Sex-related differences in the association of fundamental movement skills and health and behavioral outcomes in children

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Abstract

This study aimed to assess whether sex moderates the association of fundamental movement skills (FMS) and health and behavioral outcomes. In 170 children (10.6 ± 0.3 years; 98 girls), path-analysis was used to assess the associations of FMS (Get Skilled, Get Active) with perceived sports competence (Children and Youth - Physical Self-Perception Profile), time spent in vigorous-intensity physical activity (VPA), sedentary time and body mass index (BMI) z-score. For boys, object control skill competence had a direct association with perceived sports competence (β = 0.39; 95% CI: 0.21 to 0.57) and an indirect association with sedentary time, through perceived sports competence (β = -0.19; 95% CI: -0.09 to -0.32). No significant association was observed between FMS and perceived sports competence for girls, although locomotor skills were found to predict VPA (β = 0.18; 95% CI: 0.08 to 0.27). Perceived sports competence was associated with sedentary time, with this stronger for boys (β = -0.48; 95% CI: -0.64 to -0.31), than girls (β = -0.29; 95% CI: -0.39 to -0.19). The study supports a holistic approach to health-related interventions and highlights a key association of perceived sports competence and the time children spend sedentary.

Key words: Exercise, Motor development, Physical activity, Self-efficacy, Motor performance, Pediatrics

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Fundamental movement skills (FMS), which include object control and locomotor skills, are referred to as foundational ‘building-block movements’ and are proposed to provide a crucial underpinning to the development of more complex movement patterns (Gallahue, Ozmun, & Goodway, 2012). Object control skills refer to FMS that allow for the manipulation and controlling of objects, such as throwing and catching, whilst locomotor skills consist of those FMS associated with the propulsion and navigation of individuals through space, such as running and hopping (Gallahue et al., 2012). FMS are primarily ontogenetic; competence is influenced through dynamic interactions with the environment, coupled with biological and psychological constraints that change over time (Robinson et al., 2015). Along with being associated with health and behavioral outcomes, FMS are identified as a precursor to physical activity, and more recently, time spent sedentary (Adank et al., 2018; Robinson et al., 2015). Current physical activity guidelines state that children and young people aged 5-18 years should engage in an average of at least 60 minutes moderate-to-vigorous physical activity (MVPA) per day across the week, and should minimize time spent sedentary (Davies et al., 2019). Despite this, few children accrue the required levels of physical activity, with less than 25% of school-aged children meeting recommended guidelines (National Health Service, 2019). Furthermore, sedentary behavior, attributable in part to reductions in active play, organized sport, and a concomitant rise in exposure to screen devices, has been highlighted as an independent risk factor for many non-communicable diseases (Saunders, Chaput, & Tremblay, 2014).

Typically developing children have the potential to be proficient in many FMS by six years (Gallahue et al., 2012). However, the literature has shown that proficiency remains low, with the standardized fundamental movement skill levels of children aged 6-10 years deemed "below average", and less than half of all children aged 9-15 years proficient across all FMS (Bolger et al., 2020; Hardy, Barnett, Espinel, & Okely, 2013). Sex-specific differences also exist, with boys consistently reported as being more proficient in object control skills, though evidence relating to locomotor skills remains equivocal (Barnett et al., 2016). Such sex-specific differences in fundamental movement skill competence likely reflect the influence of environmental and socio-cultural factors, such as the level of family support and encouragement. These factors are proposed to underpin physical activity and sport participation choice, with boys often engaging in activities requiring a high object control skill competence, such as rugby, football and basketball, and girls often engaging in activities underpinned by locomotor skill competence, such as gymnastics and dance (Barnett, Hinkley, Okely, & Salmon, 2013; Slykerman, Ridgers, Stevenson, & Barnett, 2016).

Stodden and colleagues (2008) proposed a conceptual model that represented the inter-dependence of the developmental trajectories of FMS, physical activity and associated health-related outcomes. The narrative review of Robinson and colleagues (2015) alongside more recent meta-analyses (Barnett et al., 2016; Utesch et al., 2019) have supported the direct and, to a lesser degree, indirect, associations of FMS and the health and behavioral outcomes included within the Stodden et al. (2008) model. From mid-childhood, the association between FMS and physical activity is hypothesized to become increasingly reciprocal, with FMS a driver for sustained engagement in a variety of physical activities that subsequently promote perceived competence, physical fitness, and a healthy weight status (Stodden et al., 2008). Whilst a positive association between perceived and actual competence has been identified as a key predictor of health benefits (De Meester, Stodden, et al., 2016), high perceived competence, irrespective of actual competence, may induce similarly favorable outcomes (De Meester, Maes, et al., 2016). The model further proposes that poor competence in FMS, coupled with low self-perception, is a precursor to a negative spiral of disengagement, expressed through a higher risk of being physically inactive and obese (Stodden et al., 2008).

Evidence suggests that the role of FMS may differ according to age, sex and the specific health and behavioral outcomes of interest (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Luz, Cordovil, Almeida, & Rodrigues, 2017). The developmental influences on the associations between FMS and health and behavioral outcomes are emphasized in the Stodden et al. (2008) model. Increasing age has been found to positively moderate the relationship between FMS and physical fitness (Utesch, Bardid, Büsch, & Strauss, 2019). In addition, competence in object control skills, rather than locomotor skills, has been found to be more strongly associated with physical activity (Barnett et al., 2011), whilst a stronger association between FMS and physical activity has been observed in girls (Jarvis et al., 2018). Given the role of perceived competence within the Stodden et al. (2008) model, further evidence is required to identify whether its association with additional outcomes is moderated by sex and fundamental movement skill construct (Barnett, Morgan, van Beurden, & Beard, 2008; Khodaverdi, Bahram, Stodden, & Kazemnejad, 2016). Previous studies have reached little consensus on which skills are most strongly associated with perceived competence (Barnett, Ridgers, & Salmon, 2015; Khodaverdi et al., 2016).

Although the association between FMS and MVPA has been consistently reported (Robinson et al., 2015), there is a need to better understand the association between FMS and specific intensities and characteristics of physical activity (Lima et al., 2017). Time spent in vigorous physical activity (VPA) has been shown to provide enhanced benefits in comparison to light- and moderate-intensity physical activity across a range of cardiometabolic, cognitive and fitness indicators (Carson et al., 2014; Poitras et al., 2016). VPA is also proposed to be more strongly associated with participation in sport than lower intensities of physical activity (Kokko et al., 2019; Pfeiffer et al., 2006). Children can accrue high levels of MVPA from free-play, where proficiency in FMS may be less critical to engagement (Lubans, Morgan, Cliff, Barnett, & Okely, 2010) and therefore the influence of FMS may become more evident in VPA. Conversely, a reciprocal association between FMS and time spent sedentary may exist, fostered by the same confounders that promote inactivity (i.e., weight status, perceived competence and sex). Sedentary behavior has been found to track from childhood into adolescence, and an inverse influence of time spent sedentary on wider outcomes, such as academic attainment, has also been identified (Biddle, Pearson, Ross, & Braithwaite, 2010; Haapala et al., 2017). As such, understanding the role of FMS as a mechanism through which to reduce time spent sedentary is warranted. Few studies have investigated the sex-related influence of FMS on these characteristics of physical activity and sedentary time, with an absence of available evidence pertaining to how these associations may be moderated by sex and additional health-related outcomes.

Guided by the Stodden et al. (2008) conceptual framework, the aim of this study was to use path-analysis to investigate the influence of sex on the associations between FMS, perceived sports competence, time spent in VPA, time spent sedentary and BMI z-score in late childhood. It was hypothesized that for girls, locomotor skill competence, and for boys, object control skill competence, would be associated with time spent in VPA. In addition, irrespective of sex, perceived sports competence would have an important mediating role on the association of fundamental movement skill constructs with VPA, time spent sedentary and BMI z-score.

Methods

Participants

Following written informed parental consent and child assent, 190 (110 girls; 80 boys) children from school year 6 (10.6 ± 0.3 years), recruited from 16 primary (elementary) schools within the Borough of Wigan, England, participated in this study. School year 6 represents the final year of primary education prior to the transition to secondary education, and as such is a key developmental stage for children where they have the potential to have mastered FMS. All children were invited to participate and were only excluded if they had any functional impairment that precluded regular physical activity participation. Home postcodes were used to generate Indices of multiple deprivation (IMD) scores for each participant and these along with the percentage of children per school eligible for free school meals were used to define school-level socio-economic status (SES). Within each neighbourhood management area, one high and one low SES school were randomly selected to take part to ensure acceptable representation. Participant data has been combined from one cross-sectional study (n = 46) and baseline sub-sample data from one cluster randomized controlled trial (n = 144; Fairclough et al., 2013; Fairclough, Boddy, Mackintosh, Valencia-Peris, & Ramirez-Rico, 2015). Ethical approval was obtained from the Liverpool John Moores University Research Ethics Committee (application references 8.56 and 10/ECL/039, respectively). Ethical principles of the Declaration of Helsinki were adhered to throughout this research.

Anthropometric measures

All anthropometric measurements were conducted by a trained researcher. Standing and sitting stature were measured to the nearest 0.1cm using a stadiometer (Seca, Bodycare, Birmingham, UK). Body mass were measured to the nearest 0.1kg using calibrated scales (Seca, Bodycare, Birmingham, UK). BMI was calculated as body mass (kg) divided by height squared (m^2) and subsequently standardized using BMI z-scores. Biological maturity was assessed using a predictive equation (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002), which estimates the years from or post peak height velocity and has been validated with standard error of estimates of 0.57 and 0.59 years for boys and girls, respectively (Mirwald et al., 2002).

Instruments

The Children and Youth Physical Self-Perception Profile (CY-PSPP; Whitehead, 1995) was used to determine self-perceived competence. The CY-PSPP consists of four sub-domains (sports competence, physical condition, body attractiveness, and physical strength) positioned underneath a domain (self-worth) and global domain (global self-esteem). Each sub-domain comprises of six individual questions rated on a four-point Likert scale in a structured alternative format. For each question, the participant is initially presented with two statements from which they must select the one most identifiable to themselves and then select either 'sort of true' or 'very true'. Akin to previous studies, the CY-PSPP was completed in full, with the sub-scale for sports competence analyzed as the measure of perceived sports competence (Barnett et al., 2011, 2008; De Meester, Stodden, et al., 2016). Each sub-domain has been previously shown to provide a sensitive and reliable measure, irrespective of sex (Fox, 1989), and in the current study, the perceived sports competence sub-domain demonstrated acceptable internal consistency ($\alpha = 0.65$).

Three locomotor (sprint, hop and vertical jump) and three object control (catch, kick, overarm throw) skills were assessed using the Get skilled, Get active protocol (Department of Education and Training, 2000). These FMS are identified as core curriculum movement skills and underpin the specialized movements that are desirable for organized sport participation

(Department for Education, 2013). Children were given a verbal description and a demonstration of each skill. Each fundamental movement skill has six individual grading components that relate to a specific technical characteristic of the movement skill. FMS were completed five times, if the individual grading component was checked as being present on four out of five trials then the child was marked as possessing that specific technical characteristic of the movement skill. The summed score of the trials was used to provide an overall score for object control and locomotor skills. Following the assessment session, video analysis of each performance was completed by two trained assessors who scored a separate sub-sample of children. Inter-rater reliability was established prior to data collection (Kappa=0.77; 90% CI: 0.71 to 0.83).

Physical activity was objectively assessed using an ActiGraph GT1M accelerometer (ActiGraph, LLC, Pensicola, Florida) worn on the right hip for seven consecutive days measuring at 5s epochs. Evenson et al. (2008) cut-points were used to determine physical activity intensity. These cut-points have been shown to have acceptable classification accuracy for physical activity and inactivity in children and adolescents (Trost, Loprinzi, Moore, & Pfeiffer, 2011). Non-wear time was defined as 20 minutes of consecutive zero counts (Catellier et al., 2005). To classify wear-time and sleep-time, children completed a log sheet to record any periods during which the accelerometer was removed for sleep and additional activities (i.e., contact sport, showering). These log sheets were checked and initialed by parents at the end of each day. A minimum daily wear-time of 540 minutes on at least two weekdays and 480 minutes on a weekend day was required to be included in the analyses. These inclusion criteria have previously shown acceptable reliability in similarly aged children (Fairclough et al., 2015; Mattocks et al., 2008). From the initial sample, 20 participants were omitted from the analyses (incomplete FMS and physical activity data), leaving a sample of 170 children (10.6 ± 0.3 years; 98 girls).

Statistical analysis

Data were analyzed using IBM SPSS and AMOS for Windows, Version 25 [IBM SPSS Statistics Inc., Chicago, IL, USA]. All descriptive results are presented as means ± standard deviation (SD), with Student t-test for independent samples used to analyse between-sex differences. Path-analysis was conducted to determine direct and indirect associations between FMS (object control and locomotor skill competence), perceived sports competence, VPA, sedentary time and BMI z-score. Bootstrapping for indirect effects was based on 2,000 bootstrap samples, and confidence intervals were set as 95% (MacKinnon, Lockwood, & Williams, 2004). Path coefficients and correlations were reported as standardized estimates. Statistically significant criterion for all paths was set at $p < 0.05$. The hypothesized model was tested initially to ensure its viability. Global model fit was assessed using Chi-square statistic/Degrees of Freedom (CMIN/DF), Comparative fit index (CFI), Goodness of fit index (GFI), Root mean square error of approximation (RMSEA), and p of Close Fit (P-Close). Multi-group analysis was used to examine the moderating role of sex. This was performed by testing a constrained model (paths constrained to be equal for both sexes) and comparing this against an unconstrained model (i.e., sex-specific). A chi-squared difference test was then used to determine whether the models differed significantly by sex.

Results

Descriptive statistics are provided in Table 1. Results indicated no significant sex differences in fundamental movement skill constructs, BMI z-score, and perceived sports competence. However, boys were significantly more competent in the throw ($p < 0.05$), and accrued significantly more time in VPA ($p < 0.01$) and significantly less time sedentary

($p < 0.05$). The overall model demonstrated excellent global model fit (CMIN/DF = 1.418; CFI = 0.989; GFI = 0.989; RMSEA = 0.050; P-Close = 0.416). Maturity was removed as a covariate from the initial model because it did not have a significant effect. The multi-group analysis showed that the structural model was significantly different between girls and boys (X^2 (17) = 20.9, $p = 0.023$).

For girls (Figure 1), locomotor skill competence had a direct association with VPA ($\beta = 0.18$, $p = 0.03$). Additionally, perceived sports competence was found to have a direct association with time spent sedentary ($\beta = -0.29$, $p = 0.002$) and BMI z-score ($\beta = -0.23$, $p = 0.01$). A further direct association was found between time spent in VPA and BMI z-score ($\beta = -0.37$, $p < 0.001$). For boys (Figure 2), a direct association between object control skill competence and perceived sports competence was observed ($\beta = 0.39$, $p < 0.001$) and an indirect association was found between object control skills competence and time spent sedentary ($\beta = -0.19$, $p < 0.001$), mediated by perceived sports competence. In contrast, locomotor skill competence was negatively associated with perceived sports competence ($\beta = -0.28$, $p = 0.01$). Perceived sports competence was found to have a direct association with time spent sedentary ($\beta = -0.48$, $p < 0.001$). Additionally, time spent in VPA was found to be directly associated with BMI z-score ($\beta = -0.25$, $p = 0.03$).

Discussion

This study sought to explore whether sex moderates the association between FMS, perceived sports competence, time spent in VPA, sedentary time and BMI z-score during late childhood. Overall, the results provide evidence of the moderating role of sex on the association of FMS and selected health and behavioral outcomes, during late childhood. For boys, object control skill competence was directly associated with perceived sports competence and had an indirect association with time spent sedentary. For girls, only a direct association between locomotor skill competence and VPA was found. These results suggest that the underpinning factors most influential to the developmental health trajectories of children may differ with sex.

The present study failed to provide support to previous research that has found marked sex differences in fundamental movement skill competence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Bolger et al., 2018). Although no significant sex differences in the object control and locomotor skill constructs were found, boys were significantly more competent in the overhand throw. The higher competence of boys in the overhand throw may suggest that sex-related norms associated to sport participation still exist, with these supported by parental and societal beliefs (Clément-Guillotin & Fontayne, 2011). Coupled with boys spending more time in VPA, the higher competence of boys in the overhand throw may indicate a greater participation in sport-related activity, and fewer opportunities and/or less support for girls to develop these skills in similar contexts (Barnett et al., 2016).

Interestingly, the present study found only object control skill competence to be positively associated with perceived sports competence, which was only significant for boys. The results concur with the majority of previous studies finding object control competence as the only significant predictor of perceived sports competence (Barnett et al., 2016; Robinson et al., 2015). Proficiency in object control skills has a greater influence in many of the sports traditionally defined as masculine and within which boys commonly participate (i.e., rugby, tennis, football; Barnett et al., 2011; Clément-Guillotin & Fontayne, 2011). Boys will likely align their perceived sports competence to object control skills, as these are deemed more important to their activity choices. For boys in the current study, locomotor skills were found to be negatively associated with perceived sports competence. Although unexpected, these results may indicate a lack of alignment between actual and perceived competence with regards to locomotor skills and may also reflect that locomotor skill competence is less important for perceptions of sport competence.

As previous studies have found FMS to be positively associated with MVPA, we expected a similar influence to be evident with VPA and that this association would be mediated through perceived sports competence. VPA was selected as an independent indicator of physical activity as it has been shown to have additional health benefits, beyond those of MVPA (Carson et al., 2014; Poitras et al., 2016). Whilst our study did not provide support for an indirect association between FMS and BMI z-score, for either sex, the models for girls and boys did identify VPA as a predictor of BMI z-score. This is an important finding as this provides further evidence of the importance of VPA for achieving health-enhancing benefits (Carson et al., 2014). It was hypothesized that FMS would be more influential to activities incorporating VPA (i.e., sport participation). However, although a direct association between locomotor skills and VPA was observed for girls, object control skills were not associated with VPA, irrespective of sex. Similarly, an indirect association between FMS and VPA, through perceived sports competence, was not evident. It is possible that children at this age are still achieving a large proportion of VPA through active play, where actual and perceived fundamental movement skill competence has less influence on engagement. Additionally, sport participation in late childhood is still underpinned by development and enjoyment, with less emphasis on performance indicators (Barnett, Vazou, et al., 2016; Malina, Cumming, & Silva, 2016). For girls, the direct association between locomotor skills and VPA may reflect the greater direct importance to the physical activity and sport-related choices of many girls at these ages (i.e., track, gymnastics; Barnett et al., 2016). The lack of association between perceived sports competence and time spent in VPA particularly in early-maturing girls may suggest that other barriers, such as physical self-perception, motivation, and societal context, exert a greater influence on time spent in VPA in comparison to perceived sports competence (Malina et al., 2016).

To our knowledge, this is the first study to use path analysis to assess both the direct and indirect association between FMS and sedentary time specific to sex. Advancing previous research, which has focused largely on the influence of FMS on physical activity levels (Robinson et al., 2015), the present study found perceived sports competence to have a crucial association with time spent sedentary. Irrespective of physical activity levels, sedentary time has been identified as an independent construct associated with acute and chronic health consequences (Saunders, Chaput, & Tremblay, 2014). Yet, in line with studies that have observed the influence of self-perception on physical inactivity (Barnett et al., 2011, 2008; Robinson et al., 2015), the present results show that, whilst independent, there are similarities in the underpinning attributes associated with sedentary time and physical inactivity. Perceived competence has previously been suggested to be as important as actual competence in predicting physical inactivity (Robinson et al., 2015). Advancing this, the present results found perceived sports competence to be strongly associated with sedentary time. Along with fundamental movement skill competence, it can be postulated that psychosocial factors (i.e., low perceived competence, lack of enjoyment) influence sedentary behaviors in children, especially during weekdays where leisure-time is more finite (Hardy, Ding, Peralta, Mihrshahi, & Merom, 2018). This association between FMS, self-perception, and sedentary time may become amplified in adolescents with greater autonomy and where the biological drive to be physically active is less (Malina et al., 2016).

Whilst there are numerous strengths associated with the present study, such as using device-measured physical activity and using a validated fundamental movement skill assessment, it is important to acknowledge the limitations. As a cross-sectional study, causal inferences were not possible, and it is therefore important that future studies seek to identify bidirectional associations. The hypothesized directionality of the data in the current study was based on the conceptual model of Stodden et al. (2008). In addition, the questions used to analyze perceived sports competence (i.e., some kids do very well at all kinds of sports, but other kids don't feel they are good when it comes to sport) were not specific to the assessed FMS. Similarly, the use of accelerometers to measure sedentary time has been challenged, although 100 counts·min^{-1}, as used in the current study, has been identified as a valid measure of youth sedentary time (Kim, Lee, Peters, Gaesser, & Welk, 2014). Future research should also look to incorporate a fitness measurement, such as peak oxygen uptake, to provide analysis of all parameters within the Stodden et al. (2008) model.

Conclusion

The findings from the current study extend previous research by identifying sex-related differences in the influence of FMS upon health and behavioral outcomes. Specifically, for boys in late childhood, object control skills appear more important to a positive trajectory of health than their female counterparts. In contrast, for girls, it is locomotor skills that may have a greater association with health and behavioural outcomes. Importantly, this study highlights the crucial role of perceived competence in predicting time spent sedentary, irrespective of sex. These results support the adoption of a more holistic pedagogical approach that seeks to understand and enhance a child's perceived competence along with FMS. Furthermore, this study emphasizes the importance of adopting this form of approach during childhood to provide children with a strong movement profile and a motivation from which they can embrace a physically active lifestyle during adolescence.

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Table 1

Participant characteristics

Variables	Boys (*N* = 72)	Girls (*N* = 98)	All (*N* = 170)
Age (years)	10.6 ± 0.3	10.7 ± 0.3	10.6 ± 0.3
Height (cm)	143.1 ± 7.6	144.7±8.2	144.0 ± 8.0
Body mass (kg)	36.3 ± 7.9	38.3 ± 9.5	37.4 ± 8.9
BMI ($kg \cdot m^{-2}$)	17.6 ± 2.6	18.3 ± 3.8	18.0 ± 3.4
BMI z-score	0.12 ± 1.28	0.06 ± 1.32	0.09 ± 1.30
Maturity offset (years)	-3.1 ± 0.4	-1.3 ± 0.6	-2.0 ± 1.1
Catch (0-6)	4.8 ± 1.6	4.8 ± 1.5	4.8 ± 1.5
Throw (0-6)	3.6 ± 1.8	2.8 ± 1.7*	3.2 ± 1.8
Kick (0-6)	3.1 ± 1.6	2.8 ± 1.5	2.9 ± 1.5
Sprint (0-6)	3.0 ± 1.1	2.7 ± 1.2	2.9 ± 1.2
Vertical jump (0-6)	4.2 ± 0.9	4.1 ± 0.9	4.1 ± 0.9
Hop (0-6)	4.1 ± 0.9	3.9 ± 0.9	4.0 ± 0.9
Object control skills (0-18)	11.5 ± 4.1	10.5 ± 3.6	10.9 ± 3.8
Object control skills (range)	3-18	4-18	3-18
Locomotor skills (0-18)	11.3 ± 1.9	10.7 ± 2.2	11.0 ± 2.1
Locomotor skills (range)	7-16	7-17	7-17
Perceived sports competence	16.1 ± 3.4	15.6 ± 3.0	15.8 ± 3.2
VPA (min/day)	22.8 ± 6.8	17.4 ± 6.4**	19.7 ± 7.1
Sedentary time (min/day)	563.5 ± 63.9	579.0 ± 56*	572.4 ± 59.8

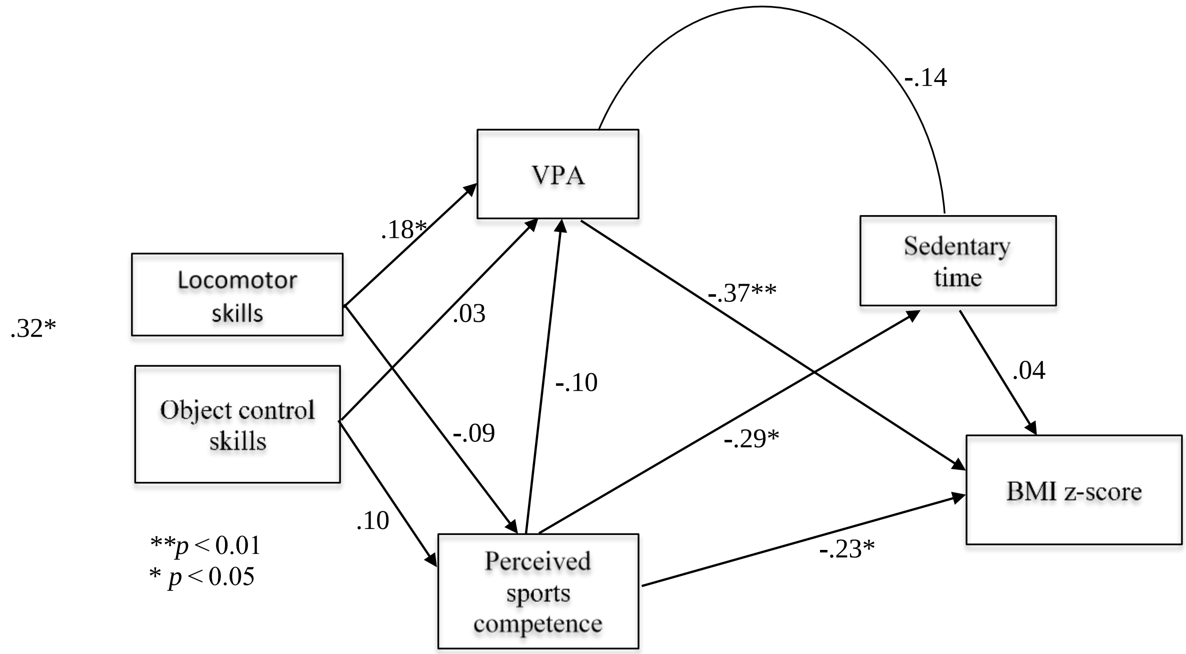
Means ± SD. BMI = Body mass index, VPA = Vigorous physical activity

* Significant difference between boys and girls ($p < 0.05$)

** Significant difference between boys and girls ($p < 0.01$)

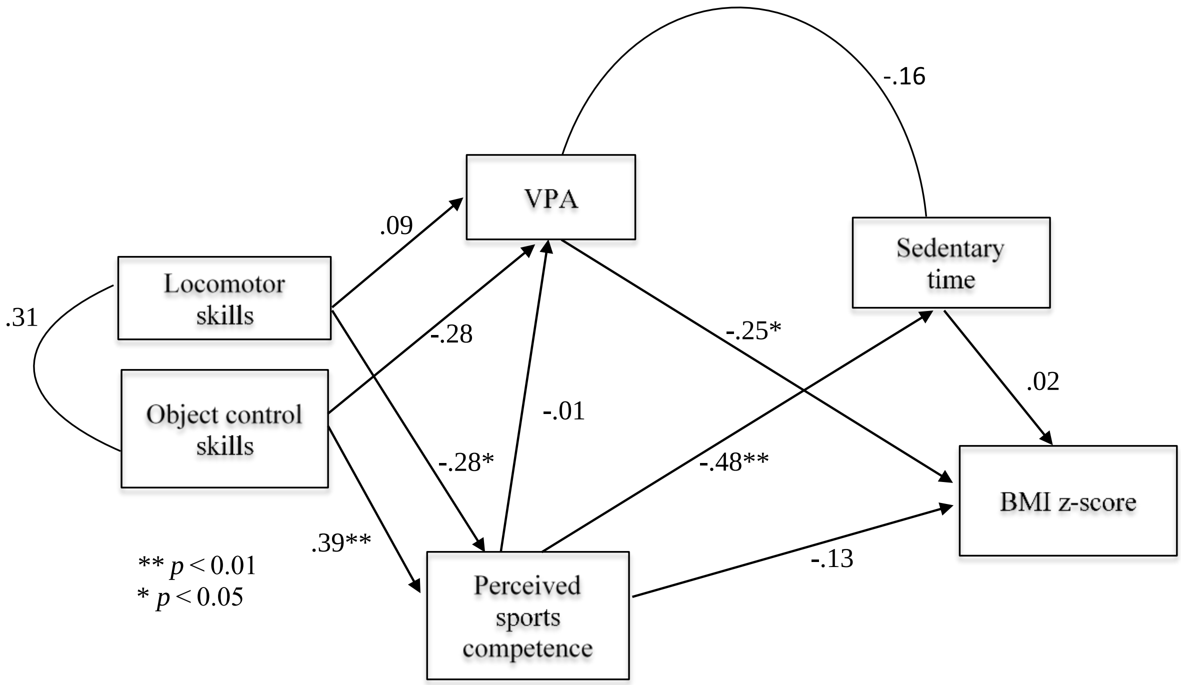
Figure 1

Structural equation model of FMS (locomotor skills and object control skills) and their influence on perceived sports competence, VPA (vigorous-intensity physical activity), sedentary time, and BMI z-score in girls, with standardized beta coefficients (*$p < 0.05$; **$p < 0.01$).



569 **Figure 2**

570 Structural equation model of FMS (locomotor skills and object control skills) and their
571 influence on perceived sports competence, VPA (vigorous-intensity physical activity),
572 sedentary time, and BMI z-score in boys, with standardized beta coefficients (*p < 0.05;
573 **p < 0.01).
574



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