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From intention to behavior: Within- and between-person moderators of the relationship between intention and physical activity

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ABSTRACT

Intention is a proximal predictor of behavior in many theories of behavior change, but intentions to be physically active do not always translate to actual physical activity. Little research has examined intensive longitudinal changes in physical activity and corresponding within-person moderators needed to elucidate the mechanisms, hurdles, and facilitators of individuals' everyday physical activity behaviors. The present study set out to evaluate the possible moderators of the intention-physical activity relationship across within-person and between-person levels, including cross-level interactions. Data comprise the first intensive measurement burst (14 days) of the longitudinal prospective Healthy Aging in Industrial Environment (HAIE) study, with N = 1135 participants (N = 10,030 person-days), aged 18–65. Physical activity was operationalized as step counts measured objectively using Fitbit Charge 3/4 fitness monitor. Intention, barriers to physical activity, and social support for physical activity were measured daily via smartphone surveys. Stable characteristics, i.e., physical activity habit and exercise identity, were measured using an online questionnaire. A multilevel moderation regression model with Bayesian estimator was fitted. At the within-person level, the relation between intention and steps was weaker on days when barriers were more severe than usual for a given person (Estimate = −0.267; CI_{95} = [−0.340, −0.196]) and social support was below average for a given person (Est = 0.143; CI_{95} = [0.023, 0.262]). Additionally, the daily intention-behavior relationship was stronger for people with lower average severity of barriers (Est = −0.153; CI_{95} = [−0.268, −0.052]), higher exercise identity (Est = 0.300; CI_{95} = [0.047, 0.546]), men (Est = −1.294, CI_{95} = [−1.854, −0.707]), and older individuals (Est = 0.042, CI_{95} = [0.017, 0.064]). At the between-person level, only physical activity habit strengthened the intention-behavior link (Est = 0.794; CI_{95} = [0.090, 1.486]). Our results underscore the need to separate the between-person differences from the within-person fluctuations to better understand the individual dynamics in physical activity behaviors. Personalized interventions aimed at helping individuals translate intentions to actual physical activity could be tailored and become more intensive when there is a higher risk of intention-behavior gap on a given day for a specific individual (i.e., a day with more severe barriers and less social support), by increasing the dosage or deploying more precisely targeted intervention strategies and components. In addition, interventionists should take gender and age into account when tailoring everyday strategies to help individuals act on their intentions.

1. Background

Engaging in physical activity and maintaining physical activity levels over time has been linked to pronounced benefits for physical health, mental functioning, and well-being across lifespan and various populations (WHO, 2020). However, many people still fail to reach adequate levels of physical activity (Guthold et al., 2018). Central to many theories explaining health behaviors, including engaging in physical activity, is the construct of intention (Ajzen, 1991; Bandura, 1986; Schwarzer, 2008) and it is generally believed to be the closest predictor of actual behavior (Ajzen, 1991; Bandura, 1986; McEachan et al., 2011). Nevertheless, previous research has shown that there is a significant gap between the behavioral intentions that people form and their actual subsequent behavior (Armitage & Conner, 2001), with physical activity being no exception (Rhodes & de Bruijn, 2013; Rhodes & Dickau, 2012).

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1.1. Bridging the intention-behavior gap

Researchers have focused on bridging this "intention-behavior gap" by studying the potential moderators of this relationship. Rhodes et al. (2022) recently conducted an updated systematic review of the moderators of the intention-physical activity relationship utilizing the Capability-Opportunity-Motivation-Behavior (COM-B) framework (Michie et al., 2011). The supported moderators of the intention-physical activity relationship were, among others, exercise identity or self-schema, several aspects of reflective motivation (e.g., goal conflict, anticipated regret), behavioral processes, and employment status. For several variables such as age, habit, and action and coping planning, the results were inconsistent, and the direction of the effect could not be determined. Interestingly, there were several variables for which no effect on the intention-physical activity relationship was found, including social support, norms, and gender (Rhodes et al., 2022).

Exercise identity. Among the supported moderators of the intention-physical activity relationship was exercise identity or self-schema. Identity is argued to be a key component of motivation and behavior (Rise et al., 2010) as people tend to make intentions and behave in line with their self-identity and self-ascribed roles (Hagger & Chatzisarantis, 2006; Stets & Burke, 2000). Although not all support the moderating effect of identity on the intention-physical activity relationship (e.g., Banting et al., 2009), there is convincing evidence that people who see themselves as exercisers or as physically active individuals have a stronger relationship between intentions and physical activity (e.g., de Bruijn et al., 2012a, 2012b; de Bruijn & van den Putte, 2012; Sheeran & Abraham, 2003). Thus, exercise identity may represent a relatively stable individual characteristic that could modulate the intention-physical activity relationship.

Exercise habit. For exercise habit or automaticity, the results of Rhodes et al.'s (2022) review were inconsistent, and the direction of the effect could not be determined. Habit-oriented theories propose that successfully repeating a behavior helps form habits, an automatic tendency to behave in a certain way based on learned associations with contextual cues or triggers (Verplanken, 2006). Additionally, Hagger (2019) notes that intervening on self-regulatory skills in tandem with stable cues or context is needed for successful habit formation. Without the presence of an intervention, habits tend to be perceived as relatively stable and are conceptually different from behavioral tendency (Verplanken & Melkevik, 2008). Habits, once formed, can help enact the corresponding behavior with less cognitive control and resources (Kwasnicka et al., 2016). In line with this, studies have reported stronger intention-behavior relationships at higher levels of physical activity habit strength (e.g., de Bruijn, 2011; de Bruijn et al., 2012a, 2012b; Rhodes et al., 2012), meaning that people for whom physical activity is more automatic are more able to translate their intentions into physical activity behavior. In contrast, it has been shown that intentions might play a more important role, i.e., be related to physical activity more strongly, for people with weak habits than for people with strong habits (de Bruijn & Rhodes, 2011; Di Maio et al., 2021; Rebar et al., 2014; van Bree et al., 2013). This indicates that automatic regulatory processes play a role in the intention-behavior coupling.

Social support. Intriguingly, among the variables that showed no moderating effect on the intention-physical activity relationship in the review (Rhodes et al., 2022) was social support. This was despite the evidence that social support for exercise or physical activity from others is linked with higher levels of physical activity (Carron et al., 1996; Trost et al., 2002) and the theoretical suppositions of most social cognitive theories that posit that social support can enhance an individual's motivation, self-efficacy, and ability to translate their intentions into actual behavior by, for example, reducing perceived barriers and providing cues to action, all processes that can transpire on the day-to-day level. Indeed, evidence has shown that daily social support may be associated with more physical activity at the within-person level, with studies demonstrating that on days with more perceived social support to exercise, participants were more active (Hekler et al., 2012). Nevertheless, direct support for the strengthening effect of social support on the intention-physical activity relationship is lacking with some studies, which focused on general and not exercise specific social support, indicating no effect (e.g., Schumacher et al., 2021; Sniehotta et al., 2013). Nevertheless, perceived social support can serve important health-enhancing functions as a daily resource for managing stress (Hefner & Eisenberg, 2009; Pilcher et al., 2016). Perceived social support has also been proposed as a potential resource of self-control, a component of decision-making crucial for effective management and regulation of day-to-day life, especially under stress-inducing situations (Pilcher et al., 2016). Thus, feeling supported in exercising by family and friends could help individuals regulate their behavior accordingly in critical moments and help them follow through on their initial intentions despite encountering stressful situations during the day, although direct empirical tests of these effects are currently lacking.

Barriers to exercise. Another moderator that has shown emerging evidence in affecting, specifically weakening, the link between intention and physical activity are perceived barriers to exercising or physical activity. Barriers to exercising are negatively associated with levels of physical activity (Bautista et al., 2011; Trost et al., 2002). Moreover, more perceived barriers were linked to lower exercise intention (Godin et al., 1991, 1994) and low and high intenders were found to differ in perceived barriers (Godin et al., 1994). However, the effect of perceived barriers to exercising or physical activity directly on the relationship between intention and physical activity has not been explored yet. Studies in other areas such as cardiac rehabilitation or vaccinations have however indicated that barriers could negatively affect the intention-behavior relationship (daCosta Dibonaventura & Chapman, 2005; Williamson et al., 2020).

Demographic variables. The intention-behavior relationship could also be additionally moderated by various demographic characteristics such as gender and age, although the Rhodes et al.'s (2022) findings on the effect of gender are highly inconsistent. Whereas several studies indicated that for women, the relationship between intention to be active and actual physical activity is weaker than for men, meaning that women are less able to follow through on their intentions (Dodd et al., 2012; Plotnikoff et al., 2012; Santina et al., 2017), others report opposite results (Nigg et al., 2009; Xin et al., 2019), or no effect of gender (e.g., Godin et al., 2010; Lange et al., 2018). Similarly, regarding the effect of age, the current evidence is insufficient to determine the effect (Rhodes et al., 2022). The relationship between intention and behavior was stronger for older adults compared with younger adults in the context of leisure-time PA and cycling behavior (Amireault et al., 2008; Xin et al., 2019). However, there is some evidence to the contrary (e.g., Nigg et al., 2009), supported especially for certain populations such as cancer survivors (Karvinen et al., 2007, 2009). It is plausible that the effect in such populations might differ from the general population.

1.2. Between- and within-person effects

Although many of the previous studies on moderators of the intention-behavior gap in physical activity were longitudinal studies, most of them included a limited number of measurement occasions and did not focus on the mechanisms of change within an individual. However, only under very specific conditions, which are rarely obtained in real psychological processes (e.g., ergodicity, stationarity, or homogeneity of the studied processes), do associations derived from differences between people translate to the within-person processes (Molenaar, 2004). To truly understand the within-person mechanisms of behavior, studies with intensive repeated assessments such as ecological momentary assessment studies (EMAs; Shiffman et al., 2008) are needed. The intensively spaced repeated measurement allows for the separation of interindividual variability (between-person differences) from intraindividual variability (within-person fluctuations). More concretely, questions concerning interindividual variability help us answer, for instance, whether *people who generally have higher levels of intention to be physically active are more active than people with lower levels of intention.* On the one hand, such research questions provide valuable information about the differences at the between-person level and could help determine the vulnerable or struggling subpopulations to focus on; it cannot be extrapolated that the same differences and relationships are present at the within-person level. Concerning intraindividual variability, on the other hand, we would be interested in answering the question of *whether a person engages in more activity on a day when they set an intention to do so*. Only by studying the relationships at the within-person level can we gain support for the underlying mechanism of change, understand the effects of daily lived experiences on behavioral processes and change (Sliwinski, 2008), and subsequently intervene on the relevant variables. Additionally, we can answer questions about the effect of between-person differences on within-person processes (cross-level). For instance, we may be interested in *whether there are differences in the within-person relationship between intention and physical activity as a function of a between-person difference in exercise identity*.

1.3. Present study

The aim of the current study is to evaluate the possible moderators of the relationship between the intention to be physically active and actual physical activity (step counts). Individual differences, i.e., exercise identity, physical activity habit, age, and gender, are evaluated as moderators of the intention-PA relationship at the between-person level. Daily barriers to physical activity and daily experienced social support for physical activity are evaluated as moderators at the within-person level. Additionally, we were interested in whether any of the individual differences served as moderators of the within-person intention-PA relationship (i.e., cross-level moderators). The present study utilizes data from a 14-day burst of a 12-month-long prospective study with an intensive measurement-burst design.

At the within-person level, we hypothesize that daily experienced social support for physical activity will strengthen the relationship between daily intention and daily physical activity. On the other hands, daily barriers to physical activity are expected to weaken the daily intention-physical activity relationship.

At the between-person level, we hypothesize that exercise identity, physical activity habit as well as average social support for physical activity (averaged across the 14 days) will strengthen the relationship between average intention and average daily physical activity while average barriers to physical activity (averaged across the 14 days) will weaken this relationship. Further, we expect that for older adults and men, the relationship between intention and physical activity will be stronger than for younger adults and women.

Additionally, we also hypothesize that exercise identity, physical activity habit, average social support for physical activity, and average intention will strengthen the within-person relationship between daily intention and daily physical activity while average barriers to physical activity will weaken this within-person relationship (i.e., cross-level moderation). We also expect the within-person relationship between intention and physical activity to be stronger for older adults and men as opposed to younger adults and women.

2. Methods

2.1. Study procedure

Participants in the present study were from the 12-month longitudinal prospective 4HAIE (Healthy Aging in Industrial Environment, Program 4) study with $N = 1314$ adult participants, aged 18 to 65, which focused on the links between air pollution, health, and aging. The overall aim of the 4HAIE project is to assess the influence of biomechanical variables, physiological variables, psychosocial and socio-economic variables, and the external environment (air pollution) and their potential interaction on the incidence of running-related injuries, physical (in)activity, health, and quality of life. To achieve this goal, a prospective cohort study was conducted in a large sample of individuals who permanently live in an environment with a strong presence of heavy industry, compared to a control group of individuals living in an area with minimal environmental pollution. The project is highly interdisciplinary and the first wave of measurement of the established cohort focused predominantly on hypotheses generation concerning the air-polluted environments. This is related to the breadth of investigated variables (for a full list of aims and hypotheses see the Supplementary Material), which will be reduced in the following waves of measurement. The various streams of data that were collected can be found on the study website here: https://www.4haie.cz/en/data-2/ and are described in the respective laboratory protocols (Cipryan et al., 2020; Elavsky et al., 2021; Jandacka et al., 2020).

The present study falls under *Aim 4: To assess the influence of psychosocial and socioeconomic variables on the incidence of running injuries, physical (in)activity, health, and quality of life* and specifically hypothesis *H4.2.3. Short-term changes in intention, social* support*, affect, and stress predict changes in physical activity.* Please note that multiple studies and analyses might be related to one hypothesis, e.g., the present study focuses on intention, social support and barriers while a subsequent study will focus on the relationship between affect and physical activity, specifically.

The study procedures were approved by the Ethical Committee of the University of Ostrava and study participants completed a written informed consent. The sample was obtained using non-probabilistic quota sampling of volunteers from two regions in the Czech Republic in central Europe (Moravian-Silesian region and South-Bohemian region), balanced on age, gender, and physical activity status (60 % active runners vs. 40 % insufficiently active – i.e., not meeting the WHO recommendations of 150 min MVPA/week; WHO, 2020). Data was collected from April 2019 to September 2022. Participants went through laboratory baseline testing at the University of Ostrava and were then followed for 12 months using a fitness monitor. Participants wore a fitness monitor Fitbit Charge 3 (or Fitbit Charge 4 in later phases of the study) and were instructed to wear their device all day, including sleep, sedentary periods, and exercise bouts except for activities where a watch could pose a risk of injury (e.g., climbing, playing volleyball). Participants connected and synchronized their devices through their own smartphones and were instructed to check if the synchronization was working correctly, which was also monitored periodically by study staff.

During the 12-month follow-up period, participants completed brief smartphone surveys administered through a custom app during four intensive data collection bursts (baseline, month 4, month 8, and month 12). Each burst lasted 2 weeks and involved ecological momentary assessment using 4 short smartphone surveys per day. EMA smartphone questionnaires were sent to participant smartphones at pseudo-random times within specific time windows (morning 8:00 AM - 11:59 AM; afternoon 12:00 PM - 3:59 PM; evening 4:00 PM-7:59 PM; night 8:00 PM - 9:59 PM). Questionnaires were available to fill out for 45 min (with a timestamp of actual completion) and were designed to take less than 2 min to complete. Details on the full behavioral, psychological, and neuroimaging study protocol can be found elsewhere (Elavsky et al., 2021). The current study utilizes the EMA survey and physical activity data from the first 14-day burst of intensive monitoring as well as data from online questionnaires completed at baseline testing and at 6 months after baseline testing (in the case of physical activity habit, which was added later).

2.2. Participants

To determine the sufficient sample size and power to detect the respective effects, we draw upon a Monte Carlo simulation of minimum detectable effect size for multi-level studies by Arend and Schäfer (2019). For data with high intraclass correlation (as is the case in repeated measurements of the same individual) and power set at 0.80, the simulation with 14 measurements per individual and a sample of 200 individuals shows the following minimum detectable effect sizes: i) for within-person effects 0.09, ii) for between-person effects 0.21, and iii) for cross-level interaction 0.23. Thus, our sample size is enough to detect a within-person predictor's effect with small effect size. As for the between-person and cross-level effects, the sample size of 200 individuals was sufficient to detect the effect with small to medium effect size. Given that our sample size is significantly larger, it is very likely that even a small effect size can be detected.

The final sample used in this study consisted of N = 1135 participants and N = 10,030 valid person-days. A valid day was defined as a day when participants provided valid EMA self-reports (i.e., answers on specific items in the morning and night questionnaires, see details in section 2.3.2. EMA Data), had valid fitness monitor data of at least 10 non-sleep hours, and recorded non-zero step counts. Missing data were addressed using Mplus' default method with a Bayesian estimator (Asparouhov & Muthén, 2010). This approach imputes missing values in dependent variables (i.e., step counts) with model-implied plausible values, while excluding lines of data with missing independent variables (e.g., physical activity habit, daily barriers to physical activity; see Fig. 1 for model specification).

On average, valid days per participant that were used in the analyses were M = 8.84, SD = 3.56. The majority of participants (74.7 %, N = 848) had at least 7 valid person-days included in the analyses, accounting for at least half of the measurement period.

Table 1 provides descriptive statistics of the participants included in the final analysis and excluded participants with missing data on the variables of interest. The average age of the included participants was *M* = 38.68, *SD* = 12.64 and 47.3 % (n = 537) were women. At baseline, 56.7 % (n = 644) of the participants in the final sample were classified as runners and 43.7 % (n = 491) as inactive participants. The only significant difference between included and excluded participants was with regard to age, with included participants being slightly older.

Table 1
Descriptive statistics of the sample.

Variable	*M (SD);* Range/Percentage (n)	
	Included Participants n = 1135	Excluded Participants n = 180
Age	38.73 (12.54); 18-65	34.20 (12.02); 18–65 *
Gender	Women 47.3 % (537)	Women 40.0 % (72)
Location	Moravian-Silesian region 57.7 % (655)	Moravian-Silesian region 52.8 % (95)
Activity Status	Runners 56.7 % (644)	Runners 57.2 % (103)
Education	Primary 4.4 % (50) Secondary 48.1 % (542) Tertiary 47.4 % (534) *Data available for n = 1126*	Primary 7.3 % (13) Secondary 52.8 % (94) Tertiary 39.9 % (71) *Data available for n = 178*

* Significant difference between included and excluded participants; $p < 0.001$, *Cohen's d* = 0.36
Note. *M* = mean, *SD* = standard deviation

2.3. Measures

2.3.1. Fitbit data

Fitbit weartime. Total daily minutes of non-sleep Fitbit wear were calculated and subsequently recoded as hours/day. A valid minute was defined as a minute where either (at least one) HR value or non-zero step counts were recorded. Minutes that were tagged as sleep by Fitbit were excluded. Four participants did not provide any Fitbit data throughout the study and were completely excluded. Among other participants, days with less than 10 h of valid wear time were excluded from the analyses, resulting in an exclusion of 1313 person-days (7.2 % of the total number of person-days) and 19 participants.

Daily physical activity (step counts). Daily physical activity was objectively assessed as total daily step counts. Fitbit provides step counts for an interval of every few seconds, which were then aggregated to total daily step counts. Minutes that were tagged as sleep by Fitbit were excluded. Days with 0 steps were excluded (17 person-days). For the analyses, daily step counts were divided by 1000 to assimilate the scale of the other variables.

2.3.2. EMA data

Daily intention to be physically active. Intention to be physically

Level 1 Within-Person Level Equations

$$\textbf{Daily Steps}_{di} = \beta_{0i} + \beta_{1i}(\text{Intention})_{di} + \beta_{2i}(\text{Severity of Barriers to Physical Activity})_{di} + \beta_{3i}(\text{Social Support for Physical Activity})_{di} + \beta_{4i}(\text{Intention x Barriers})_{di} + \beta_{5i}(\text{Intention x Social Support})_{di} + \beta_{6i}(\text{Weartime})_{di} + e_{di} \quad (1)$$

Level 2 Between-Person Level Equations

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Gender})_i + \gamma_{02}(\text{Age})_i + \gamma_{03}(\text{Avg Intention})_i + \gamma_{04}(\text{Avg Barriers})_i + \gamma_{05}(\text{Avg Social Support})_i + \gamma_{06}(\text{Exercise Identity})_i + \gamma_{07}(\text{PA Habit})_i + \gamma_{08}(\text{Avg Intention x Gender})_i + \gamma_{09}(\text{Avg Intention x Age})_i + \gamma_{0;10}(\text{Avg Intention x Avg Barriers})_i + \gamma_{0;11}(\text{Avg Intention x Avg Social Support})_i + \gamma_{0;12}(\text{Avg Intention x Exercise Identity})_i + \gamma_{0;13}(\text{Avg Intention x PA Habit})_i + u_{0i} \quad (2)$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{Gender})_i + \gamma_{12}(\text{Age})_i + \gamma_{13}(\text{Avg Intention})_i + \gamma_{14}(\text{Avg Barriers})_i + \gamma_{15}(\text{Avg Social Support})_i + \gamma_{16}(\text{Exercise Identity})_i + \gamma_{17}(\text{PA Habit})_i + u_{1i} \quad (3)$$

$$\beta_{2i} = \gamma_{20} + u_{2i} \quad (4)$$

$$\beta_{3i} = \gamma_{30} + u_{3i}$$

$$\beta_{4i} = \gamma_{40} + u_{4i}$$

$$\beta_{5i} = \gamma_{50} + u_{5i}$$

$$\beta_{6i} = \gamma_{60} + u_{6i}$$

Figure 1. Evaluated multilevel model equations. *Note.* Avg – average

active was reported daily in the morning questionnaire via a "yes/no" item: *Do you plan to workout, exercise, or do any other physical activity today?* A total number of 40 participants provided no data on intention to be active throughout the 2-week burst period.

Severity of daily barriers to physical activity. Barriers to exercising or being physically active were reported daily in the night questionnaire. First, participants chose all the relevant barriers they experienced from a list of 13 potential barriers (a multi-select, multiple-choice question). The list of barriers was derived from a 30-item Physical Activity Barriers Efficacy scale (Conroy et al., 2012). The presented barriers included low intrinsic motivation (e.g., *I did not have enough motivation*), competing time demands (e.g., *I had too much to do at home, work, or school*), self-consciousness (e.g., *I was embarrassed by my body in front of others*), fatigue (e.g., *I felt tired*), hostile weather (e.g., *Unfavorable weather*), low self-efficacy (e.g., *I did not know how to*), poor environment (e.g., *I had nowhere to exercise/do sport*), injury (e.g., *Pain, injury, illness*), or other barriers. Participants then rated the severity (*How much did the following keep from exercising or doing physical activity today?*) of the selected barriers on a slider from *0 not at all* to *100 very much*. The total score of barriers was calculated as the average severity rating across all barriers (when a barrier was not reported, the severity rating was calculated as 0). A total number of 34 participants provided no data on barriers throughout the 2-week burst period.

Daily social support for physical activity. Social support for physical activity from others was reported daily in the night questionnaire. The slider question *To what extent have you felt* supported *today by your friends or family to be physically active?* was rated from *0 not at all* to *100 very much*. A total number of 35 participants provided no data on social support throughout the 2-week burst period.

2.3.3. Questionnaire data

Exercise identity. Exercise identity was measured at baseline using a 9-item scale developed by Anderson and Cychosz (1994). The statements were rated on a 7-point response scale from *1 strongly disagree* to *7 strongly agree*. Example items were: *I consider myself an exerciser; I need to exercise to feel good about myself; I would feel a real loss if I were forced to give up exercising.* The total score was calculated as the mean across all items. Cronbach's α in the current study was .940. A total number of 5 participants did not provide answers for the exercise identity questionnaire.

Physical activity habit. Habit was measured at 6 months using the 12-item Self-Report Habit Index developed by Verplanken and Orbell (2003). The statements were rated on a 7-point response scale from *1 strongly disagree* to *7 strongly agree*. Example items were: *Physical activity is something I do automatically.; Physical activity is something that I do without thinking.; Physical activity is something that belongs to my routine.* The total score was calculated as the mean across all items. Cronbach's α in the current study was 0.966. A total number of 135 participants did not provide answers for the habit questionnaire.

2.3.4. Data analyses

The hypotheses were evaluated using a multi-level moderation regression model with Bayesian estimator. Analyses were conducted in Mplus Version 7.4 (Muthén & Muthén, 1998-2017). The multi-level models can accommodate the nested structure of the data, i.e., multiple measurement occasions (e.g., days; level 1) for individual participants (level 2). Multi-level models allow for the decomposition of the between- and within-person variance, and thus can help evaluate relationships at the between-person level, (e.g., interindividual differences), the within-person level (e.g., intraindividual variability) as well as relationships that span both levels (e.g., a stable characteristic that can help explain differences in patterns of intraindividual variability or so-called "cross-level" moderators). The evaluated model is described in Fig. 1,

Where i denotes person and d denotes day. All level 1 variables (within-person level), which were measured daily (i.e., intention, social support, barriers to exercise, and weartime), were person-mean centered, meaning that they capture deviations from an individual's person-specific empirical mean across the 14 measurement days. Level 2 variables (between-person level) were either measured only once (i.e., exercise identity, PA habit, age, gender) or obtained by computing the empirical averages of the daily measured variables across the 14 days for each individual (i.e., average intention, average social support, average barriers), followed in both cases by centering around the sample grand mean, meaning that they now represent deviations from the means across participants. Due to convergence difficulties given the need to accommodate all the within- and between-person processes including random effects as well as the various interaction effects, latent mean decomposition in Mplus was not conducted.

The within-person component, depicted in equation (1), models each person i's physical activity on day d as a function of the intercept (β_{0i}), daily intention (β_{1i}), daily barriers to exercise (β_{2i}), daily social support for exercise (β_{3i}) as well as the interaction terms of daily intention*daily barriers (β_{4i}) and daily intention*daily social support (β_{5i}), evaluating the moderating effects of barriers and social support on the daily intention-steps relationship. Wear time (β_{6i}) is included at the within-person level to control for different length of Fitbit wear for each participant on each day.

Equations (2–4) describe the between-person component of the model where (γ_{00}-γ_{60}) represent the fixed intercepts. Equation 2 tests whether gender (γ_{01}), age (γ_{02}), average intentions (γ_{03}), average barriers (γ_{04}), average social support (γ_{05}), exercise identity (γ_{06}), and PA habit (γ_{07}) as well as the interaction terms of avg intention*gender (γ_{08}), avg intention*age (γ_{09}), avg intention*avg barriers ($\gamma_{0;10}$), avg intention*avg social support ($\gamma_{0;11}$), avg intention*exercise identity ($\gamma_{0;12}$), avg intention*PA habit ($\gamma_{0;13}$) explain interindividual differences in physical activity. Equation 3 test the cross-level moderating effects of gender (γ_{11}), age (γ_{12}), avg intention (γ_{13}), avg barriers (γ_{14}), avg social support (γ_{15}), exercise identity (γ_{16}) and PA habit (γ_{17}) on the within-person relationship between daily intention and physical activity. In other words, the slope coefficients (γ_{11}-γ_{17}) in equation (3) denote whether daily relationship between intention and physical activity is moderated by person-level characteristics.

All level-1 coefficients are allowed to vary between people and include a random effect component (u_{0i}–u_{6i}), representing the unexplained variance in the within-person model coefficients (β_{0i}–β_{6i}) by the between-person constraints.

Additionally, to control for other study design-related variables, we evaluated a further model that included activity status at baseline (runner vs. inactive), location (region 1 vs. region 2), and continuous study day. To further evaluate the robustness of the results, we also reran the model depicted in Fig. 1 with minutes of moderate-to-vigorous intensity physical activity (MVPA) as the dependent variable. Description of the additional evaluated models and the model results are presented in the Supplementary Material.

The models were estimated using the Bayesian estimator utilizing the default settings of Mplus (Asparouhov & Muthén, 2010). The model convergence was assessed by potential scale reduction (PSR) value (Gelman & Rubin, 1992). Thus, the reported coefficients are supplemented with the posterior standard deviation and the 95% credible interval values for the coefficient.

3. Results

3.1. Descriptive statistics

Grand means, i.e., mean of person means, were calculated for all the variables measured at daily level for the included participants (see Table 2). The average level of daily steps across the participants was 14 063 ($SD = 5116$) with average Fitbit wear-time of 15.72 h per day ($SD = 0.99$). Most participants reported none or only few barriers to physical activity ($M = 0.60$, $SD = 0.95$, range 0–9) and the respective severity

Table 2
Descriptive statistics of included variables.

Variable	*M (SD)*, range	*ICC*
Fitbit Variables		
Daily Steps	14 063 (5116); 2150–35 396	0.40
Daily Fitbit Valid Wear (Hours)	15.72 (1.00); 11.75–22.80	0.19
EMA Variables		
Intention to be Physically Active	0.53 (0.30); 0.00–1.00	0.29
Severity of Barriers to Physical Activity	3.40 (3.41); 0.00–42.92	0.26
Social Support for Physical Activity	51.84 (26.27); 0.00–100.00	0.50
Questionnaire Variables		
Exercise Identity	4.41 (1.63); 1.00–7.00	–
Physical Activity Habit	4.65 (1.69); 1.00–7.00	–

Note. *M* = mean, *SD* = standard deviation, *ICC* = intra-class correlation coefficient

ratings. Averaging these severity ratings across the other non-reported barriers (rated at 0) led to relatively low overall severity values with an average of 3.40 and a positively skewed distribution. The most commonly reported barriers were competing time demands (*I had too much to do at home, work, or school*), fatigue (*I felt tired*), negative affect (*I wasn't in the mood to exercise*), and injury (*Pain/injury/illness*), respectively. Table 2 also provides average scores and descriptive statistics for the questionnaire measures of exercise identity and physical activity habit. For a correlation table of the predictor variables, see the Supplementary Material.

3.2. Multi-level moderation model

For Bayesian estimation of the multi-level moderation model, we used two chains and a minimum number of 10,000 iterations for each chain. The first half of each chain was used as burn-in iterations. The point estimates were obtained using the median of the MCMC samples after burn-in. Table 3 presents the final coefficients from the hypothesized multi-level model of step counts with Bayesian estimator described in detail in Fig. 1. Table 4 presents the random effect covariance matrix.

3.2.1. Within-person effects

At the within-person level, daily intentions and social support were positively related to the daily step counts, while barriers to physical activity were negatively associated. Additionally, valid weartime was positively associated with daily step counts. Consistent with our moderation hypotheses, while higher intention was positively associated with increased step counts, this relationship was influenced by daily barriers and social support. Specifically, when individuals faced more severe barriers than usual during the day, the positive association between intention and step counts was weakened ($\gamma_{40} = -0.267$; CI_{95} = [−0.340, −0.196]). Conversely, when individuals received greater support for physical activity than usual on a given day, the positive effect of intention on step counts was amplified ($\gamma_{50} = 0.143$; CI_{95} = [0.023, 0.262]). In other words, on a day when a participant reports barrier severity that was 1SD above their average level, setting an intention to be physically active results in appx. 1200 steps less than on a day with average severity of barriers for that given participant. Above average social support (1SD above the person-mean), on the other hand, results in appx. 340 more steps on that day. Both associations also varied between individuals (barriers: $\sigma^2_{u4i} = 0.081$, CI_{95} = [0.040, 0.151]; social support: $\sigma^2_{u5i} = 0.233$, CI_{95} = [0.095, 0.445]).

3.2.2. Between-person effects

At the between-person level, gender, age, person-average intention, and person-average severity of barriers predicted person-average step counts while person-average social support for physical activity did not. As for the moderators, only physical activity habit was shown to strengthen the intention-steps relationship ($\gamma_{0;13} = 0.794$; CI_{95} = [0.090, 1.486]). For individuals with strong habit relative to other participants

Table 3
Coefficients from multilevel moderation regression model with Bayesian Estimator.

Predictor Variable			95% *CI*	
	Estimate	*SD*$_{post}$	Lower	Higher
Fixed Effects for Within-Person Level (L1)				
Intercept steps γ_{00}	13.532[a]	0.151	13.233	13.823
Daily Intention γ_{10}	2.998[a]	0.154	2.697	3.297
Daily Severity of Barriers γ_{20}	−0.231[a]	0.015	−0.261	−0.200
Daily Social Support γ_{30}	0.372[a]	0.028	0.319	0.427
Daily Intention x Barriers γ_{40}	−0.267[a]	0.037	−0.34	−0.196
Daily Intention x Social Support γ_{50}	0.143[a]	0.061	0.023	0.262
Daily Weartime γ_{60}	0.575[a]	0.042	0.493	0.656
Fixed Effects for Between-Person (L2)				
Gender γ_{01}	−0.701[a]	0.271	−1.235	−0.17
Age γ_{02}	0.033[a]	0.011	0.013	0.055
Average Intention γ_{03}	3.710[a]	0.528	2.692	4.770
Average Severity of Barriers γ_{04}	−0.174[a]	0.046	−0.268	−0.085
Average Social Support γ_{05}	0.004	0.052	−0.098	0.106
Exercise Identity γ_{06}	0.429[a]	0.117	0.201	0.664
PA Habit γ_{07}	0.621[a]	0.11	0.403	0.835
Average Intention x Gender γ_{08}	−1.214	0.892	−2.959	0.541
Average Intention x Age γ_{09}	−0.003	0.034	−0.068	0.064
Average Intention x Average Barriers $\gamma_{0;10}$	−0.187	0.134	−0.451	0.074
Average Intention x Average Social Support $\gamma_{0;11}$	−0.042	0.166	−0.358	0.291
Average Intention x Exercise Identity $\gamma_{0;12}$	−0.092	0.372	−0.826	0.626
Average Intention x Physical Activity Habit $\gamma_{0;13}$	0.794[a]	0.357	0.09	1.486
Fixed Effects for Cross-Level Interaction				
Daily Intention x Gender γ_{11}	−1.294[a]	0.289	−1.854	−0.707
Daily Intention x Age γ_{12}	0.042[a]	0.012	0.017	0.064
Daily Intention x Average Intention γ_{13}	1.054	0.824	−0.569	2.697
Daily Intention x Average Barriers γ_{14}	−0.153[a]	0.054	−0.268	−0.052
Daily Intention x Average Social Support γ_{15}	−0.012	0.060	−0.127	0.105
Daily Intention x Exercise Identity γ_{16}	0.300[a]	0.126	0.047	0.546
Daily Intention x Physical Activity Habit γ_{17}	0.164	0.120	−0.07	0.403
Random Effects				
Residual variance in daily intention slope σ^2_{u1i}	3.312[a]	0.786	1.992	5.058
Variance in daily barriers slope σ^2_{u2i}	0.029[a]	0.006	0.019	0.044
Variance in daily social support slope σ^2_{u3i}	0.144[a]	0.028	0.094	0.205
Variance in daily intention x barriers slope σ^2_{u4i}	0.081[a]	0.029	0.040	0.151
Variance in daily intention x social support slope σ^2_{u5i}	0.233[a]	0.088	0.095	0.445
Variance in daily weartime slope σ^2_{u6i}	0.568[a]	0.079	0.429	0.736
Within-person residual variance in steps, σ^2_{edi}	22.737[a]	0.392	21.983	23.522
Between-person residual variance in steps, σ^2_{u0i}	16.132[a]	0.840	14.588	17.887

Note. Estimate = median of posterior distribution; CI = credible interval; SD_{post} posterior standard deviation

[a] Effect for which the 95% CI does not include 0;

Table 4
Random effect covariance matrix.[a]

	u1i	u2i	u3i	u4i	u5i	u6i
u1i	1.000					
u2i	−0.128[a]	1.000				
u3i	0.102	−0.004	1.000			
u4i	−0.301[a]	0.036[a]	−0.010	1.000		
u5i	0.262	0.005	0.100[a]	−0.005	1.000	
u6i	0.010	0.057	0.104[a]	0.042	0.110	1.000

[a] Effect for which the 95% credible interval does not include 0.

(1SD above the grand mean), higher average number of days when they formed an intention was linked with 1340 more steps on their average day (calculated across the 14-day period) compared to someone with average habit. Contrary to our hypotheses, no other variables moderated the intention-physical activity relationship at the between-person level, i.e., neither gender ($\gamma_{08} = -1.214$; $CI_{95} = [-2.959, 0.541]$) age ($\gamma_{09} = -0.003$; $CI_{95} = [-0.068, 0.064]$), person-average severity of barriers ($\gamma_{0;10} = -0.187$; $CI_{95} = [-0.451, 0.074]$), person-average social support ($\gamma_{0;11} = -0.042$; $CI_{95} = [-0.358, 0.291]$), nor exercise identity ($\gamma_{0;12} = -0.092$; $CI_{95} = [-0.826, 0.626]$).

3.2.3. Effect of between-person variables on the within-person effects

Additionally, we evaluated the moderating effect of stable characteristics on the within-person intention-PA relationship (i.e., cross-level moderators). Consistent with our hypotheses, gender ($\gamma_{11} = -1.294$; $CI_{95} = [-1.854, -0.707]$), age ($\gamma_{12} = 0.042$; $CI_{95} = [0.017, 0.064]$), and person-average severity of barriers to physical activity ($\gamma_{14} = -0.153$; $CI_{95} = [-0.268, -0.052]$) and exercise identity ($\gamma_{16} = 0.300$; $CI_{95} = [0.047, 0.546]$) moderated the within-person relationship between daily intentions and daily step counts. The effect of setting an intention on a given day on step counts was stronger for men, older adults, and individuals with stronger exercise identity and weaker for individuals with higher average barriers. This means that on a day when they set an intention, men record 1300 more steps than women, older participants (by a "unit" of 10 years) record 420 more steps. Individuals with higher average severity of barriers (1SD above grand mean), on a day when they set an intention, record 520 less steps and conversely, individuals with higher exercise identity (1SD above grand mean) record 490 more steps. Contrary to our hypotheses, no other variables, including person-average social support ($\gamma_{15} = -0.012$; $CI_{95} = [-0.127, 0.105]$), person-average intention ($\gamma_{13} = 1.054$; $CI_{95} = [-0.569, 2.697]$), and physical activity habit ($\gamma_{17} = 0.164$; $CI_{95} = [-0.070, 0.403]$), moderated the within-person relationship between intentions and physical activity.

The additional evaluated models are presented in the Supplementary Material. The model with additional design-related variables included activity status at baseline, location, and day in study as predictors of step counts. When included in the model, the between-person effect of activity status on steps was credibly different from zero, while the between-person effect of exercise identity on steps diminished. This could be due to the close relationship between activity status and exercise identity (*Pearson's* $r = 0.694$, see Supplementary Material). All other effects, including the moderation effects, remained identical to the main model described above. We also evaluated a model with moderate-to-vigorous intensity physical activity as the dependent variable. This model also showed consistent results with the main model, specifically in terms of the moderation effects at various levels of analysis.

4. Discussion

The present study provided a rare evaluation of within- and between-person moderators of the day-to-day relationship between individuals' intentions to be physically active and actual physical activity. The strength of the present study lies in the inclusion of multiple moderators of the intention-behavior relationship at both the within- and between-person level in a single model. Our intensive measurement design and a large sample size allowed us to separate the interindividual variability and intraindividual variability and explore the individual dynamics in the relationship between intentions and actual physical activity. To date, a limited number of studies have focused on the intention-behavior moderators at the within-person level (e.g., Arigo et al., 2022; Haag et al, 2023; Schumacher et al., 2021), thus, the present study is an important addition.

Our results show that moderation effects present at the within-person level do not necessarily translate to the between person level and vice-versa, stressing the importance of multilevel approaches to data analysis. While only the physical activity habit moderated the relation between intention and physical activity at the between-person level, the within-person intention-activity relationship was affected by other time-varying variables including daily severity of barriers to physical activity and social support for physical activity as well as person-level characteristics such as gender, age, and exercise identity.

Specifically, at the level of an individual, results show that both daily perceived severity of barriers to physical activity and daily social support for physical activity affected how much daily intentions to be physically active were translated into actual step counts. Regarding the effect of barriers, on a day when an individual faced more severe barriers to physical activity than usual, setting an intention to be physically active had weaker association with behavior. We also supported the moderating effect of average barriers on the daily intention-activity relationship, meaning that individuals with higher average experienced barrier severity had a weaker intention-behavior link. The moderating effect of barriers has been supported for other behaviors such as vaccinations (daCosta Dibonaventura & Chapman, 2005) and in the context of cardiac rehabilitation (Williamson et al., 2020), however it has not been previously evaluated at the within-person level with respect to physical activity. This is an important finding because it suggests that it is crucial to evaluate the barriers that individuals face daily and find ways to reduce their severity or tailor intervention strategies to various levels of severity of barriers experienced by an individual on a given day. Personalized interventions could for instance become more intensive (e.g., increase dose or deploy more strategies) or use different strategies on days when more severe barriers are faced or expected. Barriers in the present study were measured as subjectively perceived barriers across various dimensions (e.g., competing time demands, hostile weather, negative affect, poor environment) and their severity that were combined into a measure of overall experienced severity of barriers. Future studies could focus on disentangling the various types of barriers and evaluating their individual roles in the intention-behavior relationship. For instance, one of the most reported barriers to exercising - "lack of time", might encompass other reasons for not being active such as competing activities, prioritizing other activities, suboptimal time-management skills.

Our results further indicated that having more social support for physical activity than usual on a given day strengthened the relationship between intention to be physically active and physical activity. This finding adds empirical support for the moderating effect of social support on the intention-behavior relationship which lacked support in previous studies (e.g., Rhodes et al., 2022; Sniehotta et al., 2013), possibly due to the between-person focus of the studies. Our results indicate that perceived social support for physical activity could serve as a daily "inner" resource for managing stress and increasing self-control crucial for effective regulation of behavior in day-to-day life (Hefner & Eisenberg, 2009; Pilcher et al., 2016), and thus help individuals follow through with their intentions. Importantly, we found that there were differences among individuals in how much the daily barriers and social support affected whether an intention translated to more physical activity on that day. This further underlines the importance of examining person-specific behavioral trajectories and models or weighing the individual heavily in the models of behavior.

The present study also found that several demographic characteristics affected the intention-physical activity relationship. Results show that the relationship between intentions and physical activity is stronger for men as opposed to women. However, this effect was present only at the cross-level which means that the individual daily within-person relationship between intention and physical activity was stronger for men as opposed to women, but not at the average between-person level. So far, findings on the effect of gender have been highly inconsistent with some proposing that men are more able to follow through on their intentions (e.g., Dodd et al., 2012; Plotnikoff et al., 2012; Santina et al., 2017) while others stating the opposite (Nigg et al., 2009; Xin et al., 2019). The effects have been evaluated largely at the between-person level (i.e., average differences between individuals). The mechanisms behind the differences based on gender remain unclear but could involve gender associated attitudes, gender roles, or gender-based constraints associated with physical activity (Biddle & Bailey, 1985; Reading & LaRose, 2020). Future studies on the role of gender in the intention-physical activity relationship are needed to clarify the role of gender, its mechanisms of action, and appropriateness of gender as a "tailoring" variable in intervention development. Although the intention-physical activity relationship did not differ based on age at the between-person level, the within-person relationship between intention and behavior was stronger for older participants. It is possible that as individuals age, they may know themselves and their daily demands better and as a result may be able to use more efficient behavior regulation strategies such as selection, optimization, and compensation for planning (Reuter et al., 2010), or simply prefer and engage in consistent activities compared to their younger counterparts (Brown et al., 2005).

Regarding the moderating effects of physical activity habit and exercise identity, our results were inconsistent across the levels of analysis with habit strengthening the intention-behavior link only at the between-person level; and exercise identity strengthening the daily within-person relationship between intention and physical activity. In the case of exercise identity, there has been convincing evidence that people with higher exercise identity or self-schema have a stronger relationship between intentions and physical activity (e.g., de Bruijn & van den Putte, 2012; Sheeran & Abraham, 2003; see also review by Rhodes et al., 2022). However, it should be noted that in the majority of these studies both physical activity and exercise identity were assessed by self-report, possibly inflating the strength of the associations with intentions due to common method and social desirability biases. Regarding the role of habit, the existing literature has been inconsistent and there is an ongoing debate on the relationship between habit, intentions, and behavioral enactment. In line with our results, some studies have found that those who are more used to exercising and being physically active (higher habit) are more able to translate their intentions to be physically active to actual behavior (e.g., de Bruijn, 2011; de Bruijn, Rhodes, & van Osch, 2012; Rhodes et al., 2012). However, other studies have shown that intentions are related to physical activity more strongly or only for people with weak habits (de Bruijn & Rhodes, 2011; Rebar et al., 2014; van Bree et al., 2013). The latter position would suggest that for people with strong habits, intentions do not play such an important role as their behavior relies more on automatic and habitual processes. Based on the previous research, it is plausible that different mechanisms and processes are at play for people with low vs. high habits and the effect on the relationship between intentions and physical activity might not be linear. This suggestion, however, warrants further research. Additionally, in the present study as well as the majority of previous studies, habit was measured via a self-report questionnaire which might not accurately reflect the automatic process it aims to capture due to the interaction with reflective processes when answering the questionnaire. Further studies could also include other measures of automaticity such as affective evaluations or implicit beliefs (De Houwer & Moors, 2012; Hagger, 2020).

5. Limitations

Several limitations of this study should be noted. This study utilizes data from a single 14-day burst of intensive EMA data collection and thus provides a limited window into the dynamical processes within an individual. Future analyses and studies should aim at including more measurement points or bursts of EMA monitoring, especially to allow for a sufficient number of time-points for person-specific modeling of behavior. Secondly, to include social support for physical activity, barriers to physical activity, and intentions as between-person level predictors, we calculated each person's mean value across the 14 days. It is possible that although it provides us with a temporally stable variable describing the average level of that variable across the 14-day burst, this does not necessarily align with the average level of that variable over a longer period of time. It could have been the case that individuals might have experienced exceptionally high or low support, barriers, or intention formation during the 14-day burst for various (unmeasured) reasons.

The list of perceived barriers in the EMA survey was developed at Pennsylvania State University but has not been previously validated and would require more psychometric support and evaluation. As of now, a standardized way of calculating the total barrier score has not been proposed. Our approach in the present study, i.e., first marking the perceived barriers and then reporting the severity only of those barriers, did not allow us to evaluate the scale's internal consistency. Further exploration into the possible ways of quantifying (the severity) of barriers and the implications of the various operationalizations on the evaluated relationships is needed.

Another limitation could be seen in the reliance on several single-item measures in the intensive measurement (e.g., intention to be physically active, social support for physical activity). Although this is not ideal from the psychometric standpoint, it is a common approach for ecological momentary assessment studies that must leverage frequent repeated assessments for a longer period of time with the participant burden it imposes. Although the used items did not undergo a systematic validation, they have been used in previous research on similar samples and proved to have clear face validity. Nevertheless, the single-item measure of daily social support for physical activity did not allow us to disentangle the various aspects of social support (e.g., emotional, instrumental, informational) and future studies could aim to capture the specific aspects and evaluate their respective effects.

A further limitation to be noted pertains to physical activity habit being measured at 6 months in the study and not at baseline, as was the case for exercise identity. In the present study, we aimed to evaluate the moderating effect of both the aspects of identity related to exercising and the extent to which physical activity feels automatic, where we had to compromise on non-concurrent measurement timepoints. Although physical activity habits tend to be rather slow changing without the presence of an intervention, the effect of habit in the present study should be interpreted with the measurement time-lag in mind. Future studies are needed to further support the moderating effect of habit on the intention-behavior relationship.

Lastly, our sample and its specifics should be acknowledged. Although our sample size was large, balanced on age and gender, and included participants from two regions of the Czech Republic, it should be noted that the sampling was non-probabilistic, and our sample is not representative of the Czech adult population. Our sample included more educated adults than is the average in the Czech Republic (ČSÚ, 2023) which could be related to the inclusion criterion of owning a smartphone. Results should also be interpreted with the activity level of the sample in mind. Even though the sample included 40 % inactive participants who self-reported not meeting the WHO guidelines on physical activity (WHO, 2020) at baseline, the sample as a whole turned out to be very active with an average of 13–14 000 steps per day and portions of the two sub-groups (runners and inactive participants) overlapped with respect to average levels of physical activity. This overlap could partially be due to fluctuating levels of physical activity across the 12-month monitoring period among participants in the respective groups.

6. Conclusions

The present study set out to evaluate the moderators of the relationship between intentions to be physically active and physical activity at the within-person and between-person levels as well as the effect of individual difference predictors on the within-person relationship. Daily perceived severity of barriers to physical activity were found to weaken the daily association between intention to be physically active and actual behavior while social support for physical activity was found to strengthen the relationship. Additionally, men and older adults had stronger association between daily intentions and physical activity compared to women and younger adults. Personalized interventions could be tailored, e.g., become more intensive or use different strategies, based on these variables. The present study underscores the need to separate the between-person differences from the within-person fluctuations to better understand the individual dynamics in physical activity behaviors.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2023.102566.

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