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Exploring the links between bodily and psychological health dimensions in primary school children

Supplementary Information

The online version of this article (https://doi.org/10.1007/s12662-025-01066-5) contains supplementary material, which is available to authorized users.

Introduction

Stodden et al. (2008) proposed a conceptual model positing a relationship between motor skill competence and physical activity mediated by perceived motor competence and health-related fitness. The model further suggests that all four factors are linked to weight status, with these associations strengthening throughout childhood. This framework helped to shift the focus of motor development research toward public health (Barnett et al., 2022). Building on a systematic review of studies testing the connections proposed in Stodden's model, Lima, Drenowatz, and Pfeiffer (2022) published a commentary in which they proposed an expansion of the framework to include additional child and adolescent health outcomes. These included metabolic health, mental health, cognition, and academic performance, each hypothesized to be linked to motor competence, physical activity, and health-related fitness either directly or indirectly via weight status. Against this backdrop, a comprehensive evaluation of a broader range of components and their connections becomes essential.

In the proposed expansion, Lima et al. (2022) call for empirical testing of the model's pathways, ideally including as many original and newly added components as possible. As motor competence and physical activity lie at the core of both the original and the extended model, most existing studies have focused on this connection (Barnett et al., 2022). To broaden the evidence base, our study investigates associations between factors that have so far been considered more peripheral—namely muscular fitness (as part of health-related fitness), physical self-concept, and mental health (represented in this study by psychological wellbeing and self-compassion). We also introduce posture as a novel and relevant variable that has not yet been integrated into the model, despite its theoretical and empirical relevance. Posture has shown close associations with two key constructs in Stodden's model—weight status and physical activity. For instance, physical activity level and body composition have been shown to influence posture (Wyszyńska et al., 2016). Moreover, Calcaterra et al. (2022) highlight that obesity may contribute to poor posture, which in turn can limit participation in physical activity. Given these connections, posture warrants closer investigation within this framework, particularly since it has not yet been formally incorporated. The following sections provide a brief overview of the selected constructs and the relationships between them as the basis of our investigation.

Muscular fitness, particularly muscular strength and endurance, has been extensively studied for its health benefits and has been consistently situated within the health-related fitness component of Stodden's model (Barnett et al., 2022). Among youths, higher levels of muscular fitness correlate with lower obesity rates, improved cardiovascular health, and enhanced bone development (Smith et al., 2014). In light of declining fitness levels, Faigenbaum, MacDonald, Stracciolini, and Rebullido (2020) emphasize the importance of prioritizing muscular fitness in physical activity guidelines to support long-term health. Beyond these general benefits, muscular fitness has also been linked to several of the other factors assessed in our study; it correlates positively with psychological wellbeing, self-esteem, and physical self-perceptions in children and adolescents (Bermejo-Cantarero et al., 2021; Smith et al., 2014).

Closely related to these physical dimensions is the construct of physical self-concept, which plays a key role in shaping children's perceptions of their abilities. Physical self-concept, as part of the nonacademic self-concept, encompasses perceptions of physical ability and appearance. The component assessing general athleticism has been further differentiated into strength, endurance, mobility, coordination, and speed (Stiller, Würth, & Alfermann, 2004). The construct of perceived motor competence, as referenced in Stodden's model, is often defined differently across studies or encompasses varying domains. In some studies, it has been used synonymously with a positive physical self-concept (Utesch,

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Dreiskämper, Naul, & Geukes, 2018), while in others it has been narrowly defined as the evaluation of one's abilities in fundamental movement skills, especially in children (Estevan & Barnett, 2018). In the present study, we include all subscales of the physical self-concept and classify them under the umbrella of perceived motor competence. Research suggests that physical self-concept influences physical activity, obesity, health-related fitness, and life satisfaction in children and adolescents (Dreiskämper, Tietjens, Honemann, Naul, & Freund, 2015). Furthermore, it is considered a key factor in the development of a healthy, active lifestyle through adolescence, although its exact role in this process remains unclear, as highlighted in a comprehensive meta-analysis (Babic et al., 2014). Physical self-concept is also related to the other observed factors. For instance, low physical self-concept has been associated with lower psychological wellbeing in children (Delgado-Floody, Soto-García, Caamaño-Navarrete, Carter-Thuillier, & Guzmán-Guzmán, 2022). In comparison, a more positive physical self-concept is linked to higher psychological wellbeing in this age group (Dreiskämper et al., 2015). Turning to the psychological domain, we now focus on the importance of self-compassion and its connections to the other key variables in this study.

Self-compassion has been increasingly studied for its potential to reduce suffering and distress. In contrast to the state of psychological wellbeing, it is described as an attitude (Neff, 2003). Neff (2023) defines it as a continuum with three elements: mindfulness over over-identification, connection over isolation, and self-kindness over self-criticism (Neff, 2023). According to Neff (2023), these interrelated aspects of self-compassion mutually reinforce each other. In research, alongside the six factors mentioned above, the negative and positive poles of self-compassion are often examined separately. They are based on distinct processes and may show differing associations with other constructs, such as psychopathology (Neuenschwander & von Gunten, 2025). In adolescents, self-compassion has been linked to improved psychological and physical wellbeing as well as reduced depression, anxiety, and stress (Egan et al., 2022; Marsh, Chan, & MacBeth, 2018; Sutton, Schonert-Reichl, Wu, & Lawlor, 2018). Additionally, self-compassion has been found to correlate positively with physical activity in adolescents, which in turn is associated with muscular fitness, suggesting a potential indirect link between muscular fitness and self-compassion (Barnett et al., 2022; Martínez-Gómez et al., 2011; Wong, Chung, & Leung, 2021). Furthermore, interventions aimed at enhancing self-compassion have been shown to reduce self-critical behavior (Wakelin, Perman, & Simonds, 2022), which may translate into a more positive physical self-concept by reducing self-critical evaluations of one's body and physical abilities. However, research on self-compassion in younger children remains limited (Sutton et al., 2018). Although interventions have been observed to effectively increase self-compassion, the underlying processes and specific components driving this effect are still unclear (Neuenschwander & von Gunten, 2025). Neuenschwander and von Gunten (2025) suggest that one possible reason for the limited investigation of self-compassion in childhood is that the necessary cognitive and emotional abilities are still developing at this age.

This is as childhood is a pivotal period for shaping mental structures, with lasting effects across the lifespan. Among the key domains is psychological wellbeing, which has been identified as one of five distinct dimensions of child wellbeing (Pollard & Lee, 2003). Psychological wellbeing is a multifaceted construct encompassing positive mental, psychological, and emotional states that foster personal growth and life satisfaction. Core components include resilience and self-concept, while factors such as loneliness, depression, and self-esteem are also frequently examined under this umbrella (Abed, Pakdaman, Heidari, & Tahmassian, 2016). In our study, self-concept was selected as a central indicator of psychological wellbeing and is positioned within the model in the domain of mental health. Self-concept undergoes notable changes during childhood, particularly with the introduction of external influences such as school. While most children enter school with a positive self-concept, the start of formal education brings more achievement-based evaluations and social comparisons. As cognitive abilities develop, children's self-assessments become more realistic and often less positive between the ages of 6 and 8, making this a critical period for assessing wellbeing (Kroesbergen, van Hooijdonk, van Viersen, Middel-Lalleman, & Reijnders, 2016). Psychological wellbeing is linked to other factors in our study, as it is positively associated with higher levels of self-compassion in adults, as demonstrated by López, Sanderman, Ranchor, and Schroevers (2018).

Finally, posture represents a novel addition to the model, offering a unique perspective on the interplay between physical and psychological domains. Posture, considered a psychomotor habit, is closely linked to somatic development, body composition, and structural alignment. It represents a dynamic and adaptive process, essential for maintaining stability and balance (Wilczyński, Lipińska-Stańczak, & Wilczyński, 2020). Proper posture relies on symmetrical body alignment, supported by a well-functioning nervous system, musculature, and motor skills (Grabara, Bieniec, & Nawrocka, 2017). During childhood and adolescence, posture is considered an important aspect of physical development, as rapid physical growth increases the risk of postural problems. These imbalances may lead to chronic pain, functional impairments, and a diminished quality of life (Sharma & Rawat, 2023). Given its significance, posture should be considered a key factor in developmental health. The examination of the connection between posture and the other factors included in the model builds on previously explored associations. For example, muscular strength and functional movement in overweight children have been linked to better postural alignment, underscoring the interplay between fitness and posture (Molina-Garcia et al., 2020). Beyond its link to muscular fitness, posture has also been suggested to be connected to psychological characteristics. Embodiment theory proposes a direct relationship between body posture and general psychological wellbeing (Michalak, Burg, & Heidenreich, 2012). For instance, upright body posture has been linked to positive effects on affect and fatigue in individuals with mild-to-moderate depression (Wilkes, Kydd, Sagar, & Broadbent, 2017). In contrast, a slumped posture is commonly observed in those with this clinical condition (Dehcheshmeh, Majelan, & Maleki, 2024). Among children, upright sitting posture has been found to promote an acute positive psychological state (Inagaki, Shimizu, & Sakairi, 2018), suggesting a possible connection between sustained posture and psychological wellbeing even at this young age. Briñol, Petty, and Wagner (2009) found that upright, confident posture influences self-evaluative confidence, potentially shaping how individuals assess their own bodies and thus impacting physical self-concept. Additionally, mindfulness practices that incorporate focused body postures, such as in yoga exercises, have been shown to increase self-compassion, suggesting a possible link between posture and self-compassion (A. R. Beck, Verticchio, Seeman, Milliken, & Schaab, 2017). While previous research has suggested these links between posture and psychological outcomes, findings remain heterogeneous, particularly in children, highlighting the need for more targeted investigation into these relationships in younger populations.

Taken together, the reviewed literature highlights a range of interrelations among physical and psychological health indicators in children. Muscular fitness and posture have been shown to co-occur and are both influenced by broader health and activity factors (Molina-Garcia et al., 2020; Wyszyńska et al., 2016). In turn, physical self-concept, psychological wellbeing, and self-compassion reflect key aspects of children's psychological functioning and are also interconnected (Dreiskämper et al., 2015; López et al., 2018; Sutton et al., 2018). However, empirical studies examining all these variables within a single framework remain scarce, especially in younger children (Barnett et al., 2022; Neuenschwander & von Gunten, 2025).

Abstract

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Abstract

This cross-sectional study examined associations between physical and psychological health indicators in primary school children, focusing on constructs that have received less attention in previous models. In addition to muscular fitness, physical self-concept, and mental health—represented by self-compassion and psychological wellbeing—posture was included as an additional health variable to explore its potential relevance within this framework. A total of 174 children aged 6–11 years participated in the observational study. Standardized measures were used to assess muscular fitness, posture, psychological wellbeing, physical self-concept, and self-compassion. Associations between variables were examined using structural equation modeling with 12 manifest variables. The hypotheses targeted positive correlations within and between the physical and psychological domains. The results confirmed a strong association between muscular fitness and posture. However, no significant links were found between posture or muscular fitness and psychological wellbeing, self-compassion, or physical self-concept. In contrast, positive associations emerged between psychological wellbeing, positive self-compassion, and physical self-concept. These findings suggest that psychophysical relationships may not yet be fully established or measurable at this developmental stage. Future research should investigate the developmental trajectories of these relationships in more diverse populations. However, the present findings must be interpreted with caution due to the high parental educational level in the sample.

Keywords

Posture · Muscular fitness · Psychological wellbeing · Self-compassion · Physical self-concept

To our knowledge, this is among the first studies to systematically examine the interplay among diverse physical and psychological factors, including the understudied role of posture, within an extended model. A visual representation of the conceptual framework and the hypotheses tested in the present study is shown in **Fig. 1**.

These considerations form the basis of the following hypotheses:

1. We expect a positive association between muscular fitness and the ability to maintain an upright body posture (H1).
2. We hypothesize a positive relationship between posture and psychological wellbeing. Additionally, we expect posture to be positively associated with a better physical self-concept (H2).
3. We hypothesize that muscular fitness is positively associated with psychological wellbeing and higher self-compassion. Furthermore, we expect muscular fitness to be linked to a better physical self-concept (H3).
4. We hypothesize positive associations between the physical self-concept and psychological wellbeing. Moreover, we expect psychological wellbeing to be related to self-compassion and self-compassion to be positively associated with the physical self-concept (H4).

Beyond these hypotheses, we also conducted exploratory analyses. Specifically, we investigated whether self-compassion is positively linked to the upright posture assessed in our study. Additionally, we explored the relationship between functional mobility and the two trunk-muscle endurance measures, as previous studies have reported no significant associations in adults (Okada, Huxel, & Nesser, 2011) but weak associations in children (Mitchell, Johnson, & Adamson, 2015).

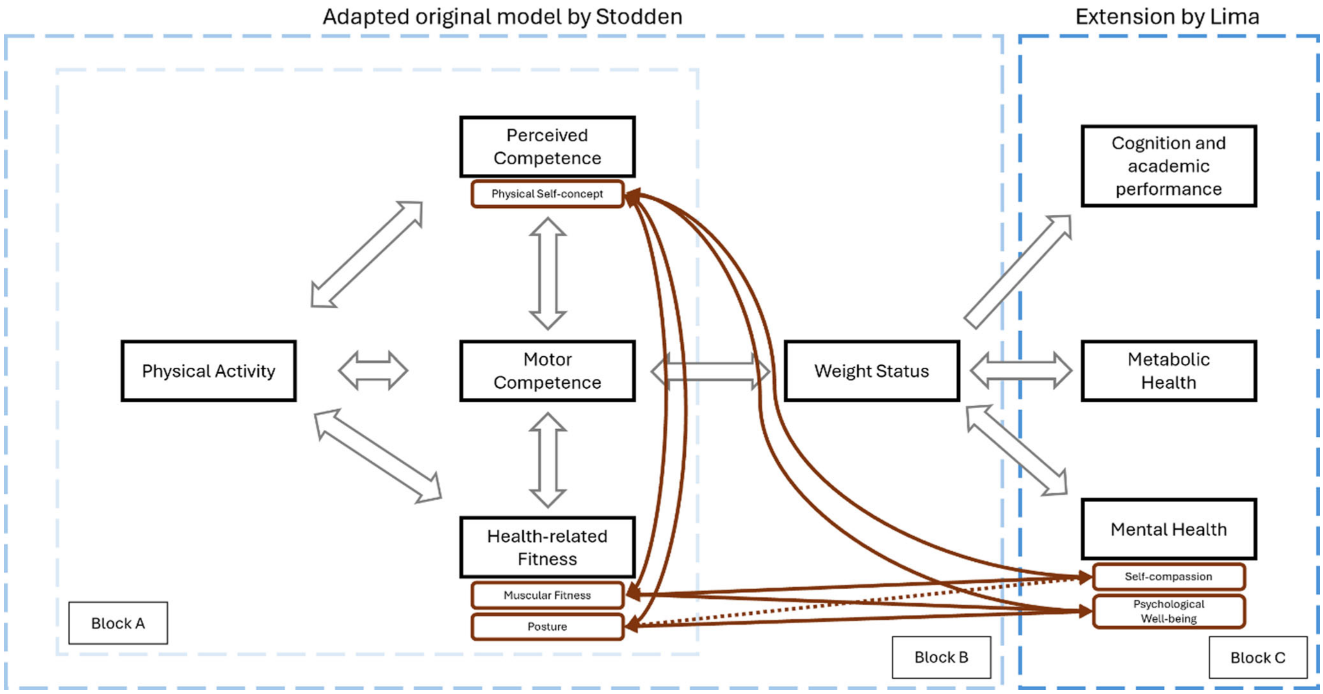

Fig. 1 ▲ Adapted version of the Stodden model (Stodden et al., 2008), extended by additional outcomes as proposed by Lima et al. (2022). *Grey arrows* represent theoretical relationships from the original and the extended model. *Solid brown arrows* indicate hypothesized associations tested in this study. The *dotted arrow* reflects an exploratory analysis based on limited prior evidence. Labels under the boxes denote the specific constructs and measures used in the current study

Materials and methods

Participants

A total of 177 children were enrolled by their parents to participate in a back pain prevention project. The current study was conducted as part of the pretesting phase of this intervention. Participants were reached through pediatricians, youth centers, parishes, sports clubs, and the university's family service and media department. Local radio stations also promoted the back pain prevention study. Exclusion criteria included (a) structural diseases (e.g., scoliosis), (b) medical conditions restricting participation in strengthening exercises, (c) neurological disorders, (d) involvement in other scientific studies, and (e) missing more than 10% of a questionnaire. Three children were excluded: one with scoliosis, one due to language barriers, and one for refusing to complete over 90% of some questionnaires.

The final sample consisted of 174 children (mean, M = 8.61; standard deviation, SD = 1.33) aged 6 to 11 years (originally planned for 7–11, but one 6-year-old was included as their seventh birthday was imminent). The sample comprised 77 girls (44.3%) and 97 boys (55.7%). Anthropometric data are presented in Additional File 1, and weight categorization followed body mass index (BMI) percentiles (Kromeyer-Hauschild et al., 2001).

Since the analysis method was adjusted during the review process, the a priori power analysis (Faul, Erdfelder, Lang, & Buchner, 2007)[1] no longer directly applies, as it was based on a different analytic approach involving multiple comparisons. Instead, the final analysis was based on a structural equation model that included only manifest variables and estimated bivariate correlations between them. Simulation studies by Wolf, Harrington, Clark, and Miller (2013) demonstrated that sample size requirements in structural equation models (SEMs) vary substantially depending on model complexity, the number of indicators, and the magnitude of factor loadings. In their analyses, even models with latent variables and moderate-to-strong factor loadings required as few as 90–120 participants to achieve sufficient power and unbiased parameter estimates. Although the present model did not include latent constructs and is therefore structurally simpler, the excellent model fit suggests that the achieved sample size ($N = 174$) was sufficient. Given that simpler models generally require fewer participants, the current sample size aligns with empirical recommendations for stable estimation in low-complexity SEMs.

[1] Assuming $d = 0.25$, $\alpha = 0.0167$, $\beta = 0.8$: required $N = 135$.

Measurements

Muscular fitness assessment

Muscular fitness was assessed through three tests from two different test batteries. Functional mobility, trunk extensor endurance, and trunk flexor endurance were evaluated. The individual scores were standardized as $\textit{standardized value} = \frac{value - mean}{SD}$, and the muscular fitness score was calculated as the mean of the three standardized scores.

Functional mobility was measured using the functional movement screen

(FMS; Cook, Burton, Hoogenboom, & Voight, 2014a; Cook, Burton, Hoogenboom, & Voight, 2014b), which includes ten exercises: deep squat, hurdle step (left/right), inline lunge (left/right), shoulder mobility (left/right), shoulder clearing test (left/right), active straight leg raise (left/right), trunk stability pushup, extension clearing test, rotary stability (left/right), and flexion clearing test. Each exercise was scored from 0 to 3, with a maximum total score of 21. For bilateral exercises, only the lower score was included. Pain during exercises or clearing tests resulted in a score of zero.

Both tests evaluating trunk muscle endurance were taken from the McGill endurance tests (McGill, Childs, & Liebenson, 1999) and slightly modified. For *trunk extensor endurance*, participants lay face-down cantilevered on a bench, arms crossed, with pelvis, knees, and hips secured by straps. A horizontal bar touching the shoulder blades ensured proper alignment. The time maintaining this position was recorded, with a maximum of 300 s. The test concluded after three losses of contact with the bar. For *trunk flexor endurance*, participants held a 50° sit-up position against a wedge, which was pulled 10 cm backward at the start of the test. Feet were strapped, hands crossed, and knees/hips flexed at 90°. The position was maintained without leaning back against the wedge or holding the knees, with a maximum of 300 s.

Posture assessment

Posture was evaluated using the Matthiaß test, which is part of a German posture test for children originally developed for use in the orthopedic and motor function context to identify posture-related deficits in strength and flexibility (Tittlbach & Bös, 2002). Participants were scored based on the duration (in seconds) for which they could sustain an upright body posture with both arms held horizontally in front of a grid pattern with squares measuring 5 × 5 cm. The test was stopped when the participant's position varied by at least one square, the participant ended the test, or the maximum time was reached. The maximum achievable score was 120 s.

Physical self-concept assessment

The assessment of physical self-concept utilized the physical self-concept in childhood questionnaire (PSK-K; Dreiskämper et al., 2015), which comprises 21 items distributed across seven subscales. Participants respond to each item on a four-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (4). The subscales include general athleticism, attractiveness, endurance, mobility, coordination, strength, and speed. Subscale scores for physical self-concept were derived by calculating the mean score of the three items within each subscale. We compared a one-factor model with a seven-factor model for our sample. In accordance with the original publication of the questionnaire, the seven-factor model showed a notably better fit (CFI = 0.88, RMSEA = 0.09, SRMR = 0.07) compared to the one-factor model (CFI = 0.75, RMSEA = 0.12, SRMR = 0.08), suggesting a more adequate representation of the underlying structure. To analyze internal reliability, Cronbach's alpha and McDonald's omega were calculated for every subscale. The subscales for general athleticism ($\alpha = 0.815$, $\omega = 0.816$), endurance ($\alpha = 0.712$, $\omega = 0.721$), mobility ($\alpha = 0.822$, $\omega = 0.823$), strength ($\alpha = 0.750$, $\omega = 0.753$), and speed ($\alpha = 0.780$, $\omega = 0.787$) showed good values, whereas attractiveness ($\alpha = 0.619$, $\omega = 0.636$) and coordination ($\alpha = 0.622$, $\omega = 0.653$) stayed just below the 0.70 benchmark typically recommended for good reliability. The lower values for these two subscales are consistent with the original publication of the questionnaire (Dreiskämper et al., 2015), which suggested that these constructs may not yet be fully developed at this age.

Psychological wellbeing assessment

As self-concept was chosen as the primary representation of psychological wellbeing in this study, psychological wellbeing was assessed using the self-concept subscale of the German version of the Beck Youth Inventories—2nd edition (BSCI-Y; J. S. Beck, Beck, & Jolly, 2018). It consists of 20 items that are answered on a four-point Likert scale ranging from "never" (0) to "always" (3). The total score was calculated by summing up all scores, with a maximum score of 60. Although the one-factor model demonstrated suboptimal fit (CFI = 0.80, RMSEA = 0.08, SRMR = 0.07), we followed the questionnaire manual's recommendation to use a total score in the analyses. The internal reliability was assessed via Cronbach's alpha and McDonald's omega, where two participants had to be excluded due to a missing value. The results suggest good internal consistency, with $\alpha = 0.882$ and $\omega = 0.879$.

Self-compassion assessment

Due to its established associations with psychological wellbeing, self-compassion was examined as a distinct construct in this study. It was assessed with a German translation of the self-compassion scale short form adapted for children (SCS-C; Sutton et al., 2018). Two translators with a finished English degree translated the English questionnaire forward and backward. The scale comprises 12 items categorized into two subscales, each answered on a five-point Likert scale ranging from "never" (1) to "always" (5). The subscales measure positive and negative self-compassion. To account for negatively framed items, reverse coding was applied. Subscale scores for self-compassion were obtained by calculating the mean score of the six items within the respective subscale.

When comparing a one-factor with a two-factor model suggested in the original publication, the two-factor model demonstrated substantially better fit (CFI = 0.92, RMSEA = 0.05, SRMR = 0.07) compared to the one-factor model (CFI = 0.52, RMSEA = 0.13, SRMR = 0.13), indicating a more adequate representation of the underlying structure. To assess the internal reliability of the subscales as proposed by Sutton et al. (2018), Cronbach's alpha and McDonald's omega were computed. The analysis yielded $\alpha = 0.676$ and $\omega = 0.674$ for positive self-compassion and $\alpha = 0.708$ and $\omega = 0.719$ for negative self-compassion. While these values suggest an acceptable internal consistency, values for positive self-compassion do not fully meet the

0.70 benchmark typically recommended for good reliability.

Assessment of parental educational level

Due to the conceptual challenges associated with measuring socioeconomic status (SES; Antonoplis, 2023), we focused on gathering more detailed information about the family situation by assessing the parents' educational level as part of the SES measurement (Jöckel et al., 1998). The mother and father's educational levels were rated from 1 to 8 on a scale. The classification was based on the German version of the ISCED 2011 framework by UNESCO developed for national and international comparison in educational statistics (Statistisches Bundesamt, 2023). The higher of the two values was used to represent the family's education level.

Procedure and design

The study was conducted as an observational study. The testing was carried out as part of the pretests for an intervention study to prevent back pain in children. Assessments took place at the Institute of Sport Science laboratories. Parents accompanied the children but remained outside their line of sight to minimize distractions. Each session lasted 60 to 90 min. After obtaining child and parental consent, testing began with a posture examination, a key component of the back prevention intervention, and the posture test. The self-compassion questionnaire and a brief warm-up preceded the motor tests, administered by a second tester in a new setting. The FMS was conducted first, followed by the back knowledge questionnaire for the intervention. Trunk flexor endurance was assessed next, followed by the psychological wellbeing questionnaire. Trunk extensor endurance was then tested, with the physical self-concept questionnaire concluding the session. The study was preregistered on OSF (https://osf.io/2f4jq/?view_only=f81740d40a0b435e9d7e22378151a756). The study adhered to the ethical guidelines of the Helsinki declaration and was approved by the ethics research board of the university (vote no. 23-3522-101).

Statistical analysis

Descriptive statistics (including incidences, means, standard deviations, and ranges) were calculated.

To examine the hypothesized correlations between the constructs, a structural equation model (SEM) was specified, including 12 manifest variables: two self-compassion subscales (positive and negative), seven physical self-concept subscales, the muscular fitness index, the posture score, and the psychological wellbeing score. All theoretically relevant correlations between these variables were freely estimated, except for the correlation between posture and self-compassion, which was fixed to zero due to a lack of theoretical justification; however, this association was explored separately outside the SEM framework. The model was estimated using the robust maximum likelihood estimator (MLR), which provides robust standard errors and fit indices corrected for nonnormality, with confidence intervals calculated based on the robust sandwich standard errors. Model fit was evaluated using the robust χ^2 test statistic, robust CFI, robust TLI, robust RMSEA with 90% confidence intervals, and SRMR. In line with the recommendations by Hu and Bentler (1999), good model fit was defined as CFI and TLI $\geq$ 0.95, RMSEA $\leq$ 0.06, and SRMR $\leq$ 0.08. To account for differing measurement scales and ensure comparability of correlation coefficients, posture and psychological wellbeing were z-standardized before model estimation. Internal consistency was assessed using both Cronbach's alpha and McDonald's omega. While omega is considered a more accurate reliability estimate (Dunn, Baguley, & Brunsden, 2014), alpha was additionally reported to ensure comparability with previous studies, where it is still commonly used. For exploratory analyses, Spearman's rank correlations were calculated to examine the explorative associations between nonnormally distributed variables. All data preprocessing and analyses were conducted in R (R Foundation, Vienna, Austria) using the lavaan package (Rosseel, 2012) and IBM SPSS Statistics 29 (IBM Inc., Armonk, NY, USA).

Deviations from preregistration

Several deviations from the preregistration plan were implemented during the study. First, the manuscript title differs from that in the preregistration. For the BSCI-Y questionnaire, the total score was used instead of the average score across all items, following the test manual. Additionally, due to the results of the factor analysis, no total scores were calculated or used for the PSK-K and SCS-C scales. The hypotheses were reorganized into four major categories to group thematically related analyses. Additionally, a preregistered hypothesis that predicted no relationship between core endurance and FMS was deemed inadmissible and reassigned to the exploratory analysis to investigate a possible link.

The power analysis from the preregistration was adjusted and recalculated for this study following the method of Faul et al. (2007). Since strong correlations were observed between psychological wellbeing, self-compassion subscales, and physical self-concept; a regression analysis using psychological wellbeing as an outcome variable was not conducted.

Findings

Descriptives

The descriptive results of the measured variables are presented in **Table 1**.

Results

The structural equation model showed excellent fit to the data: $\chi^2(2) = 2.26$, $p = 0.324$, robust CFI = 1.000, robust TLI = 0.989, robust RMSEA = 0.027 (90% CI [0.000, 0.163]), and SRMR = 0.020. All reported coefficients r are standardized estimates. An overview of the model structure and the significant versus nonsignificant paths is shown in **Fig. 2**.

In line with H1, muscular fitness was strongly positively correlated with posture ($r = 0.48$, 95% CI [0.260, 0.460], $p <$

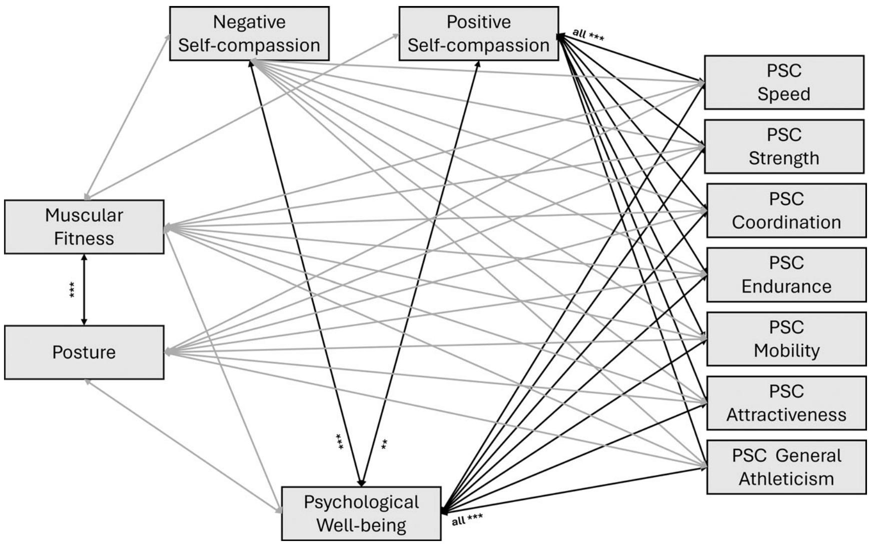

Fig. 2 ▲ Structural equation model tested in the present study; all arrows represent bidirectional paths between manifest variables. *Black arrows* statistically significant associations: **p* < 0.05, ***p* < 0.01, ***p* < 0.001. *PSC* physical self-concept

0.001). Contrary to expectations (H2), posture was not significantly correlated with psychological wellbeing ($r = -0.08$, 95% CI [–0.199, 0.043], $p = 0.205$) or with any of the physical self-concept subscales ($r = -0.07$ to 0.07, all $p > 0.05$; see Additional File 2). Contrary to H3, muscular fitness was not significantly correlated with psychological wellbeing ($r = -0.04$, 95% CI [–0.155, 0.103], $p = 0.690$), positive self-compassion ($r = 0.08$, 95% CI [–0.024, 0.116], $p = 0.199$), negative self-compassion ($r = 0.05$, 95% CI [–0.051, 0.107], $p = 0.491$), or any of the physical self-concept subscales ($r = 0.01$ to 0.11, all $p > 0.05$; see Additional File 2). In line with H4, psychological wellbeing was strongly positively correlated with positive self-compassion ($r = 0.47$, 95% CI [0.240, 0.458], $p < 0.001$) and moderately positively with negative self-compassion ($r = 0.24$, 95% CI [0.061, 0.324], $p = 0.004$). Moreover, physical self-concept subscales were significantly positively correlated with psychological wellbeing ($r = 0.35$–0.45, 95% CIs [0.249, 0.540], all $p < 0.001$) and with positive self-compassion ($r = 0.35$–0.44, all $p < 0.001$). However, negative self-compassion showed no significant correlations with the physical self-concept subscales ($r = 0.03$ to 0.13, $p = 0.055$–0.718). The correlations with the physical self-concept subscales are shown in detail in ◘ **Table 2**.

Exploratory analyses

There was no significant correlation between the posture score and self-compassion: $\rho = 0.083$, $p = 0.137$, 95% CI [–0.046, 1.000]. Functional mobility showed a low significant correlation with the muscular endurance of the trunk flexors ($\rho = 0.253$, $p < 0.001$, 95% CI [0.104, 0.391]) and a medium-sized significant correlation with the trunk extensors ($\rho = 0.402$, $p < 0.001$, 95% CI [0.265, 0.523]). The values of the two trunk muscular endurance measurements were also moderately correlated: $\rho = 0.485$, $p < 0.001$, 95% CI [0.358, 0.594].

Discussion

The collected values were compared with available reference data. For the posture test, no normative data have been published. The average FMS score in our study was 13.1 (boys: 12.6, girls: 13.8), slightly lower than those reported for Moldovan children (Mitchell et al., 2015), though the pattern of higher scores among girls was consistent.

Since trunk muscle endurance norms exist only for children aged 7 years and older, the single 6-year-old in our sample was excluded. Compared to Dejanovic, Harvey, and McGill (2012), our sample showed lower endurance across all age groups and genders (details in Additional File 3). Self-compassion scores were slightly higher than those in a Canadian reference sample (Sutton et al., 2018), potentially due to cross-country differences (see Additional File 3).

Psychological wellbeing raw scores were converted to gender-specific T-scores provided in the test manual (J. S. Beck et al., 2018), yielding 24 children with significantly below-average, 25 with below-average, 76 with average, and 49 with above-average self-concept. Physical self-concept scores were similar to those reported in German third and fourth graders (Dreiskämper et al., 2015; detailed comparisons are also available in Additional File 3).

Relations between bodily and psychological wellbeing

The strong correlation between muscular fitness and posture confirms our hypothesis that these aspects of physical wellbeing are connected. This finding extends previous research, which primarily demonstrated this relationship in children with obesity (Molina-Garcia et al., 2020) and is also in line with the intended purpose of the posture test (Tittlbach & Bös, 2002). The correlation between trunk muscle endurance tests and the FMS score aligns with Mitchell et al. (2015), who found a similar link between core strength and functional mobility in children. These observations differ from those of Okada et al. (2011), who observed no such relations in adults. While our study and the adult study used the same muscle endurance tests, the child study employed the prone plank test. Mitchell et al. (2015) suggest that differing methods may explain these inconsistencies. However, our results, using two tests also applied in the adult study, suggest that in children, the developmental stage leads to less differentiated motor skill domains compared to adults. As stated by Utesch, Bardid, Büsch, and Strauss (2019), motor movements, such as those assessed by the FMS, require thousands of repetitions to be fully ac-

Table 1 Results of the measured variables

	Mean	SD	Range
Duration in upright posture [s]	86.07	29.61	14–120
FMS total score	13.13	3.09	6–20
Trunk flexor endurance [s]	49.74	41.56	0–300
Trunk extensor endurance [s]	53.60	35.53	5–222
Muscular fitness index	0.00	0.75	−1.41–3.04
Negative self-compassion	3.34	0.79	1.17–4.83
Positive self-compassion	3.44	0.75	1.17–5.00
Psychological wellbeing	43.03	8.74	12–60
PSK-K$_{\text{General Athleticism}}$	3.55	0.57	1.00–4.00
PSK-K$_{\text{Attractiveness}}$	3.00	0.65	1.00–4.00
PSK-K$_{\text{Endurance}}$	3.28	0.61	1.00–4.00
PSK-K$_{\text{Mobility}}$	3.36	0.65	1.00–4.00
PSK-K$_{\text{Coordination}}$	3.27	0.57	1.00–4.00
PSK-K$_{\text{Strength}}$	3.19	0.59	1.00–4.00
PSK-K$_{\text{Speed}}$	3.28	0.68	1.00–4.00

FMS Functional Movement Screen, *PSK-K* Physical self-concept in childhood questionnaire

Table 2 Correlations with the physical self-concept subscales

Observed connection		*r*	95% CI	*p*-value
Psychological wellbeing	PSK-K$_{\text{General Athleticism}}$	0.45	[0.161, 0.352]	< 0.001
	PSK-K$_{\text{Attractiveness}}$	0.40	[0.131, 0.390]	< 0.001
	PSK-K$_{\text{Endurance}}$	0.41	[0.144, 0.354]	< 0.001
	PSK-K$_{\text{Mobility}}$	0.45	[0.174, 0.377]	< 0.001
	PSK-K$_{\text{Coordination}}$	0.54	[0.204, 0.409]	< 0.001
	PSK-K$_{\text{Strength}}$	0.40	[0.142, 0.333]	< 0.001
	PSK-K$_{\text{Speed}}$	0.42	[0.164, 0.404]	< 0.001
Positive self-compassion	PSK-K$_{\text{General Athleticism}}$	0.25	[0.043, 0.168]	0.001
	PSK-K$_{\text{Attractiveness}}$	0.35	[0.094, 0.245]	< 0.001
	PSK-K$_{\text{Endurance}}$	0.28	[0.061, 0.194]	< 0.001
	PSK-K$_{\text{Mobility}}$	0.24	[0.047, 0.181]	0.001
	PSK-K$_{\text{Coordination}}$	0.44	[0.120, 0.250]	< 0.001
	PSK-K$_{\text{Strength}}$	0.23	[0.034, 0.164]	0.003
	PSK-K$_{\text{Speed}}$	0.27	[0.056, 0.214]	0.001
Negative self-compassion	PSK-K$_{\text{General Athleticism}}$	0.09	[−0.021, 0.105]	0.188
	PSK-K$_{\text{Attractiveness}}$	0.06	[−0.062, 0.124]	0.513
	PSK-K$_{\text{Endurance}}$	0.08	[−0.029, 0.124]	0.261
	PSK-K$_{\text{Mobility}}$	0.13	[−0.002, −137]	0.055
	PSK-K$_{\text{Coordination}}$	0.03	[−0.057, 0.083]	0.718
	PSK-K$_{\text{Strength}}$	0.08	[−0.033, 0.103]	0.318
	PSK-K$_{\text{Speed}}$	0.12	[−0.014, 0.144]	0.105

PSK-K Physical self-concept in childhood questionnaire

quired and refined. At this young age, many specific movement patterns have simply not yet been consolidated. Therefore, general physical activity participation and overall sportiness are likely the primary determinants of performance, rather than specialized motor abilities (Malina, 2025).

With regard to the psychological variables, both hypotheses regarding the relationship between psychological and physical health aspects must be rejected, representing the main finding of this study. This absence of significant associations between posture, muscular fitness, and psychological variables challenges assumed psychophysical links in children and calls for a closer examination of possible developmental, theoretical, and methodological explanations.

Dreiskämper et al. (2015) stated that research findings vary regarding the age at which children can validly report or assess their global and domain-specific self-concept. As psychological wellbeing is also represented by self-concept in our study, this should also be considered when interpreting the current findings. In this context, it is also important to note that we treated physical self-concept and psychological wellbeing as analytically distinct constructs, despite their conceptual overlap in hierarchical models such as that of Shavelson, Hubner, and Stanton (1976). This decision was based on the theoretical structure of the combined model applied in this study. Physical self-concept was aligned with the physical domain and corresponds to the construct of perceived motor competence in the model by Stodden et al. (2008), whereas psychological wellbeing, as captured via general self-concept, was situated within the mental health domain proposed in the extended framework by Lima et al. (2022). Separating these constructs allowed for a more differentiated examination of domain-specific associations and does not imply a conceptual disconnection between them. Furthermore, Crone, Green, van de Groep, and van der Cruijsen (2022) also emphasize the numerous changes and influencing factors, such as social comparison, cognitive development, and the ability to adopt different perspectives, that shape the development of self-concept during childhood and adolescence. They argue that forming a stable self-concept is a primary developmental task of adolescence and, therefore, has not yet been fully achieved in childhood. The authors further note that due to frequent and overly positive external feedback, children's self-perception tends to be excessively positive. This inflated self-view may also extend to physical self-perceptions, such as those reflected in the physical self-concept.

The third hypothesis was formulated based on two review studies that identified a connection between muscular fitness and psychological wellbeing (Bermejo-Cantarero et al., 2021; Smith et al., 2014). These reviews combined research on both children and adolescents which suggests that older participants possess a more differentiated ability to self-assess psychological components, potentially influencing the observed relationships.

The indirect relationship between self-compassion and muscular fitness through physical activity could also not be replicated in children. One possible explanation is the significant difference in muscular fitness between childhood and adolescence (Beunen & Thomis, 2000), with notable increases during adolescence, particularly in boys. Similarly, the relationship between self-compassion and physical activity may also be less direct in children than in adolescents and adults (Wong et al., 2021). Another possible explanation is that the underlying factors may continue to develop throughout childhood and adolescence. Due to the limited number of studies on the development of self-compassion in children, these insights are often drawn from the broader field of compassion research. However, there is ongoing debate as to whether these two forms of compassion can be understood within the same overarching framework: while they may share many underlying structures, there are also notable differences—such as the development of prosocial behavior (Neuenschwander & von Gunten, 2025).

Recent research on the development of bodily self-consciousness suggests that while children as young as 6 or 7 years can self-identify with a body representation, the more complex integration of multisensory signals—such as touch referral and shifts in perceived self-location—develops only later in childhood or adolescence (Cowie et al., 2018). Moreover, as summarized by Gottwald et al. (2021), the sensory bases for perceiving one's own body characteristics are still immature in childhood, with proprioceptive estimates and the integration of visual and proprioceptive information remaining error prone even at age 8–10. This gradual developmental trajectory suggests that posture may not yet represent a salient or clearly differentiated construct in children's self-perception of wellbeing and health. A certain level of cognitive and physical maturation may be required before children are able to meaningfully recognize and relate postural aspects to their internal psychological states. Consequently, the assumed link between posture and psychological wellbeing—proposed by embodiment theory (Michalak et al., 2012)—may not yet be functionally established in younger children, as the bodily cues required for such embodied self-evaluations are likely not fully accessible or integrated at this stage of development. Furthermore, studies that suggest a link between posture and psychological variables, such as mood, often examine the short-term effects of deliberately adopted postures on emotional states (Inagaki et al., 2018; Körner, Köhler, & Schütz, 2020). These short-term effects do not necessarily imply the existence of stable, long-term associations or a consciously reflected perception of habitual posture. However, it is precisely this habitual or chronically maintained posture that is of greater relevance in the context of our posture assessment and hypotheses. The choice of posture assessment method may also have influenced the findings. The posture test used in this study was originally developed for orthopedic screening purposes and focuses on physical aspects of posture in children, particularly strength and flexibility (Tittlbach & Bös, 2002). It was not designed to capture postural expressions related to psychological states such as mood, affect regulation, or self-perception. Therefore, any interpretation of its results in relation to psychological constructs should be made with caution.

Future studies aiming to examine posture as a construct relevant to embodiment or psychosocial functioning may benefit from alternative assessment approaches that have been used in cognitive or affective embodiment research. These include comparisons of open versus closed or upright versus slumped body positions (Andolfi, Di Nuzzo, & Antonietti, 2017; Nair, Sagar, Sollers, Consedine, & Broadbent, 2015), sensor-based measures that capture habitual posture patterns over time (Mosenia, Sur-Kolay, Raghunathan, & Jha, 2017), or even video-based behavioral analysis, as applied in workplace settings (Roberts, Torres Calderon, Tang, & Golparvar-Fard, 2020). Such approaches may be more sensitive to the psychological relevance of posture in everyday life than the more orthopedic and motor-oriented assessment applied in the present study.

In the theoretical domain of physical self-concept and perceived motor competence, conceptual clarity remains lacking. Different terms are often used to refer to the same construct, while the same term may describe differing underlying concepts or definitions. Although this issue has been discussed in the literature for some time, no consistent terminology or shared definitions have yet been established (Dreiskämper, Tietjens, & Schott, 2022).

A possible methodological explanation for our observations could lie in differing approaches to posture measurement. While the cited studies focused on subconsciously adopted long-term posture, our study examined the ability to consciously maintain an upright posture for an extended period, which are two postural states between which the posture differs (Ludwig, Mazet, Mazet, Hammes, & Schmitt, 2016). Although this ability to stay upright could help to maintain an upright posture unconsciously over time, factors like habitual behaviors, extending beyond motor and physical abilities, play a significant role in sustaining unconscious posture (Clark & Lucett, 2010). Additionally, 55 of the 174 participants (31.6%) achieved the maximum score by maintaining the required upright posture for 120 s. This high proportion suggests a potential ceiling effect, likely influencing posture correlations.

Additionally, the decision to use assessment instruments for measuring physical self-concept during childhood is a complex one, as outlined by Dreiskämper et al. (2022). This applies not only to the conceptual level, such as choosing between uni- and multidimensional approaches, but also to the mode of assessment (e.g., questionnaires vs. pictorial scales), given the wide range of available measurement tools. More complex instruments may not be appropriate for younger children whose physical self-concept is still underdeveloped, while simpler instruments may fail to adequately reflect the more differentiated self-perceptions of older children. The hierarchical and multifaceted nature of the physical self-concept is closely tied to cognitive maturity and typically develops in middle-to-late childhood (Dreiskämper et al., 2022). Thus, given the relatively broad age and developmental range of our sample, it is plausible that for some children, a unidimensional instrument might have been more appropriate than the domain-specific questionnaire employed in this study. Contrary to our study, previous research has primarily found associations between physical self-concept and physical fitness in primary school children when domain-specific fitness tests were employed that directly measured the physical abilities reflected in corresponding subdomains of the physical self-concept (Tietjens et al., 2020). However, even in that study, the associations within the domain of physical fitness were relatively weak, which the authors attributed to the possibility that such relationships may develop later in childhood or adolescence. Similarly, although the self-compassion questionnaire used in this study was originally developed for children in English-speaking contexts and showed valid associations with measures of mindfulness, self-concept, and psychological wellbeing during validation (Sutton et al., 2018), it remains unclear whether children—depending on their individual stage of development—are cognitively able to consciously understand and reflect on the abstract constructs involved in self-compassion.

Our results mostly support our fourth hypothesis, confirming significant positive associations between psychological wellbeing, positive self-compassion, and physical self-concept in children. The strong correlation between psychological wellbeing and physical self-concept aligns with previous findings linking a positive physical self-concept to improved wellbeing in this age group (Delgado-Floody et al., 2022; Dreiskämper et al., 2015). Similarly, the strong relationship between positive self-compassion and psychological wellbeing in this study mirrors observations in adults, where higher self-compassion was associated with reduced self-criticism and better psychological outcomes (López et al., 2018; Wakelin et al., 2022). Interestingly, the negative subscale of self-compassion was not related to physical self-concept dimensions, in contrast to the positive subscale. These differing associations between the two aspects of self-compassion may be explained by the distinct underlying systems on which they are based (Neuenschwander & von Gunten, 2025). As these systems develop independently, they may show associations with other variables at different points in time. Future studies should consider longitudinal designs to explore causal pathways, as Lee et al. (2021) did in adults, to determine whether similar patterns emerge in childhood.

Taken together, the results do not support the assumption that the physical and psychological contextual factors proposed in Lima's extended model (Lima et al., 2022) are strongly interconnected. It should be noted that the proposed extension, which includes the mental health components, was proposed within a commentary article that builds upon existing empirical research but does not represent a systematic review. Therefore, further empirical work is needed to substantiate these suggested links more conclusively. While we did not examine links to the model's core components, such as physical activity and motor competence, our focus on more peripheral factors revealed no substantial associations. Although previous studies have demonstrated connections between the core constructs and both physical and psychological variables, our findings suggest that the broader network of peripheral influences may be less tightly connected than hypothesized.

Limitations

As outlined in the discussion, several limitations need to be considered when interpreting the results. First, while the study focused on key constructs such as self-compassion and physical self-concept, it remains unclear whether these constructs are fully developmentally appropriate and reliably measurable in children of this age, potentially limiting the interpretability of the findings. The relatively wide age range of our sample, which, particularly in the context of a childhood study, covers a broad span of developmental stages, must also be taken into consideration. Moreover, there may be a mismatch between some measurement instruments and the specific tests used; for example, stronger associations are typically found when skill-specific self-concept measures are paired with corresponding motor performance tasks, which was not the case here. Additionally, the suitability of the measurement instruments should be considered a limitation, as the multidimensional structure of the PSK-K may have exceeded the cognitive and reflective capacities of some younger participants, potentially limiting its validity in this age group. Caution is also warranted when interpreting posture in relation to psychological constructs due to the nature of the measurement used. The test applied was originally developed for orthopedic motor screening and does not capture psychological dimensions of posture such as emotional expression or body-related self-awareness. Similarly, the self-compassion scale, although adapted for children, may still rely on abstract self-reflective abilities that are not yet fully developed in all participants, which could have affected the reliability and interpretability of the responses. Furthermore, the analytical separation of physical self-concept and psychological wellbeing, despite their conceptual overlap, should be considered a limitation. This approach may have underestimated shared variance between the constructs or masked potential integrative effects. Additionally, the relatively homogeneous sample, particularly with respect to the high parental educational level, may have restricted variability, limiting the ability to detect associations that might emerge in more diverse populations. Furthermore, sample characteristics such as the younger mean age ($M = 8.61$, $SD = 1.13$) and the study's recruitment context may have influenced key outcomes. For example, the relatively low FMS scores observed may be partly explained by participants' age, which also showed a significant positive correlation with motor performance. Additionally, the study's back pain prevention setting may have attracted parents with heightened awareness of posture-related issues, potentially biasing the sample toward children with specific motor weaknesses. Cultural differences between our sample and comparison samples may also underlie the observed variation in self-compassion scores. One further limitation of the present study concerns the relatively low participant-to-parameter ratio in the structural equation model (approximately 2:1). While traditional guidelines recommend larger samples, the perfect model fit suggests that the parameter estimates are robust and the model is well specified. Nonetheless, future research should aim to replicate the findings with a larger and more diverse sample to ensure the generalizability and stability of the parameter estimates. Furthermore, recruitment through the back pain prevention project likely attracted families who were already highly engaged with their children's health and demonstrated strong research interest, further reducing the generalizability of the findings. Finally, the main limitation of the study lies in its cross-sectional design, which precludes conclusions about causal directions, indirect relationships (e.g., mediation effects), or developmental trajectories over time.

Conclusion

The present findings offer important insights into the relationship between physical and psychological health in children. Notably, both hypotheses concerning psychophysical associations between posture, muscular fitness, and psychological outcomes had to be rejected, suggesting that such connections may not yet be established or measurable in this age group. These null findings highlight the importance of considering developmental, methodological, and theoretical factors when investigating embodied psychological processes in children. Given the cross-sectional design, no conclusions can be drawn about causal directions or developmental trajectories. Therefore, longitudinal research is urgently needed to examine how and when links between physical function and psychological wellbeing begin to emerge across childhood and adolescence, including potential indirect pathways.

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Declarations

Conflict of interest. S. Weigel and P. Jansen declare that they have no competing interests.

The study adhered to the ethical guidelines of the Helsinki declaration and was approved by the Ethics Research Board of the University of Regensburg (no. 23-3522-101). Written informed consent was obtained from the participants and one parent or legal guardian after providing detailed information about the study.

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