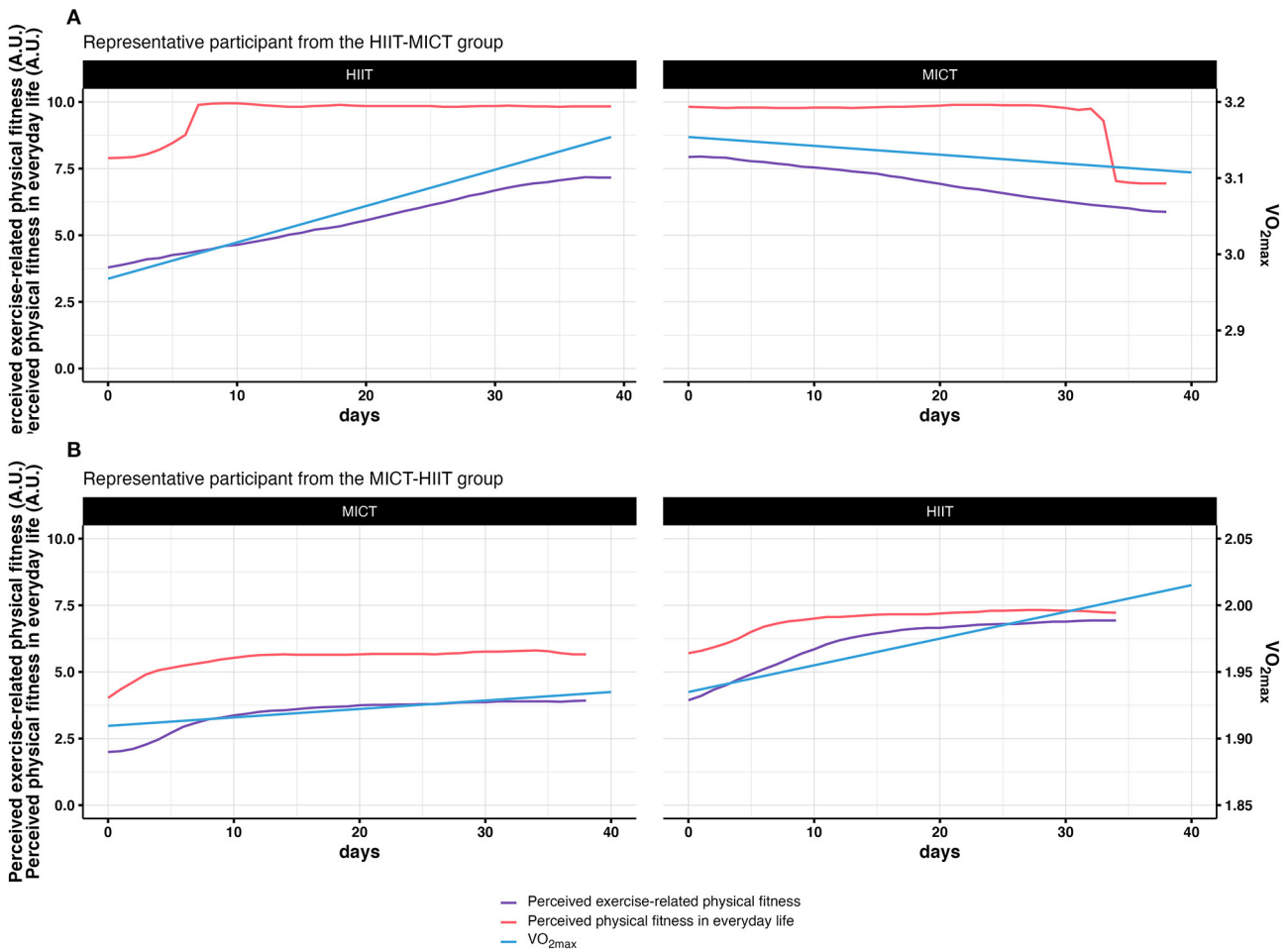

FIGURE 7 | Integration of physiological and subjective measures of fitness. **(A)** displays the integrated results for a representative particpant in the HIIT-MICT group. **(B)** displays the integrated results for a representative particpant in the MICT-HIIT group.

during the early phase of the COVID-19 pandemic. Second, our study did not include an inactive control group that did not exercise at all. However, this was an intentional choice as particularly the effects of a sequential order of MICT and HIIT were of interest and the HIIT-MICT group and the MICT-HIIT group were thus used as controls for each other. Third, our study was designed to include young inactive adults from all social milieus. However, maybe due to the extraordinary time expenditure required for the participation, mainly students who were enrolled at the university signed up for the study. Although some participants were already employed, those were only few. In general, our findings relate in particular to a well-educated sample of young inactive adults. Fourth, limitations with regard to our methodological approach have to be considered. Our goal was to integrate physiological and subjectively experienced physical fitness measures. One of the main limitations in this regard is the potential lack in correspondence between our physical fitness proxies. The physiological variable for physical fitness in our study is VO_{2max}, which refers primarily to CRF. On the other hand, our approach to collect experiential data on physical fitness was based on an open understanding of physical fitness, with the only specification being that we distinguished between exercise-related physical fitness and physical fitness in everyday life. Other than that, participants were free to choose their own definition of the concept. The high degree of specificity for the physiological outcome on the one hand, and the openness with regard to the subjectively experienced outcomes on the other, may have led participants to refer to different dimensions of fitness (e.g., including musculoskeletal fitness or flexibility). In addition, with regard to the assessment of subjective experiences, we relied on retrospectively constructed (i.e., reconstructed) accounts. While those reconstructed experiences do not display perceptions during or immediately after an exercise cue, they are evaluative judgments that can express participants' current (i.e., after the exercise intervention at the time of data collection) attitudes, for example toward different training modes. These attitudes, in turn, are based on previous experiences that are comparatively evaluated (e.g., with regard to different training modes) in hindsight. We are aware that the sequential analysis of training modes as presented here is rather uncommon,

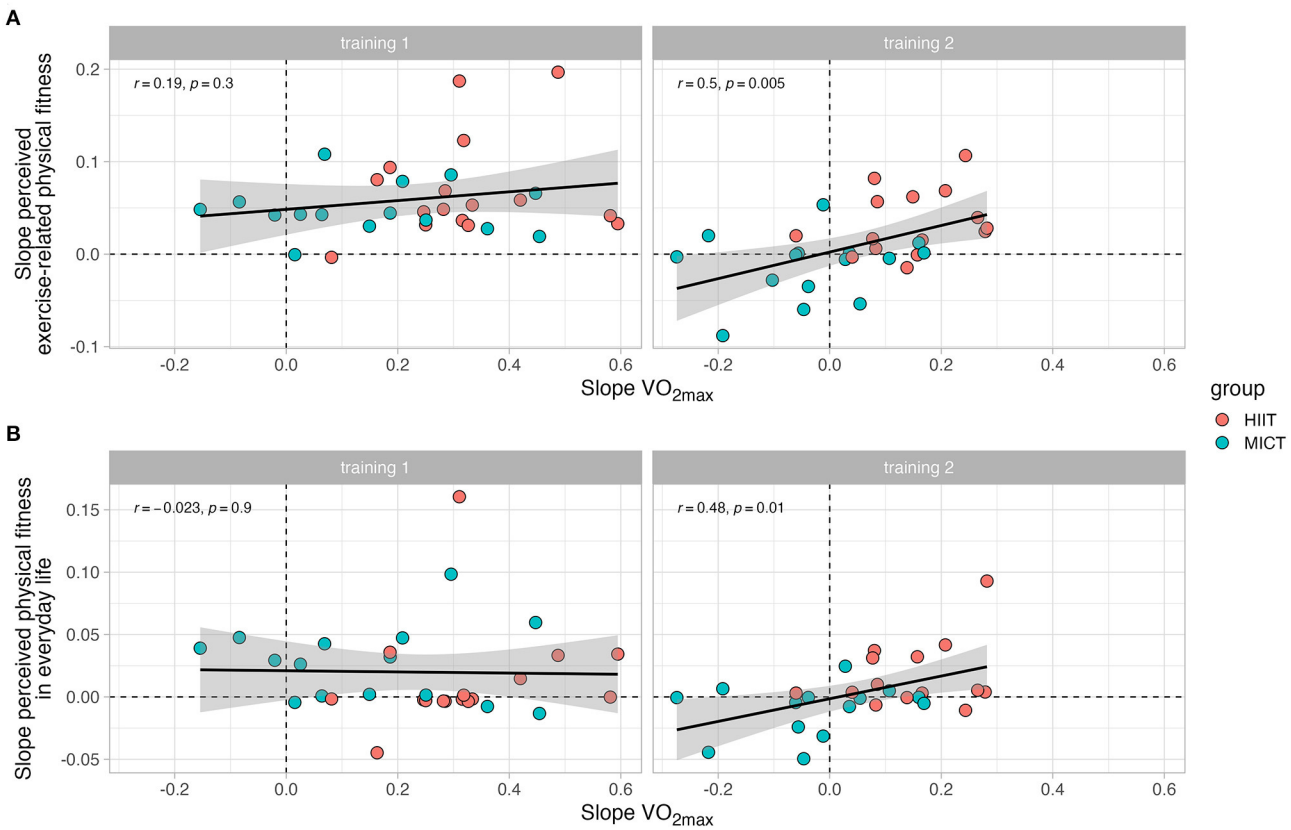

FIGURE 8 | Comparison of the rate of change (i.e., slopes) in VO_{2max} with the rate of change in subjective scales of fitness. **(A)** displays the association between the slopes associated with VO_{2max} and the slopes associated with perceived exercise-related physical fitness. **(B)** displays the association between the slopes associated with VO_{2max} and the slopes associated with perceived physical fitness in everyday life. Each panel is separated into training 1 (from baseline to follow-up I) and training 2 (from follow-up I to follow-up II).

however, we think that our results indicate that this particular comparison might have practical implications. For example, our results show that training moderately after having trained with HIIT for a while, might be less beneficial both physiologically and psychologically. Yet, we have to acknowledge that our study provided a highly structured intervention setting, in which participants had to exercise on a regular basis, had to adhere to a minimum amount of training sessions, were monitored in their progress, and participated in a wide range of biopsychosocial assessments. This "clinical" procedure does not necessarily translate to PA, exercise, and sport in everyday life. Subjective experiences of feeling fit probably differ across contexts, activities, and, as we have indicated, training type. Additionally, while we assume that feeling fit might be one motivational determinant of regular exercise and PA, we are aware that PA is a complex phenomenon that is associated with a multitude of determinants and correlates and lab-based exercise interventions may be able to only account for some them. The question therefore remains, how sustainable our exercise intervention was. Unfortunately, we cannot make any statements as to which extent our study actually motivated participants to remain active after they completed the 15 weeks, since the major goal was to assess more or less immediate individual biopsychosocial responses to exercise as well as subjectively reconstructed experiences of those responses.

We are convinced that our findings provide a new and important perspective on how physical fitness develops according to the prescribed training modes and how changes are subjectively experienced. Future research might build on the strengths of our study and aim to counteract the potential limitations we have described. In particular, when it comes to relating physiological fitness measures to subjective experiences of physical fitness, future studies might aim to go into more depth and include more measures of physiological fitness (e.g., musculoskeletal fitness or flexibility) and more differentiated measures of perceived physical fitness (e.g., by asking specifically about perceived cardiorespiratory fitness or perceived strength). Moreover, future studies might aim to provide deeper insights and explanations for the observed trends by assessing individual and subjective accounts of physical fitness from a mainly qualitative perspective, as inactive young adults "respond differently to different forms of exercise and the factors that influence participation in interval or continuous exercise are far more complex than can be captured by quantitative

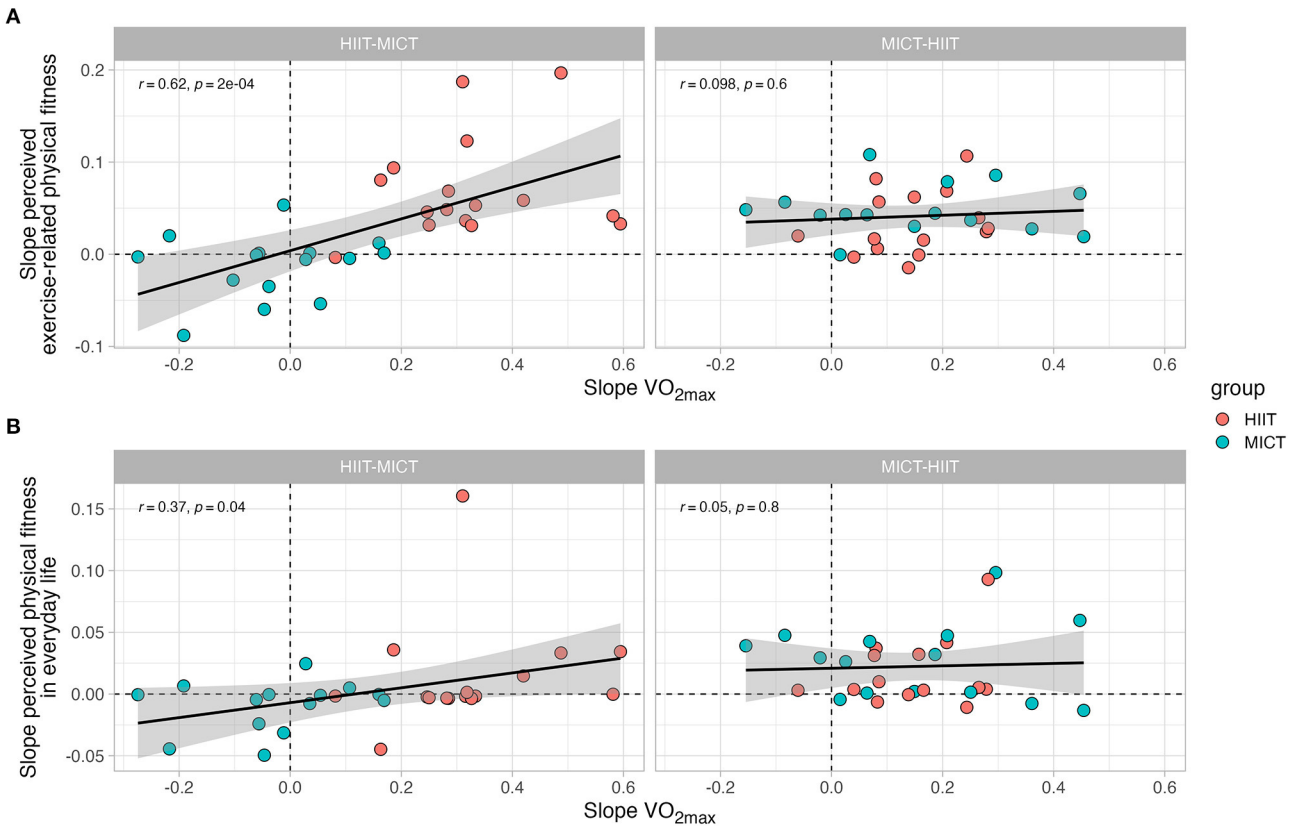

FIGURE 9 | Comparison of the rate of change (i.e., slopes) in VO_{2max} with the rate of change in subjective scales of fitness. **(A)** displays the association between the slopes associated with VO_{2max} and the slopes associated with perceived exercise-related physical fitness. **(B)** displays the association between the slopes associated with VO_{2max} and the slopes associated with perceived physical fitness in everyday life. Each panel is separated into each training group (i.e., HIIT-MICT and MICT-HIIT).

methodologies alone" (Stork et al., 2020, p. 10). Additionally, future studies might try and follow-up on participants for an extended period of time, in order to see how effective the exercise intervention actually was in terms of adoption, adherence, maintenance, and retention rates (Willinger et al., 2021).

CONCLUSION

It is well-established that regular exercise fosters substantial health-enhancing benefits. Yet, physical inactivity and sedentariness are predominant and uptrending phenomena of our time. We assume that PA and exercise are more likely to be pursued in the long run if they promote not only objective health and fitness benefits, but if those benefits can also be subjectively experienced. Exemplifying this in the context of physical fitness, our results indicate that young inactive adults can benefit from regular exercise with regard to physical fitness outcomes both physiologically and subjectively. However, the choice of exercise modes and their sequence can make a substantial difference in measured and perceived physical fitness. This should be taken into consideration by exercise researchers and PA and public health practitioners alike. In addition, our results have shown that the ways in which young inactive adults respond physiologically and experientially to exercise vary inter-individually emphasizing the necessity of individualized approaches to exercise prescriptions. While for most young inactive adults HIIT seems to foster physiological and perceivable fitness benefits, one-size-fits-all approaches cannot be the solution to such a complex phenomenon as exercise.

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 Ethics Committee of the Medical Faculty University Tübingen. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AT and AN contributed to the conception and overall design of the iReAct study and the funding acquisition. AT, AN, HG, and FMM contributed to the conception and design of

the substudy for this paper. HG conducted the biographical mappings and drafted the first version of the manuscript. FMM collected physiological data, performed the statistical analyses, and wrote sections of the manuscript. All authors contributed to critical manuscript revision and read, edited, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2021.729090/full#supplementary-material

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Validation of the Need for Competing Inventory

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Past studies have been conducted on competitiveness and achievement orientation as two noncooperative explanations for achievement motivation and achievement behavior. But a complimentary representation of a competitive-achievement orientation has yet to be explored. This paper developed and validated the need for competing inventory (NCI), and further investigated its relations with achievement orientation, emotional assessment, self-efficacy, grit, anxiety, and flow. The results from the present study support the theoretical construct of the need for competing, in the hope that it will provide a solid foundation for a competitive-achievement orientation, which is suggested to play a significant role in competitive achievement behavior. It is anticipated that the results from the present study will open a debate for including a competitive-achievement orientation in future research with the aim for a stronger predictor for achievement behavior.

Keywords: flow, competitiveness, self-efficacy, need for competing, grit, anxiety, achievement motivation, emotional assessment

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INTRODUCTION

Competition is a comprehensive and complex term with several definitions. Competition can be defined as a negative social interdependence, meaning that the situation is competitive if the progress or success of one party interferes with the progress or likelihood of success of other parties (Deutsch, 1949). Within sport psychology, competition is often described as a form of social evaluation; entailing comparison of individual or team performances against one another or against an objective standard of excellence (Martens, 1976). Previous research has highlighted the importance of achievement motivation for the explanation of achievement behavior (Gill and Deeter, 1988). Gill and Deeter (1988) argued that competitive achievement behavior is one of the most prominent features in sport and exercise activities, consisting of widespread individual differences. Some people dread any type of evaluation while others take on all competitive challenges. Those taking on competitive challenges might want to achieve personal goals or perform better than others, whereas for some fun and enjoyment are the primary motives for engaging in competition.

RELATED CONCEPTS

McClelland et al. (1953) describe competence as a basic motivator for human behavior, especially achievement behavior. When individual competence is evaluated, they strive to do well or to avoid

doing poorly, such as in school or in sports. Maehr and Nicholls (1980) made the important distinction between competitors demonstrating competence with a focus on either self-referenced mastery (task orientation) or on gaining favorable judgments of others (ego orientation). In the early 1980s achievement-goal theory was proposed as a dichotomous model that distinguished between two different goal constructs originating from task and ego orientation: mastery goals and performance goals (Maehr and Nicholls, 1980; Dweck and Elliott, 1983; Nicholls, 1984). Task oriented mastery goals were defined as the striving to develop competence through task mastery and improvement in relation to one's personal standards, and ego-oriented performance goals were defined as the striving to demonstrate competence gaining favorable judgments of others. In the mid 1990's Elliot and Harackiewicz (1996) extended the dichotomous model with the inclusion of an approach-avoidance distinction. A more recent progression has established a goal construct organized into a 2 × 2 achievement goal model, and then further developed to a 3 × 2 model by separating mastery-based goals into task-based and self-based categories (Elliot, 1999; Elliot et al., 2011). The 3 × 2 model defines competence through task, self or other goals that are fully crossed with a valence of competence as approach or avoidant that produces six goals: (1) Task-approach (focusing on attaining task-based competence); doing the activity the way it was designed to be done, for example correct execution of a skill like scoring a lot of goals in football. (2) Task-avoidance (focus on avoiding task-based incompetence); not failing to do the activity the way it was designed to be done, for example avoiding poor skill execution. (3) Self-approach (focused on self-based competence); doing better than before, for example, scoring more goals than I usually do. (4) Self-avoidance (focused on self-based incompetence); not doing worse than before, for example, not to score fewer goals than I usually do. (5) Other-approach (focus on attaining other-based competence); doing better than others, for example score more goals than my teammates and (6) Other-avoidance (focused on avoiding other-based incompetence); not doing worse than others, for example, not score fewer goals than my teammates. Mascret et al. (2015) extended this 3 × 2 achievement goal model, that had previously focused on competence striving in education environments, to the sport domain.

Achievement goals are rooted in the need to experience competence, but there might also be another factor explaining achievement behavior, namely competitiveness. Previous research has faced challenges in determining the conceptualization and operationalization of competitiveness, and achievement motivation may have supplemented the focus for a discussion on the definition of competition. In previous research, Vealey (1986) developed the Competitive Orientation Inventory (COI) using Nicholls (1984) achievement-goal theory to help define and operationalize competitiveness. Accordingly, depending on what goal the athlete possesses, competitiveness can take two different forms: performing well (performance) or winning (outcome; Vealey, 1986). Gill and Deeter (1988) argued that although the sport achievement orientation is multidimensional, the precise dimensions cannot be specified with any confidence. Thus, they developed a sport achievement orientation measure; the sport orientation questionnaire (SOQ), which included varied achievement options using an exploratory factor analysis for explaining the specific factor structure. The SOQ operationalized competitiveness as one of three achievement orientations: competitiveness, goal orientation and win orientation. The SOQ operationalizes and defines competitiveness as the desire to enter and strive for success in sport competition (Gill and Deeter, 1988). Gill and Deeter (1988) stressed that their competitiveness factor represents a basic sport-specific achievement orientation. However, the three-factor structure indicated that sports achievement orientation could be further differentiated. Two major types of outcome in sport achievement situation seemed to reflect an orientation from the two other factors; (factor 2, goal orientation) the desire to reach personal goals, and (factor 3, win orientation) the desire to win in interpersonal competition in sport. Gill and Deeter (1988), as well as Vealey (1986), also offered parallels for the achievement-goal theory where factor 2 (goal orientation) has similarities with the mastery orientation, and factor 3 (win orientation) has similarities with the performance orientation. They further operationalized the competitiveness term as one of three components in a sport-specific achievement orientation.

COMPETITIVENESS

The Achievement Goal Questionnaire (AGQ) and SOQ offer two different explanations for achievement motivation. This paper attempts to provide a clearer distinction and relation between the competitive factor and achievement factor and their contribution to achievement motivation, orientation and behavior. By conceptualizing and validating a need for competing measurement tool, and redefining the concept of competitiveness, it might offer a more suitable model for the motivation/orientation for achievement behavior, namely competitive-achievement orientation.

Competitive-Achievement Orientation

A competitive-achievement orientation is posited to offer a clearer distinction between the need/desire to compete (competitive) and the need/desire for competence (achievement). This is believed to be important because of the proposed differences between the satisfaction of competing and the satisfaction of achieving; wanting to succeed, for example, is qualitatively different from wanting to work to succeed. Establishing a competitive-achievement orientation might help understand these differences as well as the relationship between the competitive-achievement orientations, how these orientations complement each other, and the distinction between individuals with high ambitions for succeeding in competition, and those competitors who are willing to make sacrifices and work to realize their aspirations. Being willing to compete for success, means wanting to compete despite the costs of effort, risk of losing and potential experience of failure. This balance between the competitive orientation (enjoyment of the competition) and achievement orientation (the importance of achieving), might

be two closely related interactive dimensions of competitiveness. Thus, being able to generate competitive-achievement motivation and utilizing it for competition could lead to a redefinition of competitiveness.

The Importance of the Competitive-Achievement Orientation

The purpose for challenging and reconceptualizing a more appropriate and relevant model for explaining achievement orientation and behavior is to improve the measurement and predictability for achievement behavior.

THE NEED FOR COMPETING AND RELATED CONCEPTS

The need for competing is the competitive spirit or strive in the engagement of competition, and can be defined as the desire to enter, participate and enjoy the competition itself. Evidence suggests, however, that the competitive need has a comprehensive relationship with engagement and aggression, motivation, competitive flow and performance levels. Being competitive means getting more activated/aroused (emotional reactivity prone to aggression) when faced with a competitive task (Karrass et al., 2006; Carré et al., 2009; Carré and Archer, 2018; Wu et al., 2018), which can lead to negative emotions and aggressive behavior (Couppis and Kennedy, 2008; Carré and Olmstead, 2015; Carré and Archer, 2018), but it can also lead to positive emotions, engagement, flow and better performance (Elias, 1981; Csikszentmihalyi and Larson, 1987; Csikszentmihalyi and LeFevre, 1989; Roberts et al., 2007a; Jordet and Hartmen, 2008), depending on variables including enjoyment or frustration (Carré and McCormick, 2008). Moreover, Bossuyt et al. (2014) found that dominant/aggressive behavior was related to approach motivation (approaching a desired stimulus), which is associated with low anxiety levels and high performances, whereas being submissive/non-aggressive was related to avoidance motivation (avoidance of undesired stimulus), which is linked with high anxiety levels and lower performances (Schüler, 2007; Roberts et al., 2007b; Jordet and Hartmen, 2008). Being highly competitive (more engaged and aggressive), therefore, should similarly be linked to reduced anxiety levels, increased flow and better performance levels. Whether or not the competitive task is enjoyable, or frustrating is also expected to be heavily influenced by the competitors' self-efficacy, the belief in one's abilities, and are most likely positively related with the need for competing (Bandura, 1977). To be able to compete the individual must have some belief in their ability to make an impact in the competitive task, otherwise it is not competing, just losing.

Research to date has predominantly focused on the association between achievement behavior and grit [Grit Scale (GS) – Duckworth et al., 2007], self-efficacy (General Self-efficacy Scale – Scholz et al., 2002), flow (Short Dipositional Flow Scale – Jackson et al., 2008; Martin and Jackson, 2008), anxiety (Sport Anxiety Scale – Smith et al., 2006), emotional assessment [Self-Assessment Manikin (SAM) – Bradley and Lang, 1994], and achievement orientation (Achievement Goal Questionnaire – Mascret et al., 2015), but the construct validity and relation of the need for competing has yet to be explored.

OBJECTIVE

Due to the lack of research on the trait concept of the need for competing and its relation to grit, self-efficacy, flow, anxiety, emotional assessment, and achievement orientation, the present study aimed to explore this phenomenon and its potential associations. Based on the cited theories and research, the hypothesis that the need for competing is a valid construct and correlates with grit, self-efficacy, flow, anxiety, emotional assessment, and achievement orientation, was tested. In study 1, the first prediction was that the items in the need for competing inventory (NCI) would all measure the same factor, suggesting that they all measure the construct of the need for competing. In study 2, for further validation of the NCI, the second prediction was that the need for competing would be negatively related to anxiety, and positively related with positive valanced (approach-motivated) self, task and others goal (achievement orientation), emotional assessment, self-efficacy, grit, and flow. The third predication was that the elite prospect students were expected to score higher on the NCI than the students specializing in sports and the general high school education students. Validating the concept of the need for competing by validating the NCI and finding its suggested correlations, might offer a competitive orientation related to the achievement orientation. It is hoped that the suggested representation of the competitive-achievement orientation will give a more distinct and clearer explanation for motivation and orientation for achievement behavior.

METHOD

Study 1

Methods

In study 1 the aim was to develop the items for and examine the factor structure and internal consistency of the NCI.

Sample Description

In order to minimize demands for the sample size necessary to achieve statistically significant results in study 1, *a priori* power analysis was conducted, using G*power (Faul et al., 2009), which required a sample size of $N = 84$ to achieve a.3 correlational effect size. The NCI was tested on a total of 109 voluntarily participants consisting of 1^{st} and 2^{nd} year psychology students, undergraduates at the Inland Norway University of Applied Sciences. The testing was conducted in classroom settings and the participants were divided in two separate classes. Nine of the participants withdrew leaving a total of 100 participants who completed the study.

Procedure and Measure Development

The NCI was designed by following the guidance of Devellis (2003) for scale development. The need for competing was

determined to be measured (step 1) before seven relevant items were generated (step 2) into the NCI self-report questionnaire (step 3); Q1, *"I always seek challenges, not for the outcome, but for the competition itself"*; Q2, *"I'll rather seek unachievable challenges than no challenges"*; Q3, *"I'm always willing to compete, despite it being a big chance of losing"*; Q4, *"I always choose to work hard to be able to compete, rather than avoid the extra work and not be able to compete"*; Q5, *"I will stop competing when the goal is achieved"*; Q6, *"Competing is always more satisfying than the potential outcome of a competition"*; Q7, *"I always have a greater need for competing, rather than ensuring the avoidance of failure"*.

The initial item pool was reviewed by research colleagues (step 4), where the inclusion of validated items was considered (step 5) before administering the items to a development sample (step 6). Participants were informed that they would be shown statements that represented types of beliefs that they may have of themselves, and they were instructed to respond on a Likert scale from 1 (strongly disagree) to 5 (strongly agree), where higher scores indicate higher need for competing. For increased test validity a reversed score on question 5 was included (Q5) with the aim if reducing chances of acquiescence bias and boredom (Couch and Keniston, 1960; Baumgartner and Steenkamp, 2001; Podsakoff et al., 2003). After the completion of the tests, the items were evaluated (step 7) and the scale length were optimized (step 8) whereas five of the items were chosen to represent the need for competing questionnaire.

Ethical Considerations

The participants gave informed consent to participate and were informed that they had the right to withdraw their information at any time during the survey. The Norwegian Centre for Research Data (NSD) evaluated that the study did not need to seek any further ethical approval, considering that the data was anonymous.

Results

The seven items were administered to 109 participants (psychology students), with a 100 participants completing, and the resultant data were factor analyzed. SPSS v.25 was used to perform exploratory factor analysis (EFA) to help determine what the items underlying structure was. The reliability statistics reveals a high internal consistency (Cronbach's $\alpha = 0.769$) within all the seven items on the questionnaire (**Table 1**).

The Principal Component Analysis was the factor extraction method used to form uncorrelated linear combinations of the observed variables. The successive components explain progressively smaller portions of the variance and are all uncorrelated with each other. This method is used to obtain the initial factor solution (Osborne et al., 2008). Component 1 with a total score of 2.996, component 2 with a total of 1.016 and cumulative percent of 57.323, which is higher than 1 eigenvalue, and the remaining components under 1 eigenvalue.

An oblique promax rotation was performed and the NCI items were shown to have 2 distinct factors. Further on we retained all the factors whose eigenvalues were lower than 1, and therefore removed Q3 *"I'm always willing to compete, despite it being a big chance of losing"* and Q6 *"Competing is always more satisfying than the potential outcome of a competition"* to support the hypothesized one factor structure (**Table 2**). Overall, this left us with a total of 5 items on the NCI, still with a high consistency (Cronbach's $\alpha = 0.759$).

Study 2

Methods

In study 2 the aim was to further validate the NCI by examining the relationships between the need for competing factor and other key variables in the motivation literature, namely achievement orientation, emotional assessment, self-efficacy, grit, anxiety, and flow. As mentioned, these variables are thought to be linked because of the theoretical underpinning of the need for competing, and as a result of previous research that has highlighted their association (Elias, 1981; Karrass et al., 2006; Roberts et al., 2007a; Carré and McCormick, 2008; Couppis and Kennedy, 2008; Jordet and Hartmen, 2008; Carré et al., 2009; Bossuyt et al., 2014; Carré and Olmstead, 2015; Carré and Archer, 2018; Wu et al., 2018).

Sample Description

A priori power analysis using G*power was also conducted for study 2, revealing a requirement of a sample size of $N = 252$ to achieve an effect size of.25. Gathered, there were a total of 365 participants in study 2.

If the NCI does assess competitive orientation, then individuals who score higher on the need for competing measure should be more likely to enroll in the competitive classes and participate in competitive sports, rather than individuals who score lower on the need for competing. An individual's competitive achievement orientation should exert some influence although several other factors might influence the individual competitive achievement orientation also (e.g., abilities, competitive environment).

Ethical Considerations

As in study 1, in study 2 the participants gave informed consent to participate and were informed that they had the right to withdraw their information at any time during the survey. The NSD concluded that the study did not require any further ethical approval, considering that the data was anonymous.

Procedures and Measures

Testing several undergraduate classes in large group settings, the participants completed a questionnaire containing all the constructs consisting of the NCI, AGQ, GSE, GS, SAM, Sport Anxiety Scale 2 (SAS 2), and Short Dispositional Flow Scale (SDFS).

The Need for Competing Inventory

The NCI developed in study 1, consisting of five items and a Likert scale from 1 to 5. The NCI was also used to measure participants need for competing level in study 2, where the items had an acceptable internal consistency ($\alpha = 0.681$).

TABLE 1 | Item-total statistics of the NCI.

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
Q1	18.33	16.951	0.668	0.483	0.706
Q2	18.57	17.500	0.496	0.285	0.740
Q3	18.19	18.701	0.396	0.235	0.759
Q4	18.02	18.181	0.493	0.300	0.740
Q5	18.22	17.891	0.409	0.228	0.760
Q6	18.59	19.517	0.396	0.192	0.758
Q7	18.60	16.323	0.595	0.405	0.717

TABLE 2 | Component Loadings of the NCI.

	RC1	RC2	Uniqueness
Q1	0.765		0.323
Q2	0.446		0.561
Q3		0.873	0.306
Q4	0.715		0.505
Q5	0.855		0.422
Q6		0.753	0.443
Q7	0.661		0.427

Applied rotation method is promax.

Achievement Goal Questionnaire

The AGQ (Mascret et al., 2015), was translated into Norwegian and adjusted to the sport specific domain, consisting of three items for each of the six goals, resulting in a total of 18 items. The translated sport specific AGQ was further tested on 43 participants (third year BSc psychology students) in a classroom setting. The data were then analyzed with a reliability test showing a high internal consistency in achievement goals: task-approach (α = 0.689), task-avoidance (α = 0.842), self-approach (α = 0.675), self-avoidance (α = 0.765), other-approach (α = 0.953), and other-avoidance (α = 0.948) goals. After the translation the AGQ was assessed in study 2. The scores were gathered still with a high overall internal consistency (α = 0.940).

General Self-Efficacy Scale

The original general self-efficacy scale was developed by Jerusalem and Schwarzer (1979), and later translated into 33 languages (Schwarzer and Jerusalem, 2010). The GSE has shown high validity in numerous domains and across cultures (Luszczynska et al., 2005). The Norwegian translated GSE scale was assessed, consisting of ten likert-scale items from 1 to 4, where higher scores indicate higher self-efficacy (Scholz et al., 2002). According to Scholz et al. (2002), there is support for an internal consistency (α = 0.75 −0.91) revealed in several studies. In the present study the internal consistency was also acceptable (α = 0.845).

Grit Scale

A Norwegian translation of Duckworth et al.'s (2007) Grit scale was also conducted in study 2, with an acceptable internal consistency (α = 0.769). Consisting of twelve items, and a likert scale from 1 to 5. Question 1, 2, 5, 7, 10, and 11 was reversed, as the original, for reducing chances of acquiescence bias and boredom (Couch and Keniston, 1960; Baumgartner and Steenkamp, 2001; Podsakoff et al., 2003).

The Self-Assessment Manikin

The Self-Assessment Manikin is a picture-oriented questionnaire developed to measure emotional responses like valence/pleasure of the response (from positive to negative), perceived arousal (from low to high levels), and perceptions of dominance/control (from low to high levels) (Bradley and Lang, 1994). The three items in SAM were translated into Norwegian and used in the study 2 without pictures in the items, showing an acceptable internal consistency (α = 0.666). Similarly, as the original, it was used a 9-point scale measuring each item.

The Sport Anxiety Scale 2

A Norwegian translated version of the SAS 2, originally from Smith et al. (2006), was assessed for study 2. Consisting of 15 items measuring three dimensions (somatic, worry, and concentration) of the athletes experienced anxiety relating to one's sport. The somatic dimension refers to the bodily experienced anxiety symptoms, while the cognitive dimensions refers to the psychological experienced anxiety symptoms of worrying and concentration disruption before or while the participant competes (Smith et al., 2006). After assessing the questionnaire in study 2 the internal consistency was acceptable (α = 0.882). The anxiety dimension also came out internally consistent: somatic (α = 0.828), worry (α = 0.862), and (α = 0.779).

The Short Dispositional Flow Scale

The Short Dispositional Flow Scale (Jackson et al., 2008; Martin and Jackson, 2008), was translated in Norwegian and tested on 43 participants (third year BSc psychology students) in a classroom setting, showing a satisfactory internal consistency (α = 0.704). The questionnaire consists of 9 items measuring each 9 dimensions of the participants flow experiences related to his/her activity.

Results

The need for competing were correlated with the flow, grit, self-efficacy, emotional assessment, achievement goals, and anxiety variables. 365 participants participated in study 2 (**Table 3**)

TABLE 3 | Descriptives – NCI and educational program.

Educational program	Mean	SD	N
Elite sports	17.91	3.844	208
General sports	16.49	4.025	77
Regular school program	14.85	5.401	80

with a total of 208 elite prospect students scoring highest on the need for competing (M = 17.91, SD = 3.84), 77 students specializing in sports scoring second highest on the need for competing (M = 16.49, SD = 4.02), and 80 general high school education students scoring lowest on the need for competing (M = 14.85, SD = 5.4). With only 347 completing the sport anxiety scale 2, the remaining tests were completed by all the 365 participants.

Converging Evidence

Using a correlation matrix (**Table 4**), the need for competing was found to be significant positively related to the achievement orientation (r = 0.388, $p < 0.001$), self-efficacy (r = 0.561, $p < 0.001$), flow (r = 0.691, $p < 0.001$), and emotional assessment: valence (r = 0.352, $p < 0.001$), activation (r = 0.236, $p < 0.001$), and control (r = 0.309, $p < 0.001$).

Divergent Evidence

Table 4 also revealed that the need for competing was significant negatively related to grit ($r = -0.296$, $p < 0.001$), and anxiety: somatic ($r = -0.137$, $p < 0.05$), worry ($r = -0.183$, $p < 0.001$), and concentration ($r = -0.269$, $p < 0.001$).

The NCI correlated with the different goal dimensions in achievement orientation. The data results revealed a significant positive relation between need for competing and the task approach goal (r = 0.242, $p < 0.001$), the self approach goal (r = 0.256, $p < 0.001$), and other approach goals (r = 0.163, $p < 0.01$), the task avoidance goal (r = 0.130, $p < 0.05$) and self avoidance goal (r = 0.150, $p < 0.01$). The positive valanced (approach) goals had the strongest positive relations, while the negative valanced (avoidance) goals had a weaker positive correlation to the need for competing. However, the other avoidance goal had the lowest relation and turned out to be non-significant (r = 0.079, $p > 0.05$).

A one-way ANOVA revealed there was a significant difference in the amount of the need for competing score at the $p < 0.001$ level for the three groups with a medium effect size [$F(2, 362) = 15.42$, $p < .001$, $\eta^2 = 0.079$]. As demonstrated in **Tables 5**, **6** and **Figure 1**, the elite prospect students scored significantly higher on the need for competing than the general education students (MD = 3.06, $p < 0.001$), as well as a significantly higher score difference than the high school students specializing in sports (MD = 1.42, $p < 0.05$). The students specializing in sports scored higher on need for competing than the general education students, although not significantly (MD = 1.64, $p > 0.05$). These results seem to support previous assumptions that highly competitive individuals seek highly competitive environments.

TABLE 4 | Descriptive statistics and correlations for study variables.

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NCI	16.94	4.43																		
SDFS	31.92	6.80	0.691***																	
SAM	18.57	4.42	0.625***	0.727***																
GSES	30.56	5.75	0.561***	0.620***	0.574***															
AGQ	95.90	21.90	0.388***	0.410***	0.377***	0.492***														
SAS	28.56	8.27	0.139**	0.252***	0.166**	0.190***	0.200***													
GS	30.09	6.10	−0.296***	−0.182***	−0.265***	−0.282***	−0.180***	0.264***												
SAS_S	9.47	3.03	−0.137*	−0.065	−0.125*	−0.189***	−0.030	0.816***	0.214***											
SAS_W	11.75	3.45	−0.183***	−0.155**	−0.191***	−0.222***	0.079	0.832***	0.156**	0.475***										
SAS_C	6.53	1.99	−0.269***	−0.234***	−0.274***	−0.250***	−0.060	0.724***	0.382***	0.474***	0.423***									
AGQ_T_Ap	17.51	3.33	0.242***	0.246***	0.229***	0.278***	0.748***	−0.075	−0.363***	−0.087	0.039	−0.153**								
AGQ_S_Ap	17.17	3.36	0.256***	0.225***	0.210***	0.267***	0.792***	−0.025	−0.315***	−0.008	0.066	−0.119*	0.662***							
AGQ_O_Ap	14.99	4.58	0.163**	0.118*	0.117*	0.195***	0.834***	−0.025	−0.149**	−0.004	0.017	−0.047	0.532***	0.526***	–					
AGQ_T_Av	16.30	3.77	0.130*	0.123*	0.088	0.174**	0.813***	−0.027	−0.199***	−0.064	0.075	−0.035	0.583***	0.600***	0.519***	–				
AGQ_S_Av	16.65	3.68	0.150**	0.117*	0.136*	0.213***	0.824***	−0.006	−0.232***	−0.066	0.075	−0.030	0.533***	0.697***	0.519***	0.722***				
AGQ_O_Av	14.88	4.56	0.079	0.082	0.048	0.146**	0.843***	0.065	−0.103	0.047	0.112*	0.038	0.460***	0.480***	0.851***	0.583***	0.602***			
SAM V	6.83	1.26	0.352***	0.343***	0.761***	0.300***	0.148**	−0.258***	−0.314***	−0.109*	−0.201***	−0.329***	0.254***	0.254***	0.071	0.065	0.130*	0.012		
SAM A	6.02	1.54	0.236***	0.205***	0.783***	0.176***	0.221***	−0.093	−0.297***	−0.014	−0.070	−0.125*	0.201***	0.179***	0.193***	0.136*	0.211***	0.133*	0.379***	
SAM C	6.35	1.15	0.309***	0.420***	0.694***	0.331***	0.220***	−0.279***	−0.326***	−0.161**	−0.258***	−0.286***	0.255***	0.241***	0.189***	0.131*	0.146**	0.143**	0.466***	355***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ Column 1 is highlighted to show the correlation with the NCI and the other factors. NCI, Need for Competing Inventory; GS, Grit Scale; AGQ, Achievement Goal Questionnaire, T(Task), S(Self), O(Other), Ap(Approach), and Av(Avoidance); GSES, General Self-Efficacy Scale; SDFS, Short Dispositional Flow Scale; SAM, Self-Assessment Manikin, V(Valence), A(Arousal), C(Control); SAS 2, Sport Anxiety Scale, S(Somatic), W(Worry), and C(Concentration).

TABLE 5 | Results of the NCI within the respective educational programs.

Educational program	Marginal Mean	SE	Lower CI	Upper CI	t	p
Elite prospects	17.91	0.296	17.33	18.50	60.53	< 0.001
Sport students	16.49	0.486	15.54	17.45	33.91	< 0.001
General students	14.85	0.477	13.91	15.79	31.12	< 0.001

TABLE 6 | *Post hoc* comparisons of the NCI and educational programs.

			95% CI for Mean Difference					
		Mean Difference	Lower	Upper	SE	t	Cohen's d	$p_{scheffe}$
Elite sports	General sports	1.420	0.080	2.760	0.569	2.494	0.365	0.046
	Regular school program	3.063	1.742	4.385	0.561	5.456	0.707	<0.001
General sports	Regular school program	1.644	0.040	3.247	0.681	2.412	0.344	0.056

Cohen's d does not correct for multiple comparisons.

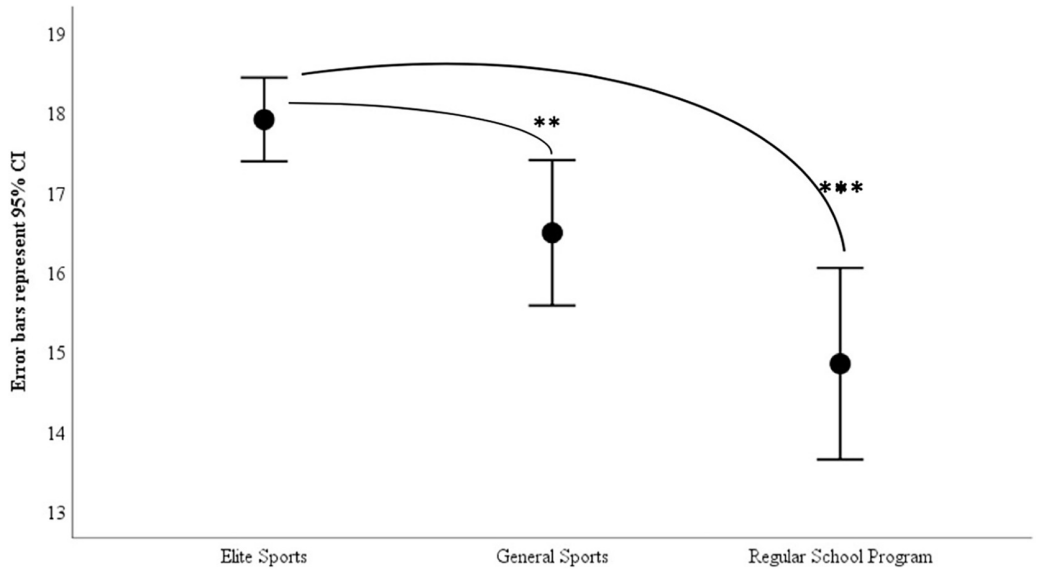

FIGURE 1 | NCI Scores for Different Educational Programs. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The figure demonstrating that elite prospect students score greater than the students in general sports and regular school program.

GENERAL DISCUSSION

Findings

Study Purpose

The purpose of this study was to further explore the need for competing and propose a more accurate representation of the competitive-achievement orientation to give a more distinct and clearer explanation for motivation and orientation for achievement behavior in the future.

Study 1 – Scale Development

The first prediction, in study 1, was that the items in the NCI would all measure the same factor, named the need for competing. An exploratory factor analysis revealed that two of the items seemed to be measuring another factor and was later removed, leaving 5 remaining items as valid measures of the need for competing factor.

Study 2 – Validation

An acceptable factorial validity and reliability do not ensure that the scale is measuring the construct it is designed to measure (Smith et al., 2006). It is vital to specify relations with other theoretically related and unrelated constructs, by attaching the underlying construct in a nomological network (Cronbach and Meehl, 1955), which implies assessing both convergent and discriminant aspects of construct validity (Campbell and Fiske, 1959), leading us to the second prediction. The second prediction was that the NCI would be negatively related to anxiety, and positively related to positive valanced (approach-motivated) self, task and others goal

(achievement orientation), emotional assessment, self-efficacy, grit, and flow.

The NCI and AGQ total score were positively correlated (**Table 2**), however, the prediction that the need for competing were going to be significant positively related to positive valanced (approach-motivated) self, task and others goal (achievement orientation), were partially supported (see **Table 4**). The positive valanced achievement goals were in fact more positively related than the negative valanced avoidance goals. Although there was no expectation of a positive relation with the need for competing and avoidance achievement goals, the task avoidance goal and self-avoidance goal had a weaker positive correlation to the need for competing, which is understandable since a highly competitive individual might have higher standards toward oneself and find the competitive standards more essential than the average person. However, the other avoidance goal had the lowest relation and turned out to be non-significant. Although, the prediction gets nuanced, the theoretical explanations remain covering the reason for that a highly competitive individual is more frequent approach motivated (Bossuyt et al., 2014).

The relation between NCI and emotional assessment (SAM) had also a positive relation, confirming the suspicion that being competitive are closely related to his/her perceived emotions and emotional response (Wu et al., 2018). This strong positive relation suggests that being highly competitive might be an indication of scoring higher on positive valence, higher activation of excitement, and the perceived control, the feeling of dominating rather than being dominated in competition (Bradley and Lang, 1994). This supports the theoretical implication and previous research that being highly competitive might be associated with higher testosterone, thus influencing their emotional reactivity levels affecting their engagement and aggressive behavior (Simon and Lu, 2006; Nelson and Trainor, 2007; Carré and McCormick, 2008; Carré et al., 2009; Bossuyt et al., 2014; Carré and Olmstead, 2015; Wu et al., 2018). The emotional assessment and self-efficacy were also significantly positively correlated, suggesting that the belief in one's abilities indicates a feeling of control and domination. Self-efficacy was also strongly positively related to the NCI, furtherly confirming the assumption that being competitive might indicate a more frequently approach motivation because of the individual's belief in his/her own ability to handle/cope with the competitive task (Bandura, 1977; Bossuyt et al., 2014). Hence, stressors are as mentioned more frequently perceived as benign appraisals (Lazarus and Folkman, 1984; Lazarus, 1991, 1998, 1999). Also, as a result of being competitive, the competitive tasks are more likely to be perceived as meaningful, increasing the tendency of benign appraisal, which again is important for being engaged. Being engaged and believing in one's abilities as resources to cope with the competitive task, are important elements for reaching a flow state. A flow state is more likely to happen when the challenge and skillset is well balanced, but when unbalanced it is more likely cause frustration and/or anxiety, hence aggressive behavior (Csikszentmihalyi, 1975, 1990, 2000; Csikszentmihalyi and Larson, 1987; Csikszentmihalyi and LeFevre, 1989).

Flow had the strongest positive relation with the need for competing, even stronger than achievement orientation (**Table 4**), confirming the assumption of the importance of the competitive factor (need for competing) in enjoying the participation of competitive tasks and reaching a highly engaged and focused psychological state. Flow had as expected from past research (Csikszentmihalyi, 1975, 1990, 2000; Stavrou et al., 2015), also in this present study significant strong positive correlations with achievement orientation, self-efficacy and emotional assessment, and a negative relation to the three anxiety dimensions, and a somewhat surprisingly negative correlation with grit (see **Table 4**).

As expected, the prediction of a negative relation between anxiety and the NCI was confirmed. This further strengthens the theoretical and empirical explanations that a highly competitive individual will more frequently respond in an aggressive fight response, rather than in an anxious flight response (Cannon, 1914; Bossuyt et al., 2014; Wu et al., 2018). Grit was negatively correlated with the NCI. This might suggest that being competitive (need for competing) does not necessarily mean that the individual contains a highly persistence for reaching his/her goals in competition (grit), but the combination of the two traits might be even more associated with successful competitive behavior than past research has revealed (Elias, 1981; Duckworth et al., 2007; Roberts et al., 2007a; Jordet and Hartmen, 2008). A possible explanation for the negative relation between grit and NCI might be that a highly competitive individuals will more often find competitive tasks attractive, hence making it harder to stay focused and resistant in only one specific competition, or to only one specific goal. Another plausible explanation might be that although being competitive contributes to positive emotions, engagement, flow and better performances when faced with challenging and reachable competitive tasks (Elias, 1981; Roberts et al., 2007a; Jordet and Hartmen, 2008), it can also contribute to negative emotions and aggressive behavior when faced with unreachable and frustrating competitive tasks (Couppis and Kennedy, 2008; Carré and Olmstead, 2015; Carré and Archer, 2018). The fact that highly competitive individuals turned out to be less persistent in reaching their competitive goals can simply be a result of poor goalsetting skills. Guiding the competitive individual when facing competitive tasks by setting challenging and reachable goals with the possibility to advance in higher levels later might help to keep the competitive goals in the same competition interesting and enjoyable (Burton et al., 2001).

In the final prediction, the elite prospect students were expected to score higher on the NCI than the students specializing in sports and the general high school education students. Study 2 confirmed the prediction, which further supports the assumption that highly competitive individuals are more likely to seek and participate in competitive environments. It also raises the question of the importance of the need for competing for successful achievement behavior.

Limitations

Although some minor weaknesses have been mentioned in this paper, four major limitations are acknowledged in the current research. First, relying exclusively on a self-report questionnaire to measure the need for competing, which is an instrument with several limitations (Lucas and Baird, 2006). Although confidentiality was assured in both studies, some participants may have been more motivated than others to look good, leaving the NCI vulnerable to social desirability bias. Also, despite the fact that the five items in the NCI have a satisfactory internal validity, developing more items would still strengthen the validity of the questionnaire. The third limitation is that the current findings do not reveal how the need for competing is related to other converging and diverging variables known to predict achievement behavior, such as testosterone (Simon and Lu, 2006; Nelson and Trainor, 2007; Carré and McCormick, 2008; Carré and Olmstead, 2015), optimistic explanatory style (Seligman and Schulman, 1986), emotion regulation (Karrass et al., 2006), and emotion-focused coping and reappraisal (Oakland and Ostell, 1996). Finally, there is concern when using students as samples for psychological studies regarding issues of representativeness, generalizability, and comparability of results, as students are usually more educated than the general public (Henrich et al., 2010; Hanel and Vione, 2016).

Future Research

Based on the current study, some future directions need to be highlighted. The vast majority of the studies are basing achievement orientation as a main predictor for achievement behavior (McClelland et al., 1953; Maehr and Nicholls, 1980; Dweck and Elliott, 1983; Nicholls, 1984; Elliot, 1999; Elliot et al., 2011; Mascret et al., 2015). The evidence presented in this study argues the case for the necessity of a competitive orientation as well for a better prediction of achievement behavior. Since competitiveness has been mainly associated with the desire to win at all cost, which could lead to bad sportsmanship and cheating, future studies are suggested to further investigate how the need for competing (enjoyment of competition itself rather than outcome) might lead to less anti-social behaviors in sport, and proposedly in other domains.

For future studies it is also suggested a bigger set of items in the NCI for increasing its validation, as well as a further exploration of more converging and diverging relational factors. For further investigation and validation of the need for competing construct it is also suggested that the NCI should be further analyzed with both the exploratory factor analysis and confirmatory factor analysis. Including the confirmatory factor analysis for future research might help finding the factor structure of the need for competing. Finally, future research should involve larger and more varied samples to improve representativeness, generalizability, and comparability.

CONCLUSION

Studies have been conducted on competitiveness and the achievement orientation as two noncooperative explanations for achievement motivation and achievement behavior. But a complimentary representation of a competitive-achievement orientation was yet to be explored, and also the objective of the current study. By developing and validating the NCI, and additionally investigate its relations with achievement orientation, emotional assessment, self-efficacy, grit, anxiety, and flow, for further validation, gave a solid foundation for a competitive orientation and its relation to the achievement orientation. This opened a possibility to include the competitive orientation with the achievement orientation. Although, the findings should be carefully interpreted due to limitations in the present data. These results encourage debate for including a competitive-achievement orientation in future research with the aim for a stronger predictor for achievement 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

The studies involving human participants were reviewed and approved by The Norwegian Centre for Research Data (NSD). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RL and KS contributed with guidance surrounding method design, data analysis, and proofreading. All authors contributed to the article and approved the submitted version.

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Humanitarian Athletic Participation and Identity Work

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Numerous studies examine youth purpose and volunteerism, but only few investigate how altruistic activities shape identity development within athletic contexts. Endurance-based humanitarian fundraising teams are becoming increasingly popular forms of volunteerism among adolescents and young adults in the United States, but little is known about their developmental role. Twenty-four participants (15–21 years of age; $M = 17.42$) were interviewed to identify the prominent themes that arose from their experiences while training for and participating in a marathon. A thematic analysis was used to determine the dominant themes that characterized the intersection of humanitarian marathon training and running with aspects of identity work. The majority of the comments of the participants were directly tied to their experiences in running the marathon. Four themes were identified including identity work, faith, purpose, and social connection. More so than exploring their possible selves, a consistent theme throughout the interview with the participants was what they learned about their current selves and the capacities they already possessed during their marathon experience.

Keywords: purpose, athletes, identity, adolescent and youth, marathon athletes

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INTRODUCTION

In the field of developmental psychology, there is a growing interest in how the youth contextualize "purpose" and what it means for them to have a purpose in their lives (Malin et al., 2014). Studies investigating positive youth development have characterized purpose as a critical marker of healthy adolescent thriving (Bundick et al., 2010). Researchers have posited links between higher levels of purpose and increases in the motivation to do good deeds, and they describe purpose as a galvanizer of character growth in adolescents (Damon et al., 2003).

Volunteerism, the act of helping another without material rewards (Haski-Leventhal, 2009), has often been studied alongside purpose. A reciprocal relationship between the two has been proposed such that higher levels of purpose may increase the motivation to volunteer, and volunteerism may enhance a sense of purpose (Law and Shek, 2009; Bronk and Riches, 2016). Although the interface between purpose and volunteerism in adolescents has been well-documented in works of literature (Penner, 2002; Barber et al., 2013), volunteerism encompasses a panoply of activities that differ in meaningful ways. In particular, little is known about how the physical or psychological difficulty of volunteer engagements might affect the development of purpose.

Charitable marathon running, a physically taxing activity that requires strenuous hours of preparation before and including the day of the activity, has increased in popularity over the past several decades (Woolf et al., 2013) and provides adolescents with the opportunity to engage in exercise that is connected to an altruistic purpose (Fernandez et al., 2016). Most studies

operationalize volunteerism as non-strenuous (e.g., "Helped out at school" and "volunteered time"; Taylor et al., 2017). Because strenuous physical activity has been shown to have positive physical and mental health effects on the youth, particularly in group settings (Vilhjalmsson and Thorlindsson, 1992), it is important to examine how the youth perceive and contextualize purpose and a "sense of self" when engaging in volunteerism that is inherently physically arduous.

Purpose and Identity Development for Adolescents and Emerging Adults

There are some differences in how purpose has been defined and measured in the various sub-fields of psychology. The field of developmental psychology tends to adhere to the definition of purpose according to Damon, which is "a stable and generalized intention to accomplish something that is at the same time meaningful to the self and consequential for the world beyond the self" (2009, p. 33). Within social, personality, and positive psychology, McKnight and Kashdan (2009) focused on how purpose provides a sense of meaning in life that organizes and stimulates goals by influencing actions, thoughts, and emotions to support that central aim. The main difference between these definitions is that the motivation to make a difference in the world beyond the self is a requisite in developmental psychology only (Bronk, 2013). The common theme across the definitions of purpose in life is the catalytic and organizing role that purpose has in the sense of identity and interaction with the world of a person. Thus, purpose and identity have been highlighted as mutually influencing each other (Bronk and Baumsteiger, 2017), but further research is needed to know how these two concepts are related (Houltberg et al., 2018).

Identities are generally defined as the subjectively construed understandings people have of who they were, are, and desire to become (Brown, 2015); as such, they are dynamic and develop throughout life (Bogaerts et al., 2019). Identity work or identity development is the process of continuously developing a deeper understanding of the self if enabled (Arnett, 2015). Identity work refers to self-exploration and self-reflection processes that are used to understand how a person fits in their proximal environments and the broader world (Morgan, 2012). Grotevant (1987) noted how identity is often construed as a stationary status that is used to correlate to other outcomes; however, he framed the concept of identity *work* as a motion of exploration (including the motivation to explore, the exploration process, and identity evaluation), which is interrelated with individual characteristics and the characteristics of the systems in which they are embedded (e.g., society, family, peers, school/work, and teammates; Grotevant, 1987). This is particularly salient in studying the role of purpose in identity work, as purpose can function as a catalyst for exploration, shape the exploration process, and influence the evaluation of the identity of a person.

The identity exploration process often begins in the period of adolescence (10–18) due in part to brain maturation, which impacts the meta-cognitive abilities of adolescents and their heightened social comparison to peers. The experiences throughout the high school years of these adolescents have been traditionally seen as formative in shaping the self-narratives of adolescents, as they identify their interests and competencies (Erikson, 1968; Marcia, 1993). This time of exploration and self-understanding has recently been shown to continue into the transition to adulthood for a large number of young people in western contexts as they try to navigate the shift toward more independence and self-determination (Arnett, 2015; Gates et al., 2016, Meca et al., 2015, Schwartz and Petrova, 2018). For this reason, a strong sense of purpose may be particularly important for adolescents and young adults by providing cohesion around character traits, morals, and values (Lerner et al., 2015) as they navigate intense times of identity exploration and self-focus (Arnett, 2004; Morrissey and Werner-Wilson, 2005; Bronk and Baumsteiger, 2017; Malin et al., 2017).

The identity work that helps form purpose involves individuals self-reflecting through new experiences to better understand their personal "self-schemas and group schemas" (Howard, 2000). Schemas are an extension of identity that guide people to understanding their purpose. Specifically, self-schemas refer to the characteristics of the self, such as personality traits and behavior patterns (Howard, 2000). Group schemas are "analogs to stereotypes…gender, race, age, or class" (Howard, 2000, p 368), which may also be relevant to purpose formation in identity work. Present studies show higher levels of life satisfaction when people better understand themselves and maintain a more purpose-based narrative, showcasing a "global-self-worth" (Houltberg et al., 2018). Further research is needed to better understand how to facilitate opportunities for the youth to engage in purpose-promotive identity work through various activities.

Youth Altruism and Volunteerism

Even though purpose in life holds much potential for enriching the lives of young people and improving communities, only one in five high school students and one in three college students across multiple studies can report a clear purpose in life (Bronk, 2013). These low numbers can be linked to either the disruption in the identity work of an individual or could be due to the individual being in the initial stages of identity development. Research does suggest, though, that participation in youth programming can universally increase purpose among the youth (with some exceptions; Blom et al., 2020). There has been ample research examining the types of purpose in qualitative research (Bronk, 2013) and the prosocial behavior correlates of purpose (Malin et al., 2014). However, such studies tend to be limited to the youth who are just beginning identity work and purpose orientation during adolescence, and these studies do not fully examine the processes by which identity work connects youth activities to purpose.

Other studies have addressed process questions by examining how young people experience and connect to purpose through engagement in altruistic activities (Bronk, 2012; Hill et al., 2014), which are defined as acts that appear to be motivated by the consideration of the needs of another individual rather than one's own (Piliavin and Charng, 1990). Engaging in altruistic activities, like charitable marathon training, provides an opportunity for young people to connect to and/or strengthen their sense of

purpose (Law and Shek, 2009) in a way that requires personal action (e.g., raising money for clean water) and a sacrifice of time and energy. It does this by assigning the individual a specific role in achieving a meaningful goal, often in a group of peers and adults. Young people are immersed in a microsystem that is well-situated to activate self-reflection in response to embodied experiences that change their understanding of the self, thus enabling a better understanding of their purpose (Haski-Leventhal, 2009).

Some researchers have even suggested that altruism and volunteerism are essential activities needed for a healthy transition to adulthood (Piliavin and Charng, 1990; Quinn, 1999). Altruism is a part of human development identified by developmental theorists (e.g., Piaget, see Lourenço, 1990) that corresponds with an emerging capacity to think beyond the self and find a broader purpose and meaning in activities that benefit others (Hustinx and Lammertyn, 2003; see also Hayton, 2016). Thus, altruism is a primary aspect of development (like the progressive development of abstract thinking) and aligns with Damon's (2009) framing of purpose (a "sensitivity to others in general" vs. simply doing a favor for someone else (Haski-Leventhal, 2009, p. 276). Moreover, contrary to the popular stereotypes that the youth are not interested in altruistic or volunteer opportunities, results from focus groups suggest otherwise (Morris Company, 1992). Thus, the intersection of what the youth need to be compared with what they want creates unique opportunities for communities to engage the youth, while simultaneously studying how these opportunities improve youth development and identity (Morrissey and Werner-Wilson, 2005).

Indeed, altruistic and volunteer engagements have a 2-fold positive effect by addressing the needs of the benefactors of such generous acts and providing psychological and health benefits for the volunteer. Multiple studies show the longitudinal, wide-ranging benefits of altruism and volunteerism for adolescents and young adults. For example, a study of 9,471 adolescents found significant positive associations between volunteering and subsequent income and education level 12 years later (Ballard et al., 2018). Another study found that adolescents who volunteered in ninth grade were more likely to graduate high school, even after accounting for family socioeconomic status and adolescent school adjustment (Moorfoot et al., 2015). There is also evidence that altruism and volunteerism affect health; one study found that the adolescents who volunteered at a peer mentoring program had significantly lowered interleukin (IL)-6 levels (cells that are released due to infection, disease, or tissue injuries), lower cholesterol levels, and lower body mass index (BMI) levels compared with adolescents in the control group who did not volunteer (Schreier et al., 2013). The same study found that those within the volunteer group who showed the greatest increases in empathy and altruistic behaviors also showed the greatest declines in cardiovascular risk over time.

It is important to note that the focus of the present study is on athletes based in the United States, but the population of athletes overall tends to be diverse by race, ethnicity, and nationality (which introduces additional social challenges; see Stura and Lepadatu, 2014). The concept of identity and purpose has emerged as a new major focus of research as it relates to both athlete development and athletic performance (Houltberg et al., 2018). Certainly, experiencing and overcoming adversity (Frankl, 1959) is not a phenomenon unique to the American youth or athletes.

Transcendent Purpose

Many young people also derive meaning in life from their religious faith or spirituality. Although there has been a recent decline in reported engagements in traditional religious activities for young people, the majority of adolescents report at least occasional attendance in religious services (Twenge, 2006; Twenge et al., 2015). Religiousness and spirituality have also been linked to adolescent and emerging adult reports of purpose in life (Pargament et al., 2005). Explicitly religious contexts provide opportunities for young people to form a coherent life narrative or a meaning system around a greater purpose (Furrow et al., 2004). The extent to which young people internalize their religious beliefs into their sense of identity has been consistently linked to more prosocial behaviors across different cultures and contexts (Cohen and Hill, 2007; Cohen et al., 2017).

Sports and religion share common features (e.g., both involve specific rituals and practices), and many athletes integrate religion and athletic competition in the United States (Vernacchia et al., 2000; Lynn, 2008). However, some studies have noted a possible identity conflict between religion and sports: for some young athletes, these two identities may feel incompatible (Stevenson, 1991; Ronkainen et al., 2020). This incompatibility would certainly be evident in research citing that athletes have some of the highest rates of substance use (depending on the sport; Moore and Werch, 2005), whereas higher religiosity tends to be inversely related to substance use (Miller et al., 2000; Wills et al., 2003). However, some studies indicate that religiousness is protective against substance use among athletes (Storch et al., 2002). Thus, although there is variability in whether and how well-religion and sports are integrated, the two are commonly activated by each other as young people in the United States engage in identity work.

Religion may create meaning in times of adversity, which may, in turn, promote psychological adjustment and growth (e.g., Park et al., 2009; Laufer et al., 2010). In the context of sports, athletes have reported using spiritual practices like prayers to help them deal with the pressures to perform (Vernacchia et al., 2000; Czech et al., 2004). Furthermore, high levels of religiosity in elite athletes were associated with high levels of global self-worth, which in turn were related to a positive coping with loss (e.g., turning to God for comfort) and seeing competition as a challenge vs. as a threat (Houltberg et al., 2017). A way that athletes may create meaning around sports participation is by viewing their bodies and the way they compete as sanctified or imbued with sacred meaning (Lynn, 2008). This may facilitate the ability to deal with adversity in ways that lead to more flow states during competitions (Dillon and Tait, 2000).

Social Support

The challenges of marathon training and running include the amount of time and energy required and the stress from obstacles that often occur along the way (e.g., injury, physical pain,

and motivational slumps). In this context, social support is especially important for young people throughout the process of training for and completing such a difficult task. Social support for athletes involves perceiving or receiving general or specific support from people in their social networks that may enhance functioning or buffer adversities (Hutchinson, 1999; Malecki and Demaray, 2002). Similarly, multiple studies have found that supportive relationships are critical for promoting purpose and meaning in life among adolescents and emerging adults (Lambert et al., 2013; Hurd et al., 2014; Bronk and Baumsteiger, 2017).

Sporting activity holds the potential for developing a more transcendent purpose through social interactions (Jordalen et al., 2016). For example, participating in sports exposes players to social environments that encourage athletes to discover and process social and cultural moral standards (Flanagan and Bundick, 2011). Being part of a team can also encourage a sense of community and engagement, which may promote the qualities of leadership and prosocial behaviors both within and outside the sport (Flanagan and Levine, 2010; Kavussanu et al., 2013; Navarro and Malvaso, 2015). However, some studies report mixed findings, such that participation can lead to psychological disruptions or antisocial behaviors (Fauth et al., 2007; Flanagan and Bundick, 2011; Kavussanu et al., 2013; Navarro and Malvaso, 2015), but if individuals perceive that they have social support, they can typically overcome these stressors and prevent psychological disturbances (Malinauskas, 2010). The key factor is that athletes must feel comfortable using that support system to experience its buffering effect in response to intense stressors (Malinauskas, 2010). There is a need for more research to voice the in-depth experiences of young people within sporting contexts to better understand and build more purpose-building contexts.

Current Study

Although investigations have studied purpose and altruism/volunteerism in the youth (e.g., Moorfoot et al., 2015; Abramoski et al., 2018), few have examined the role that these play in identity development within an athletic context (Houltberg et al., 2018). The current study qualitatively investigates the nature of purpose and identity work in a sample of youths training and participating in full- and half-marathons through a non-profit faith-based program supporting humanitarian efforts in different countries on the African continent.

As such, the broad research questions are tri-fold. First, how does humanitarian athletic participation interface with how adolescents perceive their identity? Next, how do the elements of altruistic athleticism (including preparation and the day of the marathon) exemplify or shape a sense of purpose in the youth? Lastly, how does the social context of athletic participation interface with meaning-making?

MATERIALS AND METHODS

Sample and Procedure

Participants were drawn from a larger study (Schnitker et al., 2019) that tracked youths over 18-weeks of training for the Los Angeles and Chicago Marathons with Team World Vision, a religiously affiliated philanthropy. The youth were recruited through high schools, colleges, and church youth groups to become part of the training teams that met weekly. Each team was assigned a team leader by the organization who provided workouts and inspiration throughout the training process. Following the approval of the Institutional Review Board (IRB), the youths were recruited from several teams who completed the marathon and marked an interest in being a part of post-race interviews on their assent/consent forms from the larger study. After consent/assent was ascertained from the youths (and parents of youths under 18 years of age), the researchers coordinated with the team leaders to conduct 30–45-min interviews with the youths. The youths were compensated with US$10 in the form of Amazon gift cards for their participation.

The interview participants ($N = 24$) were between the ages of 15 and 21($M = 17.42$; girls $n = 16$). Their race and ethnicity were self-identified as follows: Caucasian (41.7%), Latino (20.8%), Asian-American (20.8%), African-American (8.3%), and Multiracial/Multiethnic (8.3%). Further, the majority of the participants subscribed to a belief in a higher power (87.5%) and identified as Christians (83.3%). Ten of the participants interviewed were from public high schools, with eight youths from public high schools in Chicago and Los Angeles that received Title 1 funding (indicative of youth/families experiencing economic hardship, U.S. Department of Education, 2021). Twelve of the participants attended private Christian high schools or colleges (high school, $n = 6$; college, $n = 6$), and two participants were interviewed from a church youth group. Although 24 youths were interviewed, two of the interviews could not be used because of technical difficulties that resulted in the lack of audio recordings, which meant that those interviews could not be transcribed verbatim for the analysis.

Each youth was individually interviewed by a trained graduate student following a semi-structured interview guide. The interview guide was developed by the authors to encompass the physical and psychosocial experiences of training and running in a marathon, including religiosity, self-perception and identity development, and connections with others (e.g., social support). This resulted in a semi-structured interview guide that introduced five broad topics followed by a list of predetermined probing questions, as appropriate (example interview questions listed in italics):

- Self (purpose of running, self-perception, and broader life purpose)
  - *"First, tell me why you chose to train for and run in a marathon"*
  - *"Tell me more about you. How do you see yourself?" "How would your friends describe you?" Followed by a discussion of what they feared and hoped for themselves.*
- Relationships (friends, family, and social support)
  - *"You mentioned your family and friends see you as [insert descriptors from prior statements], tell me more about those relationships…"*

- *"If you can, share an example of a time when you were really struggling during training or during the race and someone close to you supported you. How did their support affect you?"*
- Adversity/Suffering (feelings of pain, frustration, and discouragement while training/running)
- *"When you were training for the race, did you ever feel especially discouraged, frustrated, or pained?" Prompted to describe those moments…*
- Body (physical experiences and awareness)
- *"Have your feelings toward your body changed during the process of this marathon?"*
- *"Describe a time when…" regarding feelings of surprise at what their body was able to do and unable to do.*
- Faith/Spirituality (e.g., relationship with God)
- *"How would you describe your relationship with God/higher power?"*

Thematic Analysis

Braun and Clarke's (2006, 2020) thematic analysis protocol was used to analyze the responses of the participants (A–E above) concerning how they described themselves, their relationships, and their experiences within the context of training for and running a humanitarian marathon. This approach has later been specified as a structured "coding reliability" form of thematic analysis (Braun and Clarke, 2020, p. 39). As one of the earliest qualitative approaches to studying performance-based athletic identity development, the goal of this work was to identify evidence for themes related to "purpose" and "identity work" (as defined and discussed in this paper). Thus, a coding reliability approach was used, involving multiple independent coders applying the coding frame (i.e., research- and theory-informed interview guide with items A–E listed above) to the athlete interviews (Braun and Clarke, 2020). The Nvivo qualitative analysis software (QSR International, Melbourne, Australia) was used to organize the hierarchical thematic categories and annotations.

A multi-phase team approach (Hill et al., 1997, 2005) was used by four members of the research team who individually read and categorized (i.e., coded) all transcripts. Following Braun and Clarke's (2020) thematic process, the research team members individually examined the transcripts for reoccurring themes among the voiced experiences. During the initial analysis, the responses were coded into broad themes that aligned with the guiding research questions (interview topics A through E). Additionally, the reoccurring patterns of identity and purpose were coded using the Identity Process Model of Grotevant (1987) as a sensitizing tool to identify the interview responses related to identity work (motivation to explore, exploration process, and identity evaluation).

Following the completion of the initial analysis, the research team met weekly to compare the individual codings to the transcripts and each other. The meetings occurred until all the discrepancies were discussed to reach a consensus on the broad themes (80–90%; i.e., "high level of agreement"; Braun and Clarke, 2020, p. 39). Then, each broad theme was refined to determine the dominant themes that characterized the intersection of the altruistic events (i.e., running in a humanitarian marathon) that were explicitly and more indirectly related to the aspects of identity development. Consistent with the coding reliability approach (Braun and Clarke, 2020), theme dominance was identified by summing the total number of excerpts coded from the transcripts for each theme and then calculating the proportion of the codes each theme represented. Having a diverse coding team with varying experience with athletics helped neutralize potential researcher bias when identifying the thematic evidence within each transcript. In addition, having clearly defined guiding concepts (purpose, identity work) for which the coders identified the evidence within the transcripts, and then discussing with the group, also enhanced analytic validity. The final themes were reviewed and agreed upon by the research team. Braun and Clarke's (2020) thematical analysis protocol ensured that the research team reported thematical categories that were consistent with the narrative the participants voiced.

RESULTS

The majority of the comments of the participants directly described their experiences while running in the marathon (350 excerpts coded from all transcripts making up 28% of the coded data). Their descriptions of these experiences touched on identity work (272 coded excerpts; 21%), faith (272 coded excerpts; 21%), purpose (213, 17%), and social support (165 coded excerpts; 13%). **Table 1** summarizes the thematical categories by keywords and illustrative quotes.

Marathon Experience (350 Codes, 28% of Excerpts)

Marathon experience refers to the comments of the participants concerning how they perceived the experience in general and how it impacted them individually. Overall, the youth realized that they could endure more, physically and emotionally than they previously thought before training for and running the marathon. They described that this resiliency to grow their endurance was obtained by reminding themselves that they were suffering for a cause, relying on their faith for strength, finding new limits within themselves, and/or the importance of training. Continuously building their foundational determination (self-control and self-motivation) was a goal of running the marathon.

> *Training for the marathon was very challenging for me and I think it was something that I wasn't expecting how difficult it would be. It took a lot of self-control to keep up with training. Like, it was a big mental battle for me. I mean, it was a physical battle of course, but a lot of it was mental for me. I could get up and I could go run, or I could just stay in bed and no one would bat an eye because it's something I'm doing that I don't have to do. It definitely helped me gain a lot of self-control and a lot of self-motivation. I learned how to motivate myself to do things. That's a great thing that I learned and I think it will come in handy in the future*

TABLE 1 | Thematic categories summarized.

Themes		Exemplary interview quotes
Marathon experience 350 coded excerpts (28% of excerpts)	Pride Importance of discipline and consistency Inspired Discovering/expanding resiliency	*"I could just keep running further and further and further, and like, I knew that. I looked ahead at the overall training schedule and I'm like, "Wow, at some point I'm going to have to run 20 miles in one day." That was at a time when one or two miles was a lot. Well, we'll get there. I started feeling better and I could reach those higher numbers and "alright, this is awesome."* *"I think I should take pride in it, but it's kind of like self-pride. You ran a marathon, you can do, there's not much you can't do now, so. It's kind of one of those things, I guess, which, I think is nice"* *"Don't give up. If you, there's no such thing as failing. Or there is such thing as failing, but failure only comes when you don't learn from it"*
Identity work 272 coded excerpts (21%)	Descriptions of self-awareness and self-growth: physical and psychosocial capacities Self-descriptions of personality, what one enjoys, or prioritizes: *family, faith, education*	*"I've always been a runner, but sometimes when I look at myself, I'm like, you don't look like a runner. Like, I know you can run, but you just don't have the body type of a runner–other than I have unusually large calves, so those kind of look like running material. But other than that, mmm, not so much. As I was training for the marathon and, like, watching other people train, I'm like, wait a second. Like, there is no specific body for this. You are doing what everyone else is doing. You are training. You are working hard. You are waking up at the crack of dawn to get your runs in. Your body is clearly prepared for this, and even though it doesn't look like what you see in the magazines, like, it's ready and it's working toward this race and it's being trained and conditioned. It's your body. It's your body. It's not supposed to look like somebody else's, and it's ready for this. So, I think I gained an appreciation for my body as it was and as it was able to carry out this crazy task of running a marathon."* *"Okay. I think my top three are always my faith, my family, and my friends. Umm I think my family, the relationships I have with my family and my friends umm are directly dependent upon my relationship with God and that kind of just sets the tone for everything else"* *"I feel like, physically I can do a lot more because, before I started training one mile, that just didn't sound fun at all. Now I'm like, if you ask me to go run five miles right now, I should be good. Bring it on, no problem. Ten miles, I'd be like, uh maybe I'll think about it. But yeah, I feel like I can do a lot more now. I feel more confident. I feel like I'm definitely going to do the marathon next year."*
Faith 272 coded excerpts (21%)	Dependency on faith for resiliency and strength Internally motivated to fulfill "*God's purpose*" or "*His plan*" Utilizing faith as a tool for self-reflection	*"I love bringing problems that I've had, that I have and am going through, before God because it makes me feel like that someone is there with me, and I know that he's there with me. And it's encouraging, especially through marathon training. Sometimes I imagine God is right there running next to me or running behind me, kicking me in the back, making sure I'm going"* *"God just really laid it on my heart to run the full marathon um and try and just make an impact umm and just help out the people TWV helps. Umm, so I would definitely tell them to pray about it. Umm and then if they umm really feel like umm if God keeps laying it on their heart to really just umm, just train, umm, the training just really helps a person get through everything, but they also have to look to God for strength, because they can't even with the training umm I feel like they just need God to be there with them, umm so I would tell them to pray about it and um to train but while they're training to keep praying and keep looking to God for the strength to help them get through the race."* *"I mean that's again like being dependent on God comes in, and like I said, like saying the Lord's Prayer like over and over again, crying out to him, like, um, that's the only thing I could do. Um, like the Bible says, "mourn with those who mourn, or rejoice with those who rejoice." Or, like, we are supposed to, in regards to like, those who suffer their faith, believers are supposed to be with believers, we're supposed to join with those in the midst of what they're facing umm, and that's something that I don't take lightly, I guess, in regards to we are one body, so we take on what each other faces, the problems of other people become your problems. Um, the difficulty of not having water, I want to join with those people. I want to know what it's like to have to walk miles and miles and miles. I want to know what it's like to have to face diseases from drinking water that's not clean. I want to, I want to know what that's like, because I want to know that those people"*
Purpose 213 coded excerpts (17%)	Focus on self/performance Focus on *"God's will"* Focus on the needs of others	*"I really have just been more aware of the things that I'm doing and whether I'm doing that for myself, or whether I'm doing that to fulfill God's purposes for my life,…it started off as my childhood dream, I really wanted to [run a marathon]....My focus shifted. It's not for me it's for these kids that none of us even know, but it's for these kids that have to go without even having clean water."* *"Definitely mile 18 was where [purpose] motivated me because I was really, really hurting, and I knew that I had to finish this and it was for the kids, and it was for the clean water. So just thinking about that the entire race, and especially right at the end where I knew I had to finish - I could see the finish line. I had it so close and this was what I was working for. It just all came clear at the end."* *"I think part of it was just running a race in general is really fun, umm and I love to run, and I like having a schedule to uh to train for something and to be able to have a goal and work toward it. Umm but I think the bigger part of that was kind of putting something that I love to do so much and giving it a purpose and I think umm running and raising money for umm children that have to walk four miles or more uh to get water that might not even be clean umm I think knowing that what I was doing was helping somebody else maybe on the other side of the world was umm a motivating factor"*

(Continued)

TABLE 1 | Continued

Themes		Exemplary interview quotes
Social support 165 coded excerpts (13%)	Growing relationships: *friends, educators, family, marathon supporters* Community/Team environment Reliant, dependable	*"I told my teacher, you know like my knee is hurting really bad, I can't, so he really helped me umm, you know okay well take it step through step, you know you feel bad, umm just keep on walking, and he actually when we ran a long distance, he helped me umm we walked it through the way back to school, you know because I couldn't run. That was really a connecting moment with my teacher"* *"'Hey, why don't you write your name on your jersey?' And like, 'alright I don't see why, I guess I will, why not.' Then I realized why: people will cheer out, call out for you and be like GO! And I couldn't help but smile every time. And then like for most of the race, I just had a smile on my face. And that really, that really helped a lot more than I thought it would."* *"When I first told my mom I was running a marathon she was just like, I think you're crazy. But um she, she didn't try to talk me out of it or anything. She was like, if this is something you want to do, then you should definitely do it, and I'll pray for you along the way and help you with anything you need. So I'm really grateful for that. My friends are also very supportive. They all came out to cheer us on. There was a couple other of my friends, in my big group that ran, and so the rest of them all came out and cheered us on. Yeah, they're very supportive, which is great"*

Many expressed awe at what their bodies could do:

> *I could just keep running further and further and further, and like, I knew that. I looked ahead at the overall training schedule and I'm like, "Wow, at some point I'm going to have to run 20 miles in one day." That was at a time when one or two miles was a lot. Well, we'll get there. I started feeling better and I could reach those higher numbers and "alright, this is awesome."*

Even the participants who identified themselves as experienced runners (e.g., cross-country and track) or approached the marathon as a competition made discoveries about their physical and psychosocial capacities and began to pay closer attention to their well-being. As one participant expressed:

> *I got to be physically fit and (running) actually did help me feel better… It kept me on track with things, so I wouldn't procrastinate as much … and it just made things generally better. Yeah, it just kind of improved everything else.*

Another commonly voiced perspective among the participants framed the marathon as an accomplishment and/or something that they took pride in completing. This experience also enabled another common response of growth in self-confidence, as one participant explained, "*I just did this kind of thing? It's kind of like self-pride. You ran a marathon, there's not much you can't do now*."

The participants that had to overcome an injury caused by training or running the marathon were consistent throughout the responses. These responses also included youths voicing pre-existing injuries that they anticipated would need special care or meticulous attention while training. Based on how these physical hardships were framed, they appeared to serve as pivotal aspects of the marathon experience. As one participant voiced:

> *On the 20-mile run, my right knee started going numb, and I locked up at the halfway. On the very last mile, and I couldn't run anymore, and I was afraid that was going to happen during the marathon. That was one of the reasons I was considering not running. But, I was talked back into it, and at mile 19, it started going numb again. I had seven more miles to go and I didn't know what to do. So, I tried limping and I limped in a way where the numbness would go away, and then I could jog for a bit more, not long, and then the numbness would come back and I'd have to do that again. So, for the most part, I was limping the last seven miles. It got tough… If I can keep pushing it, and as long as I have the will to, I can keep pushing. There's always going to be some energy to expend and use, so I turn to myself. There's never really going to be a limit if you really, really look at it. There's not really ever going to be an end as long as I have something to eat, have some energy, I'll be able to keep going. Also, I have asthma going into (the marathon). Part of my reasoning was so people wouldn't have an excuse not to do something. Because, like, if I have asthma and I'm not a runner, and I went in with four different injuries that I had to keep an eye on, and I limped the last seven miles… I'm like, "Alright, I don't really have any excuse not to do things now, because I went through all of that and ran a marathon."*

All-in-all, despite the physical and emotional struggles, the youths described finding joy in participating in the marathon and expressed a desire to do it again or encourage others, particularly non-runners, to do it.

Identity Work (272 Codes, 21%)

Identity work refers to the comments of the participants concerning self-awareness or self-talk as they reflect on how the activity relates to their identity. For example, the participants often described themselves using brief descriptors (e.g., introvert, student, determined, not a runner, simple, open-minded, sister, young, and athletic). However, other responses specifically touched on self-growth, generosity, competitiveness, and the importance of family, faith, and education in their identity work. One significant pattern that was discussed by the participants was the growth of their self-awareness concerning their physical and psychosocial limitations. For example, a participant stated, "I became more aware of, like, what my body is capable of, but I was shocked to know that my body is more capable of what I thought. So, I was blocking my athletic abilities mentally." Through engaging in this marathon experience, participants described how they were able to understand themselves better, both mentally and physically. Additionally, one participant was able to encapsulate the common narrative of how the marathon experience affected body image and developing identity:

"I've always been a runner, but sometimes when I look at myself, I'm like, you don't look like a runner. Like, I know you can run, but you just don't have the body type of a runner – other than I have unusually large calves, so those kind of look like running material. But other than that, mmm, not so much. As I was training for the marathon and, like, watching other people train, I'm like, wait a second. Like, there is no specific body for this. You are doing what everyone else is doing. You are training. You are working hard. You are waking up at the crack of dawn to get your runs in. Your body is clearly prepared for this, and even though it doesn't look like what you see in the magazines, like, it's ready and it's working toward this race and it's being trained and conditioned. It's your body. It's your body. It's not supposed to look like somebody else's, and it's ready for this. So, I think I gained an appreciation for my body as it was and as it was able to carry out this crazy task of running a marathon."

Many of the comments shared about self-awareness and self-growth overlapped with faith orientation. Most of the youths identified with the need to help others and found the marathon experience, combined with the faith orientation they used to get through it, helpful in encouraging them to become more disciplined and determined, test their limits, and push themselves out of their comfort zones to explore other possibilities of who they could be. However, overall, the self-talk of the participants was brief and commonly within the context of faith or athletics. The participants lacked the descriptive elaboration about who they are, characteristically, as persons.

Faith (272 Codes, 21%)

Likely due to the faith-based nature of the organization for which the youths were running, many of the interview comments intersected with their religiosity. Discussions of religiosity were found throughout their comments on why they ran, relying on their faith for resiliency, utilizing their training as a time of worship, and using faith as a tool for self-reflection and growth. The participants overwhelmingly described themselves as relying on God while running as a source of strength (e.g., healing, taking away pain and suffering). It was apparent that some participants viewed running as a time for prayer and reflection. Many said that they used prayers to keep them focused on their training or breathing and to distract themselves from the pain of the marathon. As one participant expressed:

"My prayer life, that's like my time with God when I run. I mean, I do listen to music, but like not very much. I would just pray, especially for other people, because it kind of helps to not think about how much pain I'm in when I'm thinking about others and the different things going on in life. It's just time to feel, to kind of be like, you're not stuck with God, but it's literally just you and God on your 15-mile run, and so I think that was a really cool experience."
"I walked and I was really praying. I was like, God, I know this is a training run. I know I can quit whenever I want... I'm this far away from the finish line. I can't turn back now. God, just help me please. We both know why I'm doing this. You know my heart, you know everything that's going to happen, and your will be done - but at the same time, help me get through it."

The youths also attributed their faith as the key reason why they opted to participate in the marathon experience in the first place. Specifically, they described using their talents ("gifts") and physical self for "God's will" or purpose. As one participant described:

"After the race, I feel more like I've been using my body for the purpose that God designed me to. I feel like before the race, I was using my body to glorify God and try to spread his love, but not necessarily listening to God the way he wanted me to use my body to glorify him. I was more using it for my own purposes."

They also commonly expressed how they were doing it to help others who were less fortunate, but additionally explained that the purpose of their generosity is internally motivated by their faith. They reported a sense of fulfillment from feeling like they were accomplishing this purpose. They were helping others by simply sharing their faith and using their ability to run. The enhanced focus the runners had in their bodies, both in their purpose for running and struggling during the experience, was described as helping them grow their faith.

Purpose (213 Codes, 17%)

Purpose can be framed in various ways. For the current study, purpose refers to the explanation of the participants as to why they participated in the marathon or defining their internal motivators. All runners consistently said that their purpose for running was to support a good cause and to help others. However, the complete descriptions of "why" they participated in the experience incorporated the following perceptions: (A) focus on self/performance (e.g., "I ran because last year I did the half marathon and I tried to challenge myself and do the full marathon"), (B) focus on "God's will" (e.g., "I am just kind of searching and trying to learn how to be a follower of God and how I can just use myself to tell others about him and just serve him"), and (C) focus on the needs of others (e.g., "I don't know who I want to be...but I want to benefit society").

Focus on Self/Performance

Several participants described the need to run, exercise, or get healthier as their internal motivation. These youths tended to be athletes who needed a goal to keep them in shape or others who needed a goal to motivate them to become healthier or more fit. A common pattern within this perspective is that the participants voiced a shift in the goal of the marathon they originally set out. It started out being about working out or maintaining a body image, but then during the training process, they voiced an additional goal of wanting to complete it for the sake of the children in Africa. As the following participant expressed:

"Second semester of last year, I hadn't been working out like I wanted to. I wasn't really feeling like I was being in shape and I needed something, like a good reason to, and I just happened to hear about the marathon in chapel, and I thought 'I'm probably not going to do this,' but then I had chemistry right after, so I can stay for a bit. So, I stayed and I decided to hear what they had to say. Really thought I could just not do it. And I ended up deciding I could go for it, just kind of on a whim, and I'm really glad, because…starting out it was just for me, for like my physical health, but now it's also

been able to help those kids in Africa. I didn't raise my goal, but still it was enough to help. So, that was nice."

Focus on the Needs of Others

Putting themselves through the physical struggle for a humanitarian effort to connect to the transcending purpose of helping others was defined by some participants as the goal for why they participated in the marathon. As this participant describes:

"It's probably the hardest thing I've ever done, and in terms of suffering…It's definitely suffering. I would never run, I don't think. I've told myself – and I told everyone – 'I would never run a marathon or race for fun because it hurts too much.' I think, in the midst of that suffering, you get a glimpse into what it's like to walk miles and miles to get water that's not even clean, but I think that's why I run…because I want to get, to feel that, to know what it's like. Like, I want to be able to join with those people, umm, and then in the end to relinquish that (suffering) from them – like, give them the opportunity to not have to feel that anymore."

Others in general did it because it was for a good cause and directly helped children. It was not necessarily about the suffering but using the good cause as a motivation to endure the suffering.

"Definitely mile 18 was where [purpose] motivated me because I was really, really hurting, and I knew that I had to finish this and it was for the kids, and it was for the clean water. So just thinking about that the entire race, and especially right at the end where I knew I had to finish - I could see the finish line. I had it so close and this was what I was working for. It just all came clear at the end."

Focus on "God's Will"

The majority of participants verbalized their purpose as wanting to live their lives "for God." For example, one participant expressed, "I would tell God, I was like, 'God, I know I'm doing this for a greater purpose, and I know I'm doing this for myself as well, but, I just want to do it ultimately for you."' This was described as a motivating factor to run the race, but also overlapped with a more general sense of self-purpose to live their lives "for God." Several youths described this as a tension between doing things for themselves and a higher purpose.

However, to fulfill this transcending purpose, they described depending on their faith to get them through it.

"You have to be more dependent. Your dependency on Him becomes so much more, especially if you're not a runner. Um, because you're like, 'God, I want to do this. I want to run – to provide this for these people, um, but like, I need you more than ever because I'm not a runner. Like, I don't know how to do this.' Ultimately…you're running to provide water, but in the end, you're running for God's Kingdom."

Overall, the participants voiced their internal motivators. The individual differences in explaining why can be seen in the differences in detail as to what their internal motivators or purpose are.

Social Support (165 Codes, 13%)

All participants described some form of social support that they relied on while engaging in this experience. The most common social support for the runners was their friends or peers who also signed up for the marathon. This group of friends was seen particularly as a group of co-sufferers. For example, a participant expressed, "It was just a mutual understanding of– 'we're all in pain, so let's just take it easy.' It was nice to have that understanding, especially with friends." This description is related to recovering together as a group and enduring the training together. The participants relied on their friends to run with them, help them stay accountable to train and provide emotional support, financial support (through donations), and overall encouragement. For most—but not all—youth, their faith was also interwoven with their experiences of social support.

"It really helped me grow in my faith as well, just being able to train with these people and pray with these people about, um, not only just running, but about other things in our lives. Like, we were able to build relationships where we were truly concerned about each other and about what everybody was going through."
"So, I feel like that really played a role in my ability to build relationships and my faith as well. The people that I trained with always had like a group prayer, and we always had a really strong bond, um, even if I didn't know them that well. It just seemed like there was an automatic connection. I think the group prayer and pep rally before the race really had an impact."

The family was also described as meaningful support during the marathon, but mainly through financial donations, transportation, and other instrumental resource provisions. There were a few runners who mentioned relying on their family members for emotional support or encouragement, but more than half of the runners mentioned friends as fulfilling their emotion-focused needs. Participants said they either made new friendships through training for the marathon, built on old relationships, or both.

The teachers and church groups played a role in social support, as well. In some cases, there were a few teachers that were consistently mentioned by the runners because they were their point-person for the humanitarian organization. Each runner also discussed the supportive crowd and volunteers. They found that their signs, the loud cheering, and the calling out of their names were inspiring and motivating to keep them going. A few runners even stated how it made them smile, cry, and made the marathon a little easier to complete.

"It was like (miles) 14 through 18 were just like, oh my gosh, like we're only halfway, like this is really hard – this is really hard. And then we got to mile 18.5 and I think we started crying because there was this huge cheering station. Umm, all of our friends from our community on campus, and there were like 25 of them, they had signs, and they had bells, and some of them started running with us. Like, we both lost it. That was one of the many times during the race we started crying. Umm, but they just constantly asked us, like okay, 'What do you need? What can we get you?"'

The participants expressed how they would be unsure how they would have accomplished running the marathon without social support.

DISCUSSION

The findings from this study suggest that running and training for a charitable marathon provides an ample opportunity for identity work in adolescents and emerging adults. The youth in this study described the relational, emotional, and spiritual experiences that revised their self-narratives (research question 1), promoted a transcendent purpose (research question 2) and strengthened their connections to others (research question 3).

Looking at the first question this study aimed to investigate, enduring and participating in the marathon positioned the runners in an environment that enabled self-reflection, as it was voiced to be a part of the process of understanding their physical and psychosocial capacities through training. The physical and emotional demands of preparing for such an endurance race expanded the views of many of the participants on their capacity to overcome pain and adversity and of their bodies. Several participants associated this newfound resilience with being able to face life adversities and challenges in a new way. This is consistent with previous research that has linked sports participation to life skills in other domains (Flanagan and Levine, 2010; Kavussanu et al., 2013; Navarro and Malvaso, 2015), but the current study would suggest that charitable endurance-type sports may be uniquely poised to help young people discover new capacities and strengths. Findings suggest that identity work in this context occurs at the intersection of purpose, religiosity (if a factor in the life of the youth), experience, and physical or psychological self-awareness. Previous studies have identified potential conflicts between athleticism and purpose or faith (Stevenson, 1991; Ronkainen et al., 2020), so more research is needed to understand in what contexts and with what sources of support can sports training enhance vs. deteriorate well-being and performance. However, the present findings suggest that the faith-based marathon-training context is one location for integration.

Next, we asked: How do elements of altruistic athleticism (including preparation and the day of the marathon) exemplify or shape the sense of purpose of youths? Charitable marathon running may be particularly salient for shaping purpose because it offers a personally meaningful experience, goal orientation, and a beyond-the self-motivation (Bronk, 2013). The participants in our study addressed all three of these key components of purpose in relation to their self-understanding. The young people described the meaningful experiences in overcoming challenges, having motivation toward accomplishing goals, and being action-driven by those motives. This is consistent with the emphasis of McKnight and Kashdan (2009) on the motivational and goal orientation components of purpose that fuel the pursuit of a future aim. For some participants, motivation was derived from the challenge of running a marathon, and they organized their goals and life around this purpose.

Moreover, most of the young people described beyond-the-self motivation as the primary orienting purpose emerging out of their self-reflection during the race, highlighting how the social context of athletic participation interfaces with meaning-making. In response to our third research question, purpose seemed to create a psychological cohesion around values that sparked meaningful identity work among the runners. For these young people, their self-narrative seemed to center around this greater purpose and meaning that translated to deeper self-knowledge and empathic thinking toward others. These narratives highlight the important role that purpose may have in identity formation for young people (Bronk and Baumsteiger, 2017), especially in sporting contexts where young people often build their identities around their athletic performance. Houltberg et al. (2018) found that elite athletes with purpose-based identities compared with those that have performance-based identities reported higher levels of psychological well-being and emotional resilience through adversity.

The participants also said they relied on beyond-the-self motivations to overcome moments of adversity and described these moments as transformational. This is also consistent with Frankl's (1959) classic view that purpose enables people to overcome adversity and challenge, further highlighting the potential potency of a "noble purpose" in the identity formation of young people (Damon et al., 2003). Our participants drew inspiration from their connection with God and used spiritual practices like prayers and scriptures to help them during, particularly difficult times. These findings are consistent with research on the role of goal sanctification, religious meaning-making, and spiritual practices during difficult times (Pargament and Mahoney, 2005; Park et al., 2009).

The participants also recalled a strong focus on the struggle of the children and families for whom they were fundraising, which provided a substantial transcendent motivation during difficult times of training or racing. By focusing on the pain and suffering of others, many of the participants were able to embrace their suffering for this greater purpose. Our findings suggest that there is something unique about transcendent motivations that may be especially important during difficult times and may sustain character virtues over time (Schnitker et al., 2019).

The supportive community within the training groups was also highlighted as critical for many of the young people in our study. The shared purpose of training and running for the greater good of others facilitated meaningful connection and support. Not only does this highlight the importance of social support for purpose development in young people (Lambert et al., 2013; Hurd et al., 2014; Bronk and Baumsteiger, 2017), but also demonstrates how shared purpose can be transformational for groups. The sense of belonging within the training group community propelled prosocial behaviors toward others in the group. The shared purpose of training and running may provide a context that breaks down barriers like competitiveness and social comparisons that often inhibit strong bonds within a group. This may be particularly important for adolescents and emerging adults, who tend to experience a heightened sensitivity to social comparisons and social rejections (Hare et al., 2008).

It is also important to note the potential dangers of transcendent motivation when it undermines the physical and/or emotional health of young people. For example, athletes may feel compelled to push through pain in the name of the greater

good or even to please God. Houltberg et al. (2017) found that the elite athletes who perceived the Divine as having high standards that they could not live up to reported low levels of global self-worth and high levels of perfectionistic concern, which in turn were related to high levels of shame after disappointing performances and high levels of threat appraisals of upcoming competitions. Even youths that do not believe in a Divine being or God may feel that they let down the benefactor of their altruistic efforts by dropping out of training or not completing the race. This performance-based self-narrative could lead to psychological disruptions (Houltberg et al., 2018) or the unintended consequence of youths pushing their bodies in unhealthy ways that can lead to lasting injuries. It may be important for coaches and other supportive adults in charitable endurance activities to counter these messages with the importance of body awareness and motivation behind goal pursuits.

Additionally, the tendency toward social conformity in charitable sports may also have a negative side when the messages are unintentionally reinforced to motivate the youth to persevere or endure pain in unhealthy ways. This type of social norm or motivation in the name of the "greater good" could be a way to baptize harmful sports ethics that encourages athletes to sacrifice their bodies in the name of pursuing a goal. When youths are experiencing adversity (particularly physically during extremely strenuous sports), there may be a thin line between using maladaptive strategies to endure (sometimes dangerously) pain to achieve their performance goals and leaning into their capacity to use their internal and social resources to thrive through adversity (Schnitker and Houltberg, 2016). These findings are a first step toward understanding how to help the youth navigate this line on the side of physical, emotional, spiritual, and relational wellness.

Study Strengths and Limitations

A major strength of this study is the interview with youths about their experiences training for and running a marathon with an altruistic purpose. The sample included a variety of young people from athletic and non-athletic backgrounds who all went through the same process of preparing for a marathon and then completing it. They also shared the same cooperative goal of raising money to help African communities gain access to clean water. The questions posed to the participants elicited not only their experiences of physically training and running, but they also probed into how these experiences interfaced with their senses of identity, faith life, and social connections.

However, this study was designed as an initial, exploratory step to observe the qualitative markers of identity work in these types of athletic service experiences. Based on the detailed findings, and before recommending humanitarian athletic events for positive youth development, additional mixed-method studies are needed to explore the histories and characteristics of individuals that frame participation and affect what they get out of the experience. Along these lines, more diverse participants are needed, particularly those who come from a variety of faith and non-faith backgrounds to see if the tensions and evolution of identity and purpose function similarly through these types of service activities for people with different meaning systems. Finally, the incorporation of more targeted and established identity measures (qualitative and quantitative) will be important in future research to generalize identity work observations across subgroups of the youth (athletic and non-athletic alike). The notion that difficulty and self-sacrifice (both physical and emotional) can help the youth engage in meaningful identity work has major implications for a wide variety of youth-serving programs and community experiences. However, the specific nature of the "struggle" elicited in the experience and the types of conditions in which struggle is optimal for whole-child development is unknown. Thus, this is an important direction for future researchers who aim to apply their findings directly to the practice of positive youth development.

CONCLUSION

In summary, the results in this study show that adolescents who participate in charitable endurance-type activities can be positively impacted in numerous ways. First, the engagement in these activities often facilitated the development of a self-transcending purpose that allowed the adolescents to orient themselves around values that shape meaningful identity and permeate multiple identity domains within and outside of the sporting context. Second, the supportive social components of the activity appeared to provide participants with the opportunity for prosocial behaviors that led to an increased sense of belonging, closeness to others and God, and greater empathy. Finally, the spiritual or "other" orientation contributed to the development of a beyond-the-self motivation that cultivated a sense of resiliency, leading to a greater sense of agency when faced with challenges and adversities.

DATA AVAILABILITY STATEMENT

The de-identified 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 Fuller Theological Seminary Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AT, BH, and SS contributed to conception and design of the study. AT and BH trained data collectors. AT, SB, and RF performed the data analysis. AT, BH, and SB assisted with data interpretation. AT, BH, and RF wrote the first draft of the manuscript. AT and SB drafted the results and discussion sections. BH and SS wrote critical revisions of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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The Influence of Physical Education on Self-Efficacy in Overweight Schoolgirls: A 12-Week Training Program

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The purpose of this randomized controlled study was to investigate the impact of a 12-week physical education (PE) program on the self-efficacy of overweight schoolgirls. We randomly assigned 60 overweight schoolgirls (15–17 years) to either an experimental moderate to vigorous aerobic exercise (∼90 min, three times a week) group (n = 30) or a control group (CG) (n = 30) that received non-specific regular PE lessons with activities chosen by the curricular teacher mainly focused on team games and sports skills that aimed to achieve general psycho-physical wellness (∼90 min, three times a week). To assess the starting level of students and significant changes reached, at baseline and after training, a battery of standardized assessment motor tests and a psychometric scale (generalized self-efficacy scale, GES) were administered. At the end of the intervention, the experimental group reported a considerable decrease in body mass index (BMI) and a large improvement in self-efficacy ($p < 0.001$). No significant changes were found in the CG. The results suggested that the 12-week moderate to a vigorous aerobic exercise program is an effective weight loss intervention and a vehicle to promote a range of outcomes important to the qualitative growth of adolescents. In fact, it could provide a positive and significant impact on the self-efficacy of overweight schoolgirls.

Keywords: BMI, fatness, cognitive function, health, exercise, human movement

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INTRODUCTION

Obesity, namely a state of excess storage of body fat, is a major public health concern in western countries (Esteban-Cornejo et al., 2020). It is caused mostly by improper lifestyle, i.e., on one side, unhealthy diet, while on the other, low levels of physical activity (Jakicic and Davis, 2011; Piccinno and Colella, 2017). According to WHO data, in the past few years, obesity has doubled in children and tripled in adolescents worldwide. Global estimates indicate that 27.5% of adults and 81% of adolescents do not meet 2010 WHO recommendations for physical activity. Thus, even in the latest guidelines on physical activity and sedentary behavior World Health Organization [WHO] (2020) provides recommendations for children and adolescents on the frequency, intensity, and duration of physical activity, required to offer significant physical and mental health benefits.

The consequences of childhood overweight and obesity are very alarming since it represents a condition that causes serious health damage (Włodarczyk and Nowicka, 2019). It is a major risk factor for the onset of metabolic, functional, psychosocial, or quality of life impairments, since it represents an important factor related to falls in obese adults, as it negatively impacts balance and postural sway (Bianco et al., 2014; McKelvey et al., 2019). Moreover, the most worrying aspect of this is that pediatric obesity may compromise social behavior by influencing both the relationship with the body of an individual and the others (Puhl and Suh, 2015).

Several studies have frequently documented that fatness and a higher body mass index (BMI) appear to be associated with lower self-efficacy (Bagherniya et al., 2018; Rachmah et al., 2019; Schmidt and Pichler, 2020) in adolescents, especially in girls and that physical activity has the potential to stimulate positive behavior changes in this age group (Kumar et al., 2015; D'Elia et al., 2020). Self-efficacy is defined as the belief that one has the ability to successfully engage in a specific behavior, and it is an important predictor of weight control and eating habits (Bandura, 1997; Hopkins and Bennett, 2018).

Levels of self-efficacy influence academic, social, weight control, and significant health habit performance. Individuals are able to engage in extraordinary or irrelevant behavior as a result of fluctuations in their beliefs of personal effectiveness. Those who doubt their ability avoid difficult tasks have difficulty in motivating themselves and work badly to achieve their projects (Salles, 2017). Conversely, a sense of resilient effectiveness promotes socio-cognitive functioning in many different ways. People who believe in their ability consider difficult tasks as challenges and opportunities rather than a threat (Bandura, 2012). People who expressed high levels of self-efficacy in the face of adversity remain focused on the task and think very strategically (Ashford et al., 2010). This efficient way of operating increases performance levels and reduces stress and vulnerability to stress. Their belief in their effectiveness activates and supports the involvement of the cognitive functions required to develop ability (Sheeran et al., 2016). On the contrary, considering themselves inefficient slows down the development of those sub-abilities from which more complex performances depend. Among personal risk factors for the onset of eating disorders in adolescents, the level of self-efficacy seems to take a particular meaning. According to Pont et al. (2017), overweight or obese adolescent girls show low levels of personal resources, such as self-efficacy. Previous findings indicate that adolescent girls engaged in sports activities have a higher self-efficacy than those who do not practice any kind of physical activity, and this is more evident following physical activity that requires greater cognitive involvement (Olander et al., 2013; Dishman et al., 2019). In adolescents, the relationship between female sex, higher weight status, and lower self-efficacy has frequently been documented (Losekam et al., 2010).

It is widely accepted that physical activity has a significant role in physical and psychological health since it is capable to persuade people to embrace an active lifestyle. Several previous studies support the idea that physical activity reinforces the perceived self-efficacy beliefs, which is related to changes in mood at the end of exercise (McAuley et al., 1999; Jerome et al., 2002).

As part of physical activity, a key factor in personal achievement is the belief of how to correctly perform motor skills to attain a certain purpose, namely, perception of own ability of an individual to perform a motor task. Thus, each motor experience fulfilled encourages the perceived sense of self-efficacy that is the confidence regarding the ability to successfully master a skill (Bandura, 1997; Di Battista and Vivaldo, 2015; Colella et al., 2020). Self-efficacy is linked to both the perception of the bodily self and factors that represent motor competence (Babic et al., 2014; Bardid et al., 2016). It concerns the capacity to mobilize cognitive and social resources of an individual to carry out a wide repertoire of motor skills expressible in different contexts and every activity for daily living (Robinson et al., 2015). Latest investigations (Khodaverdi et al., 2015; Dapp and Roebers, 2019) highlight how perceived self-efficacy springs from the quality of both didactic proposals and motor experiences and plays a crucial role in lifestyle changes (Colella et al., 2020).

The literature suggests that self-efficacy increases through physical activity, and that physical activity is an important mediating factor between self-efficacy and the effects of interventions on eating behavior. High self-efficacy is one of the most important indicators and predictors of psychological wellbeing, specifically about the body self-perception dimension (Colella et al., 2009). Despite self-efficacy has been linked to physical activity in overweight and obese adolescent girls, few studies were focused on targeted interventions for increasing self-efficacy and improved body composition related to physical activity in this population (Thomas et al., 2017).

Therefore, to extend the understanding of these connections, the purpose of this study was to investigate the effects of physical education (PE) program on self-efficacy in overweight adolescent girls based on the assumption that exercise could improve it also following a brief intervention. Moreover, this study has the objective of helping educational establishments to realize the significance of PE and its positive influence on physical, emotional, social, and cognitive factors. It would also be desirable that schools considered the possibility of allocating additional resources to promote the engagement of adolescents to regular physical activity because together with the family, school is the main institution to ensure healthy and balanced growth for our children.

MATERIALS AND METHODS

Study Design

We employed a randomized controlled study design to investigate the effects of a 12-week PE program on the self-efficacy of overweight adolescents.

This study was conducted in a high school, and the students took part in extra-curricular structured physical activities. They consisted of 36 lessons of moderate to vigorous aerobic exercises for the intervention group and non-specific regular PE lessons with activities chosen by the curricular teacher mainly focused on team games and sports skills that aimed to achieve general psycho-physical wellness for the control group (CG). Both the interventions were performed for 90 min 3 days per week at the end of the daily school lessons. Training sessions were

conducted in the evening from 4:00 p.m. to 5:30 p.m. on Monday, Wednesday, and Friday. The evaluation regarded 36 lessons monitoring the participants at the 1st and 12th week, respectively. Measurements were administered 1 week before training (pretest) and directly after training (posttest). To allow statistically meaningful comparisons between different types of activities, the subjects were classified as participants in activities that shared similar characteristics.

Participants

A total of 60 schoolgirls, as a convenient sample, was recruited with an age range of 15–17 years (M age = 16.13, SD = $\pm$ 0.74) from four local high schools.

In this study, participation was voluntary, and all high schoolgirls from the four local schools were eligible to participate. Inclusion criteria were the following: participants had to be a girl with a high BMI, to be able to complete a moderate-to-vigorous intensity aerobic exercise session, current students in one of the four high schools, and able to abstain from all physical activities outside the parameters of the study protocol during test days.

Any students with a normal or low BMI, those with an orthopedic condition limiting their ability to perform exercises, and those unable to abstain from all physical activity outside the confines of the study protocol on the testing days were excluded from this study.

A total of 65 subjects fulfilled the inclusion criteria and were invited to participate. Of those recruited, 60 agreed to be in this study, while five of those declined to participate due to personal reasons. As a result, the final sample consisted of 60 participants, who completed the assessments at baseline and postintervention. We matched participants randomly to one of the two treatment conditions, both included 30 overweight schoolgirls (experimental group, EG; n = 30; CG; n = 30). *A priori* power analysis indicated that 54 participants were required to detect a medium effect size (ES) (f = 0.25 or 0.4) given a coefficient of correlation p = 0.80 with 95% power and α = 0.05, using a within-between mixed design. However, to avoid experimental mortality, i.e., the loss of participants that could threaten the validity of the research design, more schoolgirls were recruited. Before the beginning of the intervention, schoolgirls and their parents were summoned in order to illustrate to them the whole plan of treatment, the study characteristics, and a complete explanation about the purpose of the experiment, its contents, and safety issues based on the Declaration of Helsinki. The researchers ensured the anonymity of the participants, and all parents of all participants provided their written informed consent before the study. This study was conducted from September 2019 to December 2019.

Procedures

The intervention programs were administered at a local public school. Before the first training session, a special briefing was given to provide an explanation of the content of the exercise training program. One week before the beginning of the intervention, participants were led to the school gym to proceed with the anthropometric measurements that included BMI and performed standardized motor assessment tests that were used to determine the starting level of the physical fitness of each participant. A cognitive test was administered to examine the self-efficacy perception of students the following day. After taking the BMI, the researchers selected a sample of 60 students and matched participants randomly to one of the two treatment conditions. The exercise intensity of each training session was monitored using the OMNI scale to respect exertion in the moderate to vigorous physical activity (MVPA) range of a 5 < rate of perceived exertion (RPE) < 8 and to avoid possible differences between training sessions (Utter et al., 2002).

The participants completed each test immediately prior to and following the intervention, at the same time of the day, and under the same experimental conditions to allow pre- and post-testing data connection and to evaluate the effects of the intervention program. Students were tested individually, and each task was explained before the participants started. Testing took 40 min for each participant. The participants wore clothing appropriate to physical activity and sports shoes throughout the intervention program. All measurements for testing and both the intervention programs were instructed, supervised, and performed by two experienced PE teachers, certified by the Italian Ministry of Education. All trials were performed using a standardized test protocol, observing the same conditions.

Measures

Anthropometric Measurements

Anthropometric measurements were obtained following a standard protocol and instruments (Weiner and Lourie, 1981). To decrease the possibility of an error during the measurement, they were performed three times each and recorded after verification by the same expert operator. After a detailed explanation of the protocol, data were collected. The subjects were sent to a private room where the measurements were taken. The height and weight of each student were measured using a digital weight floor scale with a precision of 0.1 kg (Omron HBF-375 Karada Scan, Japan) and a wall meter to the nearest 0.1 cm (Health-o-Meter Professional Wall Mounted Height Rod, PS Medical, China). For measuring weight, the scale was positioned on a flat surface, and the participant removed any coats, heavy sweaters, and shoes. The researcher secured that the participant was in the middle of the platform of the scale with the bodyweight equally distributed on both feet. Height measures were obtained ensuring that the shoes of participants were removed and that they stand with heels together, arms at sides, legs straight, and shoulders relaxed.

The BMI was calculated using the BMI equation, which is the weight of a person in kilograms divided by the square of height in meters. In children, it is converted to BMI percentile to obtain the relative position of the BMI number of the child among children of the same sex and age (Cole et al., 2000). The international (International Obesity Task Force; IOTF) BMI cutoff points were used to assess the child overweight and obesity, which represents the cutoff points by sex in the age group between 2 and 18 years, defined to pass through BMI of 25 and 30 kg/m^2 at age 18, obtained by averaging data from Asian and Caucasian children

(Cole and Lobstein, 2012). BMI data were obtained before and after the samples undergo a physical training program.

Motor Tests

The evaluation included four physical fitness tests as shown below:

1. The 20-m multistage fitness test (beep test) is a maximal running aerobic fitness test used to assess aerobic capacity.
2. The push-up test evaluates the strength and resistance of the upper body muscles.
3. Curl-up test evaluates abdominal strength and resistance.
4. Sit and reach, a common measure of flexibility of the lower back and hamstring muscles. It requires three measures, and the score is the average reached by the three distances.

Due to their simple and time-efficient implementation, these tests are simple and quick to perform (Krishnan et al., 2017). Since minimal equipment is required, their use is ideal for the school context. The physical fitness tests were conducted for both the EG and the CG at the beginning and end of the intervention program.

Generalized Self-Efficacy Scale

The Generalized Self-efficacy Scale (GES; Schwarzer and Jerusalem, 1995) is a well-validated and reliable questionnaire designed to assess self-beliefs in the competence of an individual to cope with a variety of stressful and challenging demands. The GES was a 10-item questionnaire using a 4-point Likert-type scale ($\alpha = 0.86$). The perceived sense of self-efficacy assessment required responses ranging from 1 "not at all true" to 4 "exactly true." It took approximately 10–15 min to fill out (including instruction and practice phase), and it was self-administered. The total scoring system ranges between 10 and 40, with a higher score indicating more self-efficacy.

Exercise Training Intervention

The exercise training program for the EG was composed of three diverse typologies of physical activities with different targets. According to their types, physical activities were grouped into flexibility, moderate-to-vigorous aerobic exercise, and games.

The exercise program was standardized with a typical plan beginning with a *flexibility* session (10 min) followed by a *moderate-to-vigorous aerobic exercise* session (40 min), and finally, a *games* session (30 min) (**Table 1**). Specifically, we exposed participants to a final part of competitive games with the aim to increase motivation and self-efficacy in participants through the pleasure to be active, acceptance of defeat, and full awareness of own ability of an individual. Each exercise session started with a 5-min warm-up and ends with 5-min cool-down phases with an emphasis on continuous movement and minimal standing around to maintain a safe elevated heart rate. Overall, the exercise program was designed to be enjoyable and appealing by allowing participants to use their favorite music during exercise sessions and experiencing a team mentality. Moreover, participants received weekly reports about their levels of physical activity achieved in the previous week.

The CG started each training session with a brief full-body dynamic warm-up, continued with a sequence of main exercises focused on sports skills and designed to improve general physical wellness, and ended with cool-down exercises. Warm-up included marching in place, wide toe touch, leg swings, arm swings, shoulder rotations, hip rotations, push-ups, lunges, walking jacks, jumping jacks, hip circles, and bodyweight squats. Regarding main exercises, they included the following sports and activities: volleyball, badminton, table tennis, individual, in pairs, and collective exercises, bodyweight exercises, exercises with small training gear, joint mobility exercises, and pilates exercises. Cool-down consisted of a variety of static stretching exercises which included glute stretch, standing quad stretch, side bench stretch, arm-cross shoulder stretch, overhead triceps stretch, lower back stretch, abdominal stretch, and pose of a child. It was important for muscle relaxation and the improvement of joint range of motion.

Statistical Analysis

We carried out statistical analyses using SAS JMP Statistics (Version 15.1, SAS Institute Inc., Cary, NC, United States, 2020). We presented data as group mean (M) values and SD. Normality of all variables was tested using the Shapiro–Wilk test procedure, and data were checked for assumptions of homogeneity of variances (i.e., Levene's test). We used an independent sample t-test to evaluate group differences at baseline and a two-way ANOVA (group experimental/control) × time (pre/postintervention), with repeated measures on the time dimension, conducted to examine the effect of the training on all examined variables. When "Group × Time" interactions reached significance, group-specific *post hoc* tests, such as paired t-test, were conducted to identify the significant comparisons. Partial eta squared (η^2_p) was used to estimate the magnitude of the difference within each group and interpreted using the following criteria: small ($\eta^2_p < 0.06$), medium ($0.06 \leq \eta^2_p < 0.14$), and large ($\eta^2_p \geq 0.14$). ES for the pairwise comparisons was determined by Cohen's d and interpreted as small, moderate, and large effects defined as 0.20, 0.50, and 0.80, respectively (Cohen, 1992). Statistical significance was set at $p \leq 0.05$.

RESULTS

All participants received the treatment conditions as allocated, and their average adherence (attendance) to intervention sessions was 96.6% (34.8 of 36 actual sessions). No injuries were associated with either training program. The experimental and CGs did not differ significantly at baseline in age, anthropometric characteristics, and psychological measures ($p > 0.05$) (**Table 1**). Preintervention and postintervention results for all dependent measures are presented in **Table 2**.

Motor Tests

A two-factor repeated measures ANOVA found a significant "Time × Group" interaction for the 20-m multistage fitness test ($F_{1,58} = 126.16$, $p < 0.001$, $\eta^2_p = 0.68$, large ES), push-up test ($F_{1,58} = 279.56$, $p < 0.001$, $\eta^2_p = 0.82$, large ES), curl-up ($F_{1,58} = 241.55$, $p < 0.001$, $\eta^2_p = 0.80$, large ES), and sit and reach test ($F_{1,58} = 207.34$, $p < 0.001$, $\eta^2_p = 0.78$, large ES). *Post hoc*

TABLE 1 | Weekly offered exercise sessions for the experimental group (EG).

1	Flexibility: 2 sets of 10 repetitions – Sit to stands, kneeling hip-ups, stretch arm forward, hip circle, bridge with alternating outer thigh squeeze, left clam Aerobic exercise: 2 sets of 12 repetitions – Jumping rope, skaters, jumping jacks, alternating lateral lunges, squat punches, step-ups, sit-ups, donkey kicks, straight leg jackknifes, single-leg glute bridges Game: Catch and throw balls
2	Flexibility: 2 sets of 10 repetitions – Standing march in place, standing side kick, arm circles, half roll-down, double-leg kick, twist and reach Aerobic exercise: 2 sets of 12 repetitions – Lateral toe taps, mountain climbers, side reach jacks, alternate V-sits, leg lifts, diagonal squats, scissors, hip drive step-ups, rear-foot-elevated split squats, flutter kicks Game: Freeze/Tag Zone
3	Flexibility: 2 sets of 10 repetitions – Windmills, step jacks, kneeling inchworms, leg swings, single leg extension, bird dog in knee hover Aerobic exercise: 2 sets of 12 repetitions – High knees, criss-cross jacks, x hops, reverse lunges, squats, hip bridges, russian twists, crunches, knee plank, side step-ups Game: Stay focused in rhythm
4	Flexibility: 2 sets of 10 repetitions for all exercise – Lunge and reach, standing saw, alternating step-up, standing roll-down, chest expansion, calf raises Aerobic exercise: Lateral shuffle floor taps, bench runners, sit-outs, punch jacks and knee pumps, standing × crunches, knee push-ups, chair squats, forward lunges, bicycle crunches, wall hip thrusts Game: Up, Down, Stop, Go
5	Flexibility: 2 sets of 10 repetitions – Rolling like a ball, march in place high knee, kneeling slide, open leg balance, roll up, scissor kick Aerobic exercise: 2 sets of 12 repetitions – Banded vertical jacks, fast-feet drops, knee pumps to overhead jacks, straight-leg sit-ups, walking lunges, sumo squats, standing shoulder presses, full plank, leg lifts, bottoms-up lunges Game: Survivor game
6	Flexibility: 2 sets of 10 repetitions – Standing legwork, romanian deadlift, single leg balance, double leg extension, rollback and twist, flyers Aerobic exercise: 2 sets of 12 repetitions – Jumping rope, X mountain climbers, knee to elbow-toe touches, heel taps, reaching oblique crunches, single-leg deadlifts, glute-bridges, push-ups, dumbbell thrusters, marching hip lifts Game: 4 Walls
7	Flexibility: 2 sets of 10 repetitions – Pendulum, mermaid, upper back roll, swimming, control balance, side-to-side rolling Aerobic exercise: 2 sets of 12 repetitions – Running in place, power skips, star jumps, drop squats, woodchoppers, ab rollbacks, triceps overhead extensions, knee back to knee raises, hip thrust single-arm reaches, hamstring rolls Game: Crazy 8's
8	Flexibility: 2 sets of 10 repetitions – Knees to chest, cross-over, standing quad stretch, seat straddle lotus, seat side straddle, table top Aerobic exercise: 2 sets of 12 repetitions – Fast feet, broad jumps, spiderman, hover leg extensions, bent-leg raises, dumbbell seesaw presses, squat jump, downward-facing dog, supine reverse crunches, cobra Game: Tic-tac-toe
9	Flexibility: 2 sets of 10 repetitions – Lower lift, leg circle, simple side bends, up-down dogs, roller dip, saw Aerobic exercise: 2 sets of 12 repetitions – Jumping jacks, skip, skaters, single-leg sit-to-stands, forward lunge with arm drivers, contralateral limb raises, twisting jump squat, ab roller, step ups, battle rope double arm slams Game: Slap the ball
10	Flexibility: 2 sets of 10 repetitions – Rocker, cork-screw, swan dive, side-to-side rolling, criss-cross Aerobic exercise: 2 sets of 12 repetitions – Single-leg toe touches, butt kicks, plank jacks, alternating curtsy lunges, alternate heel touches, battle rope double waves, bear crawls, bench flutter kicks, bosu ball leg pull-in, clams Game: Builders and bulldozers
11	Flexibility: 2 sets of 10 repetitions for all exercise – Leg sweep-left, leg lift and arm extension, hover leg lift, curl ups, lower back curl, pelvic curl Aerobic exercise: 2 sets of 12 repetitions – Run in place, knee to elbow and jump, toe taps, push-ups and reach, single-arm rows, half burpees, Leg Raises, banded glute bridge, agility ladder drills, bench hops Game: Kingball
12	Flexibility: 2 sets of 10 repetitions – March in place high knee, kneeling slide, open leg balance, roll up, single-leg stretch, single-leg kick Aerobic exercise: 2 sets of 12 repetitions – Fast feet, criss-cross jack, bosu ball mountain climbers, shoulder tap plank, bicep curls, burpees, dumbbell squats clean, agility ladder drills, bench swiss ball, bosu V-ups, crab walks Game: Flag football

analysis revealed that the EG made significant increase from pre- to post-test in 20-m multistage fitness test ($t = 12.14$, $p < 0.001$, $d = 2.21$, large ES) and an increase in push-up test ($t = 17.37$, $p < 0.001$, $d = 3.17$, large ES), curl-up ($t = 14.76$, $p < 0.001$, $d = 2.69$, large ES), and sit and reach test ($t = 14.32$, $p < 0.001$, $d = 2.61$, large ES). No significant changes were found for the CG.

Generalized Self-Efficacy Scale

Statistical analysis revealed significant "Time × Group" interaction for *GES* ($F_{1,58} = 186.74$, $p < 0.001$, $\eta^2_p = 0.76$, large ES). The *post hoc* analysis revealed a significant improvement in the score for this variable ($t = 12.83$, $p < 0.001$, $d = 2.34$, large ES) in the intervention group. No significant changes were found for the CG ($p > 0.05$). In this study, Cronbach's alpha reliability for the GES was $\alpha = 0.69$.

Body Max Index

Statistical analysis revealed significant "Time × Group" interaction for BMI ($F_{1,58} = 92.14$, $p < 0.001$, $\eta^2_p = 0.61$, large ES). The *post hoc* analysis revealed a significant improvement in physical fitness ($t = 8.79$, $p < 0.001$, $d = 1.60$, large ES) in the

TABLE 2 | Changes after 12-week aerobic exercise intervention.

	Experimental group (n = 30)			Control group (n = 30)		
	Baseline	**Post-test**	**Δ**	**Baseline**	**Post-test**	**Δ**
20 m Multistage fitness	4.33 (0.95)	8 (1.92)†*	3.66 (1.34)	4.63 (0.96)	3.90 (1.06)	−0.73 (0.98)
Push-up	6.26 (1.83)	13.46 (3.44)†*	7.20 (2.51)	5.96 (1.93)	5.70 (1.78)	−0.26 (0.90)
Curl-up	16.33 (3.22)	24.63 (3.28)†*	8.60 (3.19)	15.90 (2.84)	14.46 (3.10)	−1.43 (1.52)
Sit and reach	4.93 (2.30)	9.36 (3.07)†*	4.43 (1.69)	5.10 (2.17)	3.86 (2.64)	−1.23 (1.33)
Generalized self-efficacy scale	21.43 (3.89)	33.10 (4.75)†*	11.66 (4.97)	21.60 (3.69)	20.26 (4.20)	−1.33 (1.53)
BMI	88.19 (4.60)	82.41 (8.57)†*	−5 77 (6.78)	89.23 (1.92)	90.13 (1.84)	0.90 (1.27)

Values are presented as mean (±SD); Δ, pre- to post-training changes.
†Significant "Group × Time" interaction: significant effect of the intervention ($p < 0.001$).
**Significantly different from pretest ($p < 0.001$).*

intervention group. No significant changes were found for the CG ($p > 0.05$).

DISCUSSION

The aim of this study was to investigate the relationship between a 12-week PE intervention, BMI, and the perceived sense of self-efficacy among overweight high school girls, based on the assumption that the practice of physical activity may decrease their BMI and increase the perceived sense of self-efficacy, an important factor for reaching personal and social success.

In this study, the results indicate that the 12-week of PE intervention was the most effective in yielding the highest perceived sense of self-efficacy in overweight high school girls, while the non-specific regular PE lessons were the least effective in producing effects that corresponded with the objectives outlined.

The first important finding of this study was the evidence of the efficacy of physical activity programs to increase the perceived sense of self-efficacy. Several studies have demonstrated that a moderate-to-vigorous aerobic exercise can have substantial effects on self-efficacy (Hamilton et al., 2017; Flanagan and Perry, 2018; Garcia-Silva et al., 2018; Brace et al., 2020). McAuley et al. (1991) argued that participating in an aerobic exercise program is likely to bring about increases in psycho-physical conditioning and attendant increases in self-efficacy. Physical exercise influences the psychological status and psychological characteristics, such as self-efficacy, motivation, and self-esteem (Baumeister et al., 2003). In fact, the perceived sense of self-efficacy can be observed as a determinant and a consequence of physical activity (Li et al., 2018).

In the physical activity context, individuals may experience different psychological mechanisms resulting in learning a new skill, engaging in a physical activity task, or successfully self-regulating physical activity behaviors (Brown et al., 1992). In fact, physical activity might influence self-efficacy by self-management strategies, arising from thoughts, goals, plans, and acts (Dishman et al., 2004). This finding suggests that self-management strategies are a possible mechanism by which physical activity influences self-initiated self-efficacy. Bandura (1997) argued that self-efficacy affects behaviors through self-management strategies that involve cognitive, motivational, affective and selection dimensions.

Perhaps, the most striking finding of this study concerned the positive impact that the aerobic exercise program had on the BMI of overweight girls. In fact, results indicated that girls who showed better scores in the GSE pre to post-test were also those who improved their BMI. At the end of the intervention program, the BMI average in the EG was considerably improved, whereas, in the CG, it remained stable or even increased. These findings are consistent with previous studies that demonstrate an association between body weight, self-efficacy, and aerobic physical activity exists (Trost et al., 2001; Ievers-Landis et al., 2019; Morano et al., 2020). The results of these studies support the hypothesis that moderate-to-vigorous aerobic exercise activity is more effective than low-intensity exercise in inducing weight loss (Keane et al., 2017). In particular, the high-intensity exercise would produce the most significant results at inducing weight loss even without a dietary change (Irwin et al., 2003; Slentz et al., 2004; Church et al., 2009; Jakicic et al., 2011). Furthermore, we assumed that it was due to the fact that girls with high levels of a perceived sense of self-efficacy were able to be more flexible, resilient, and efficient in problem-solving and were mainly focused on achieving their objectives and pursued personal success rather than to be concentrated on difficulties encountered (Barrett Holloway et al., 1988; Schwarzer and Warner, 2013; Cassidy, 2015). In fact, girls who developed a sense of self-efficacy were able to develop positive behavior toward weight control. This is because the perceived sense of self-efficacy is able to address the personal actions of girls in high-profile healthy activities and build in a positive way their future. It can be assumed that a higher perceived sense of self-efficacy leads to higher motivation and higher self-esteem that are able to build positive behavior that drives significant changes in eating behavior and consequently in body weight (Carissimi et al., 2017). This result accords with previous literature, whereby girls who practice moderate-to-vigorous aerobic exercise perform better on certain tasks related to personal wellbeing through the improvement of planning, organization, and problem-solving skills (Hillman et al., 2014). Moreover, self-efficacy beliefs influence certain psychological and behavioral factors, such as motivation, choice

of activities, level of effort, persistence, and emotional reactions (Pender et al., 2002). In fact, overweight girls who considered themselves self-efficacy participated more promptly, worked harder, persisted longer, and responded better to difficulties than those with less self-efficacy (Cataldo et al., 2013). These results validate the idea that aerobic exercise may influence the healthy eating habits of overweight girls through the mediational role that self-efficacy plays in motivating individuals to reach their goals (Davidson et al., 2010), as previously reported by Kitsantas (2000). The author indicates that higher self-efficacy beliefs in implementing self-regulation strategies are linked to lower body weight, as it happens in the case of eating habits.

Based on what was discussed, it was possible to claim that the results of the previous research support our hypothesis, according to which overweight girls had significantly improved their perceived sense of self-efficacy and consequently their BMI following a moderate-to-vigorous aerobic exercise intervention. Despite the contribution regarding the significant relationship between aerobic exercise, self-efficacy, and decrease in BMI, some limitations were present within this study. First, this study was related to the small sample size (N = 60), generating difficulties in recruiting motivated overweight students to participate. Moreover, the sample included only girls recruited from a population of students at local public schools located in a small district. Thus, the results may not be generalizable to students from other institutions or with other demographic backgrounds. Additionally, although the authors tried to select groups normally distributed, that were as similar as possible to fairly compare the experimental with the control, and the equivalence between the two groups for the dependent variables under analysis was not evaluated *a priori*. This might have affected the results.

A second limitation of this study is the lack of psychosocial measures, such as the assessment of enjoyment, motivation, and perceived competence of participants for the activities performed. In addition, the sessions were performed by two different professionals, and thus, it could be assumed that the motivational climate created by the teachers was slightly differentiated.

Another limitation concerned the fact that we did not evaluate the long-term effects of aerobic exercise on BMI and self-efficacy. Future research would need to examine these possibilities to explain these variables. However, despite the limitations, the strengths of this study were represented by the fact that it could provide valuable information regarding the most effective types of activities in eliciting the psycho-physical health of schoolgirls. Thus, these results suggest that it is advisable to offer additional moderate-to-vigorous aerobic exercise lessons in overweight girls bearing in mind that the association between physical activity, self-efficacy, and decrease of fatness provides a unique opportunity to operate simultaneously at different levels, namely, improving both physical and mental health.

CONCLUSION

This study suggests that aerobic exercise is an effective weight loss intervention and a vehicle to promote a range of outcomes, important to the qualitative growth of adolescents. In fact, it provided a positive and significant impact on the self-efficacy of overweight schoolgirls and their body fat. In particular, self-efficacy had an immense effect on reaching weight management due to its potential in inducing important changes in the behavior of girls regarding their attention toward health.

The school environment may be the ideal setting to combine physical activity, with health education, and care of body and mind, as well as for combating and preventing childhood overweight and obesity. School is, in fact, together with the family, the main institution to ensure healthy and balanced growth for our children. It is essential that school includes in their programs the appropriate types and levels of physical activity to provide a unique opportunity to intervene in a winning way on the health of students. In this respect, despite academic achievement not being the subject of our study, we observed that girls who showed an improvement in self-efficacy and BMI were those who reported the best school grades.

Based on the data obtained, the authors believed that in order to help overweight girls in developing effective strategies of life management and self-care, much could be performed practically. In fact, it is important to supply the perceived sense of self-efficacy that helps to spark a virtuous cycle that feeds itself. Therefore, it would be advisable for Scholastic Institutions to consider the current scientific evidence providing services to the students, such as a "tutoring service." It could help students to adopt important changes in their eating and physical activity behaviors and by giving them the means to improve their physical and cognitive health. Therefore, this strategy should guide PE teachers and health educators in designing more effective interventions intended to increase the daily amount of MVPA in overweight school girls.

Thus, further research in relation to self-efficacy and physical activity with regard to sex and body weight is necessary to determine a dose-response effect and the effectiveness of any long-term benefits of aerobic exercise on fatness, self-efficacy, and academic performance.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Bari Aldo Moro. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FL designed the study, conducted the research, carried out the statistical analysis, interpreted the data, and wrote and revised the manuscript. SC collected the data, involved in the bibliographical research, and helped to supervise the intervention program.

VB collected the data, involved in the interpretation of data, and revised the manuscript. RC and MD were involved in the data collection and helped to supervise the intervention program. FF coordinated the study, interpreted the data, and revised the manuscript. All authors contributed intellectually to the manuscript, read the manuscript, and approved the submission.

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Understanding Residents' Physical Activity Intention and Behavior Amid COVID-19 Pandemic

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Proper and regular physical activity (PA) plays an important role in improving people's health. With the outbreak of the COVID-19 pandemic, which has posed a serious threat to individual health, residents' PA has aroused deep concern. Based on the theory of planned behavior, this study examines the impact of residents' PA intention and behavior in response to the COVID-19 pandemic. Data were collected from a sample of 961 residents in Wuhan in China using a questionnaire survey. The results show that residents' PA intention and behavior have been affected significantly by residents' PA attitude, subjective norms, and perceived behavioral control. The COVID-19 pandemic has a significant impact on both residents' PA intention and behavior. In addition, there were gender and region differences in this impact. The findings are of great significance in promoting residents' PA intention and PA behavior, which are of positive significance to the development of residents' physical and mental health in the period of global serious health crisis.

Keywords: theory of planned behavior (TPB), physical activity, intention, behavior, global public health event, COVID-19

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INTRODUCTION

Previous studies have shown that proper and regular physical activity (PA) could not only maintain physical health but also help people mediate anxiety and depression, release pressure, and improve the immune system to prevent the serious complications of pandemic (Mahalakshmi et al., 2020; Marchant et al., 2021). PA is defined as any bodily movement produced by skeletal muscles that require energy expenditure, and the popular forms include cycling, sports, and play (World Health Organization [WHO], 2021a).

So far, the COVID-19 pandemic has posed a serious threat to individual health, which has led to more than 200 million confirmed cases and 5 million deaths (World Health Organization [WHO], 2021b). It has dramatically threatened not only people's health but also mental health and cognitive functioning of people, such as increasing the risks of Alzheimer's disease, language fluency, and so on (Lardone et al., 2021). International organizations and countries have implemented measures and introduced guidelines to promote and foster the habit of people's PAs, especially in the period of self-isolation at home. WHO has advocated that it is important for residents to be as physically active as possible and has instructed the children aged 5–17 to play indoor games

(e.g., jumping rope, high jump, and lifting weights) for at least 60 min a day and 3 days a week, and adults could do moderate-intensity indoor PA by climbing stairs, doing housework, dancing, and so on (World Health Organization [WHO], 2020a). There is increasing global concern and advocacy for people to take regular and proper PAs (Brand et al., 2020). Whether people's PA intention and behavior have been influenced by the COVID-19 pandemic needs to be explored.

Studies have found that PA behavior is significantly affected by the social environment, individual intention, and other personal characteristics (Van Luchene et al., 2021). In addition, the intention of PA plays an essential role in predicting PA behavior (Cheon et al., 2012). Previous studies have applied the theory of planned behavior (TPB) to study an individual's intention and behavior (Sarker et al., 2021). Ajzen (1985) suggested TPB based on the theory of rational behavior (TRA), which believed that an individual's behavioral intention (INT) and behavior would be influenced by behavioral attitude (ATT), subjective norms (SNs), and perceived behavioral control (PBC; Ajzen, 1985; Venkatesh et al., 2000). Ajzen (2015) further elaborated the utility of TPB, that is, TPB is not a theory of changing behavior but is aiming to help explain and predict people's intentions and behaviors (Ajzen, 2015). Behavioral intention, which refers to the subjective degree of an individual's willingness to complete the behavior, could be measured to predict the occurrence of an individual's behavior (Fishbein and Ajzen, 2010). The stronger the intention of an individual, the more the actual behavior reflects on the cards (Davis, 2000). Attitude refers to the individual's favorable or unfavorable evaluation of the behavior (La Barbera and Ajzen, 2020). SN refers to the social pressure that a person feels about whether to take a kind of behavior, which includes normative belief and compliance motivation, namely, the individual's view and willingness to follow the opinions of important people (Ajzen, 1991). Perceived behavioral control is an individual's evaluation of influencing factors (such as experience, opportunities, and resources) that may advance or impede the behavior (Yadav and Pathak, 2017). It has been found that, when individuals experience more opportunities, resources, and fewer obstacles than expected, the level of PBC will increase (Barki, 1994). The more positive the attitude of individual behavior and the stronger the SNs and PBC ability are, the stronger the intention to perform behavior will be (Cheon et al., 2012).

Based on TPB, this study focuses on residents' PA intention and PA behavior and their influencing factors before and after the outbreak of the COVID-19 pandemic to understand the impact of the COVID-19 pandemic on residents' PA intention and behavior. In this study, Wuhan in China, which is one of the earliest outbreak cities of the COVID-19 pandemic and the earliest city to implement "lockdown" with suspending all the traffics, shops, factories, and schools on January 23, 2020, has been chosen to be the research region. The city has been unsealed since April 8, 2020, with the COVID-19 pandemic under control. In addition, the residents in Wuhan, which refer to those who have resided in Wuhan for at least 1 year from 2019, had gone through the most impressive experience of influences of the COVID-19 pandemic, especially self-isolation at home. This study puts forward the research hypotheses H1–H5 as follows.

H1: Residents' PA intention has a significantly positive impact on residents' PA behavior.

H2: Residents' PA attitude, SN, and PBC have significantly positive impacts on residents' PA intention.

H3: Residents' PA intention has been significantly influenced by the COVID-19 pandemic.

H4: Residents' PA behavior has been significantly influenced by the COVID-19 pandemic.

H5: There are gender and urban—rural differences in residents' PA intention and behavior under the influence of the COVID-19 pandemic.

MATERIALS AND METHODS

Measurement

The Theory of Planned Behavior Scale

Residents' PA intention, attitude, SN, and PBC are measured based on the TPB-related structure scale developed by Ajzen (1991). The intention of PA is measured using three items, including "*I plan/intend/hope to do physical activity for at least 20 min at least three times a week in the next 2 weeks*." The attitude of PA is measured by five items, including "*It is satisfying/pleasant/enjoyable/useful/important to me at least 20 min of physical activity at least three times a week for the next 2 weeks*." SNs are measured by three items, including "*Most people who are important to me will happy when I do physical activity in the next 2 weeks, for more than three times a week, each time for at least 20 min*," "*Most people who are important to me approve of me doing the above physical activity,*," and "*Most people who are important to me hope me to do physical activity*." PBC of PA is measured by four items, namely, "*It is easy for me to do the above physical activity*," "*I can accept myself to do the above physical activity*," "*It is beyond my ability to do physical activity*", and "*I can control myself to do physical activity*."

The internal consistency of the original measurement was 0.85 (Ajzen, 1991). All items adopted Likert's 5-point scale from "*strongly disagree*" 1 to "*strongly agree*" 5. The original questionnaire was translated into Chinese by 4 bilingual scholars with more than 5 years of experience in translation and cross-cultural identification to ensure consistency between the two translated versions. The validity was evaluated by 10 experts, and a preliminary study was conducted on 30 volunteer participants. Based on the preliminary test, the questionnaire was modified to clarify the ambiguity.

The Physical Activity Rating Scale (PARS-3)

The PARS-3 proposed by Deqing (1994) was used to assess the PA rating of residents, and its internal consistency was 0.82, which passed the reliability and validity test (Deqing, 1994). Residents' PA level is measured from three dimensions, intensity, duration, and frequency. Intensity is including "*light physical*

activity intensity", "*light physical activity with not too intense intensity*", "*moderate and mild physical activity with more intense and persistent intensity*", "*heavy but not persistent physical activity with shortness of breath and sweating a lot*", and "*heavy and persistent physical activity with shortness of breath and sweating a lot*". Duration level is divided as ≤10, 11–20, 21–30, 31–59, and ≥60 min, respectively. Frequency includes "*once a day*", "*3–5 times a week*", "*1–2 times a week*", "*2–3 times a month*", and "*once a month or less*". The three dimensions of PARS-3 just meet *The WHO Guidelines on physical activity and sedentary behavior*, which provide recommendations for people on the amount of PA (frequency, intensity, and duration) (World Health Organization [WHO], 2020b).

A Likert-type 5 point scoring method was adopted. The total score of residents' PA level was calculated using the following formula: *PA level = Intensity × (Duration-1) × Frequency* (Deqing, 1994). The evaluation criteria for light, moderate, and vigorous levels of PA is the total score ≤19, 20–42, and ≥43 points, respectively.

Data Collection and Procedures

To understand the changes in PA behavior of Wuhan residents, data were collected two times: the first time before the pandemic outbreak (June 1, 2019–June 30, 2019) and the second time after the outbreak and lockdown of the COVID-19 pandemic (June 1, 2020–June 30, 2020) in the same community. Our sample included only residents aged 5 or older who claimed to reside in Wuhan during the period from June 2019 to June 2020. A total of 1,053 responses were collected with an effective rate of 91.3%, in which 92 responses were invalid and 961 responses were valid. Questionnaires were issued anonymously, and the content of the questionnaires was strictly confidential and can be used only for academic research. In the survey, 53.3% of residents were men and 46.7% were women, with ages 5–17, 18–34, 35–59, and 60 and above as 11.3, 26.5, 39.4, and 22.7%, respectively. The proportion of urban and rural residents was 50.2 and 49.8%, respectively (refer to **Table 1**).

Stata 16.0 was used to study the relationship and changes in the PA intention and behavior of residents in Wuhan before and after the COVID-19 pandemic. Statistical analysis was conducted, and when $p \leq 0.05$, the result was considered statistically significant (Alsalhe et al., 2020).

TABLE 1 | Demographic characteristics.

Characteristics	Sub-character	N (961)	%(100)
Gender			
	Male	512	53.3
	Female	449	46.7
Age-group (years)			
	5–17	109	11.3
	18–34	255	26.5
	35–59	379	39.4
	60 +	218	22.7
Region			
	Urban	575	59.8
	Rural	386	40.2

RESULTS

Assessment of the Measurement Model

Cronbach's alpha (α) and composite reliability (CR) were adopted to examine reliability (Nunnally, 1967; Bagozzi, 1981), and the values $\alpha > 0.7$ and $CR > 0.7$ represent a commonly accepted level. As shown in **Table 2**, α values for all the scales exceeded 0.7, and the results showed that all the scales had good internal consistency. The result of $KMO = 0.95 > 0.7$ and $p = 0.000$ indicated that the variable can conduct factor analysis. The CR values exceeding 0.7 indicated that all the scales had good composite reliability.

The test of validity included convergence validity and discriminant validity (Segars, 1997). Standardized path loading (>0.7) and average variance extracted (AVE) (>0.5) were used to test convergence validity. All the values pass the test. Discriminant validity was tested by examining the correlation between the square root of the AVE and the other factors. The square roots of AVEs of scales indicate a good discriminant validity (refer to **Table 2**).

Independent Samples *t*-Test

In the *t*-test analysis, only gender and urban-rural demographic variables were significant. Therefore, this study compared the differences in PA in gender and urban-rural before and after the pandemic. Gender was divided into two groups, namely, male and female, to study the difference in PA. The homogeneity of variance test showed that data of the two groups before and after the lockdown had homogeneity of variance ($F_{before} = 0.002$, $p = 0.964 > 0.05$, $F_{after} = 0.251$, $p = 0.616 > 0.05$). The *t*-test results showed $t(\mathrm{df})_{before} = 3.424(959)$, $p = 0.001 < 0.05$, $t(\mathrm{df})_{after} = 2.473(959)$, $p = 0.014 < 0.05$. Both before and after the pandemic, the scores of male residents' PA was higher than that of female residents. However, after the pandemic, the difference in the score between male and female residents was smaller. The scores of male residents' PA declined, while the scores of female residents' PA increased. The region was divided into two groups to study the difference in PA between urban and rural. The homogeneity of variance test showed that data of the two groups before and after the pandemic had homogeneity of variance ($F_{before} = 0.478$, $p = 0.489 < 0.05$, $F_{after} = 0.047$, $p = 0.829 > 0.05$). The *t*-test results showed $t(\mathrm{df})_{before} = -3.317(826.473)$, $p = 0.001 < 0.05$, $t(\mathrm{df})_{after} = -1.472(959)$, $p = 0.141 > 0.05$. Both before and after the pandemic, the scores of rural residents' PA were higher than that of urban residents. However, after the lockdown, the difference between urban and rural scores was smaller. The scores of rural residents' PA declined, while the scores of urban residents' PA increased (refer to **Table 3**). H5 has been verified.

Regression Analysis

The behavioral intention was considered as the dependent variable, and attitude, SN, and PBC were considered as

TABLE 2 | Reliability, convergent, and discriminant validities.

		α	CR	AVE	INT	ATT	SN	PBC	PA	M ± SD
Before	INT	0.946	0.9511	0.8675	**0.9314**					4.143 ± 0.970
	ATT	0.960	0.9601	0.8279	0.831***	**0.9109**				4.165 ± 0.884
	SN	0.935	0.9356	0.8289	0.712***	0.854***	**0.9104**			4.239 ± 0.851
	PBC	0.770	0.8238	0.5846	0.693***	0.791***	0.746***	**0.7646**		3.870 ± 0.779
	PA	0.762	0.7614	0.5159	0.383***	0.364***	0.302***	0.359***	**0.7183**	32.787 ± 26.095
After	INT	0.952	0.9564	0.8805	**0.9383**					4.1079 ± 1.001
	ATT	0.956	0.9568	0.8159	0.841***	**0.9033**				4.1863 ± 0.885
	SN	0.948	0.9485	0.8600	0.773***	0.888***	**0.9274**			4.207 ± 0.900
	PBC	0.771	0.8234	0.5826	0.702***	0.790***	0.758***	**0.7633**		3.881 ± 0.790
	PA	0.741	0.7626	0.5172	0.419***	0.435***	0.413***	0.438***	**0.7192**	32.624 ± 25.354

****p < 0.001. The thickened part of the diagonal is the square root of AVE. The lower triangle is the Pearson correlation coefficient. INT, behavioral intention; ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; PA, physical activity.*

TABLE 3 | Independent samples *t*-test.

	Gender	M ± SD	Homogeneity test of variance		Independent samples *t*-test	
			F	*p*	*t* (df)	*P*
Before	Male	35.471 ± 25.821	0.002	0.964	3.424 (959)	0.001
	Female	29.726 ± 26.097				
	Urban	30.511 ± 25.973	0.478	0.489	−3.317 (826.473)	0.001
	Rural	36.176 ± 25.941				
After	Male	34.514 ± 24.758	0.251	0.616	2.473 (959)	0.014
	Female	30.470 ± 25.876				
	Urban	31.638 ± 25.618	0.047	0.829	−1.472 (959)	0.141
	Rural	34.093 ± 24.916				

independent variables of multiple regression analysis. The P-P diagram and scatter diagram showed that the residual was approximately normal distribution with no heteroscedasticity problem. Variance inflation factor (VIF) was used to determine the collinearity of independent variables. Myers (1990) believed that VIF > 10 indicated strong collinearity (Myers, 1990). The results showed that there was no serious collinearity among independent variables. The variance interpretation rates of behavior intention by independent variables before and after the pandemic were as high as 69.5% and 71.4%, respectively, and the regression model fitted well (F_{before} = 726.004, $p < 0.001$, R^2 = 0.695, F_{after} = 794.623, $p < 0.001$, R^2 = 0.714) (refer to **Table 4**).

Behavior as the dependent variable and intention as the independent variable were considered for the simple linear regression analysis. The P-P graph and scatter graph were used to test the normal distribution and heteroscedasticity. It was proved that the residual of the unary regression model was close to the normal distribution with no heteroscedasticity problem, and the VIF test (VIF = 1.000) was passed. The regression model was verified to have a good fit (F_{before} = 164.600, $p < 0.001$, R^2 = 0.146, F_{after} = 203.806, $p < 0.001$, R^2 = 0.175) (refer to **Table 5**).

Residents' behavior intention had a statistically significant impact on the behavior of PA before and after the pandemic (B_{before} = 3.432, t_{before} = 12.83, $p < 0.001$; B_{after} = 3.534, t_{after} = 14.276, $p < 0.001$). The following regression equation was used: PA_{before} = 3.432 * INT-9.875, PA_{after} = 3.534 * INT-10.928. In other words, when the intention increases by 1 unit, the behavior will increase by 3.432 and 3.534 units, respectively. When the intention increases to a certain extent ($INT_{after} > INT_{before} > 10.324$, $PA_{after} > PA_{before}$), the behavior of PA after the pandemic increases significantly compared with that before the pandemic. In terms of the PA level, the moderate level of PA increased slightly from 32.5 to 32.8%, the low level of PA decreased slightly from 30.1 to 29.8%, and the vigorous level of PA did not change significantly (37.5%). In addition, the results showed that the amount of residents' PA (32.62 ± 25.35) reduced before the pandemic (32.79 ± 26.10), and the average amount of residents' PA after was 0.17, which was lower than that before the pandemic. Specifically, after the pandemic, residents' PA intensity decreased (M_{before} = 3.01 > M_{after} = 2.99), while the frequency (M_{before} = 3.67 < M_{after} = 3.68) and duration (M_{before} = 3.46 > M_{after} = 3.50) increased slightly. Hypothesis 1 and 3 were verified.

Among the three included independent variables, before the pandemic, residents' PA attitude (B = 0.506, t = 20.062, $p < 0.001$) and PBC (B = 0.090, t = 3.234, $p < 0.01$) had statistically significant effects on intention, and the regression equation was INT = 0.506 * ATT-0.018 * SN + 0.09 * PBC + 0.725. After adjusting the collinearity changes of attitude, PBC, for every unit

TABLE 4 | Multiple linear regression analysis.

		Unstandardized coefficients		Standardized coefficients	*t*	*p*	VIF
		B	**SE**				
Before		0.725	0.282		2.576***	0.010	
	ATT	0.506	0.025	0.768	20.062***	0.000	1.261
	SN	−0.018	0.040	−0.016	−0.447	0.655	1.038
	PBC	0.090	0.028	0.097	3.234**	0.001	1.325
	R^2			0.695			
	adj R^2			0.694			
	F			726.004***			
After		−0.073	0.272		-0.268	0.789	
	ATT	0.465	0.028	0.685	16.788***	0.000	5.557
	SN	0.115	0.043	0.103	2.685**	0.007	4.909
	PBC	0.078	0.027	0.083	2.862**	0.004	2.778
	R^2			0.714			
	adj R^2			0.713			
	F			794.623***			

*Dependent variable: physical activity intention. Independent variable: physical activity attitude (ATT), physical activity subjective norm (SN), physical activity perceived behavioral control (PBC). ***p < 0.001, **p < 0.01, *p < 0.05.*

TABLE 5 | Simple linear regression analysis.

		Unstandardized coefficients		Standardized coefficients	*t*	*p*	VIF
		B	**SE**				
Before		−9.875	3.415		−2.892**	0.004	
	INT	3.432	0.267	0.383	12.83***	0.000	1.000
	R^2			0.146			
	adj R^2			0.146			
	F			164.600***			
After		−10.928	3.140		−3.48**	0.001	
	INT	3.534	0.248	0.419	14.276***	0.000	1.000
	R^2			0.175			
	adj R^2			0.174			
	F			203.806***			

*Dependent variable: physical activity behavior. Independent variable: physical activity intention (INT). ***p < 0.001, **p < 0.01, *p < 0.05.*

increase of attitude and PBC, residents' intention before and after the lockdown increased by 0.506 and 0.09 units, respectively. After the pandemic, attitude (B = 0.465, t = 16.788, $p < 0.001$), SN (B = 0.115, t = 2.685, $p < 0.01$), and PBC (B = 0.078, t = 2.862, $p < 0.01$) had statistical significance on intention. The regression equation was INT = 0.456 * ATT + 0.115 * SN + 0.078 * PBC-0.073. After adjusting the collinearity of attitude, SN, and PBC, residents' intention before and after the pandemic intention increased by 0.456, 0.115, and 0.078 units, respectively. Hypothesis 2 and 4 were verified.

DISCUSSION

In summary, the main findings of this study were as follows: (i) whether before or after the pandemic, residents' PA intention has a significantly positive impact on PA behavior; (ii) residents' PA behavior has decreased after the outbreak of the COVID-19 pandemic and there are notable gender and region differences in the aspect of physical activity behavior of residents; and (iii) there are significant changes in residents' PA intention due to the influence of the COVID-19 pandemic. Before the pandemic, residents' PA attitude and PBC have a significantly positive impact on residents' PA intention. However, after the pandemic, besides residents' PA attitude and SNs, the PBC has a significantly positive impact on residents' PA intention.

Whether before or after the pandemic, residents' PA intention has a significant impact on PA behavior. Studies have confirmed that the outbreak of pandemics did reduce residents' PA (Brand et al., 2020; Castaeda-Babarro et al., 2020). According to the results of the correlation of PA intention and behavior, it is possible to have more physical activities only if the intention is

stronger. Male residents do more PA than female residents, which has been proved by previous research (DeWolfe et al., 2020). Men are more likely to participate in physical activities in venues, such as football, but due to the lockdown, various venues have been closed, which has greatly restricted the places where men used to do PAs (Christofaro et al., 2021). Unlike men, women do more work in domestic places, which may account for the increase in PA (Armstrong et al., 2006).

Residents' PA intention is affected by attitude, PBC, and SNs. An interesting finding is that before the pandemic, residents' PA, attitude, and PBC had a significant impact on residents' PA intention, in which PA attitude has a greater impact on residents' PA intention, while SNs have no significant impact. This is consistent with the existing studies that residents' positive or negative evaluation of participating in PA, as well as their perception of their ability, experience, and opportunity to participate in PA, will affect their PA intention and behaviors (Marashi et al., 2019; Alipour-anbarani et al., 2021). After the outbreak of the pandemic, the influence of residents' PA attitude and PBC on residents' PA intention are slightly weakened and residents' PA attitude is still the most significant factor influencing residents' PA intention. However, it is worth noting that SNs have a significant impact on residents' PA intention, and the impact is greater than the PBC. The weakened predictive effect of residents' PBC on PA intention and behavior may be because residents experience more obstacles when attempting PA (such as reduced opportunities, scarce knowledge, and experience in PA, or beyond their own capabilities) (Ajzen, 1991; Yadav and Pathak, 2017; Wallace, 2020). However, the support and affirmation of important family members and friends, the promotion of policies, and the vigorous publicity of the government make residents feel unprecedented social pressure, thus affecting residents' willingness to participate in PAs and increasing residents' PAs. During the lockdown, the government in Wuhan and China have issued accurate guidelines on conducting PAs for residents, updating not only the new standards for residents' participation in PA but also the types of PA (such as yoga and aerobics). These led residents' SNs to constantly strengthen despite the weakening of attitude and perceived behavior control. *The outline of the "Healthy China 2030" plan* published by the government of China calls for a wide range of public participation in PA with specific requirements such as ensuring that students should participate in PA for more than 1 h at school and participate in PA at moderate intensity at least three times a week (Central People's Government of the People's Republic of China, 2016). The government of Wuhan has launched a *home scientific fitness guide*, which suggests children practice physical activities indoors such as standing on one foot or crawling movement; teenagers do 1 h indoor PA every day, such as fitness and aerobics; healthy adults do 150 min of indoor PAs at least 3 days a week, such as walking, jogging, or Qigong; and the elderly do 150 min of indoor PAs, such as tai chi or softball, at least 3 days a week (Wuhan Sport Bureau, 2020).

CONCLUSION AND RECOMMENDATIONS

From what has been discussed above, residents' PA intention and behavior have been significantly influenced by the COVID-19 pandemic, and residents' PA intention has been directly influenced by residents' PA attitude, PBC, and SNs. Although the residents' PBC has decreased, the function of SNs comes into play.

According to the study results, multiple and effective measures need to be put forward. First, guiding residents to form more positive attitudes, SNs, and stronger PBC. Second, promoting health education and publicity of the importance and usefulness of PA to guide residents to form correct cognition and positive attitude by international organizations and governments. Third, strengthening the role of the Internet through popularizing home PA guidelines, prompting online courses according to the needs of different groups, cultivating residents' interest and confidence, and eventually guiding residents to form a PA habit. Last but not least, giving full play to the role of family through creating a good family atmosphere to guide family members to participate in PAs and enhancing family immunity.

The generalization of these results, which is subject to certain limitations, provides avenues for future research. One of the limitations in this study, which could have affected the measurements, was the tested sample. This study chose 961 residents in Wuhan as the research object group. Although the internal consistency fell above an acceptable level, the relatively small sample size used in the study cannot be a general adaption to the whole situation. Given this, studies could be carried out in a broader population. Moreover, more accurate PA measurement tools should be considered based on more critical appraisal and consideration within the limitations to increase the validity and reliability of studies. Third, more changing factors such as the types of PA practiced by residents could be considered to conduct further research.

Notwithstanding these limitations, the study has offered some insight into promoting residents' PA intention and behavior, which are of positive significance to the development of residents' physical and mental health in the period of global serious health crisis. This would be a fruitful area for further work.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The questionnaire data were collected anonymously in this study, and the questionnaire filling was voluntary. The subjects were promised that the questionnaire data would only be used for academic research and kept strictly

confidential. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

XC: mainly responsible for data collection, analysis, and manuscript writing. WC: responsible for the revision, proofreading, and supervision of the study. Both authors contributed to the article and approved the submitted version.

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