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Abstract

Engagement in physical activity plays a central role in the prevention and treatment of childhood overweight/obesity. However, some children may lack the skills and confidence to be physically active. This three-years follow-up study aimed to form profiles based on cardiorespiratory fitness, actual motor competence, perceived motor competence, physical activity, and weight status, and to examine if these profiles remain stable from late childhood to early adolescence. All these variables were annually assessed in 1 162 Finnish schoolchildren (girls = 583, boys = 564, Mage = 11.27 ± 0.32 years). Latent profile analysis was used to identify profiles and latent transition analysis to examine the stability of latent statuses. Three profiles were identified: normal weight with high movement (NW/MOVE+), normal weight with low movement (NW/MOVE-) and overweight-obese with low movement (OW-OB/MOVE-). Profile memberships remained relatively stable over time, indicating that children with low actual and perceived motor competence, cardiorespiratory fitness, and physical activity in late childhood also tended to exhibit these characteristics also in early adolescence.

Key words: motor development, adolescence, children, physical activity

Introduction

Childhood obesity has increased globally over recent decades (NCD risk, 2017). Children with overweight/obesity are at risk for multiple health consequences (dos Santos et al., 2015) and are likely to become adults with overweight/obesity (Singh et al., 2008). Engagement in physical activity plays a central role in the prevention and treatment of childhood overweight/obesity (Mahumud et al, 2021). This has led to calls for further research into the mechanisms underlying the synergistic development of physical activity and a healthy weight status from late childhood to early adolescence (Stodden et al., 2008; Robinson et al., 2015; Barnett et al., 2021).

The conceptual model of Stodden et al. (2008) titled "A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity" has been widely used to explain physical activity and weight development from childhood to adolescence (Robinson et al., 2015). It postulates motor competence (i.e., fundamental movement skills: locomotor, object control, and stability skills) (Goodway, Ozmun & Gallahue, 2021) as a driver of physical activity, and (self-)perceived motor competence (De Meester et al., 2020) and health-related fitness (i.e., cardiorespiratory fitness and muscular fitness) (Bouchard & Shephard, 1994) as mediators between actual motor competence and physical activity engagement. According to the model, reciprocal and dynamic relationships between these variables form either a positive spiral of engagement or negative spiral of disengagement that directs the development of body weight over time in childhood and adolescence. The model suggests that children with high actual and perceived motor competence and high health-related fitness can continue physical activity engagement for longer periods, which in turn gives them more possibilities for the further development of motor competence. Thus, they have the skills and confidence to be physically active, and thus enhanced possibilities to maintain a healthy weight status. In contrast, low actual and perceived motor competence and low health-related fitness may have the opposite outcomes. This in turn may lead to an unhealthy weight status, further straining the aforementioned variables (Stodden et al., 2008). The hypothetical theoretical relationships between the variables in the model have been demonstrated in many studies (Robinson et al., 2015). Overweight/obesity has consistently been associated with poor actual motor competence (Barnett et al., 2021), low cardiorespiratory fitness (Kolunsarka et al., 2021), low perceived motor competence (Jones et al, 2010) and low physical activity engagement (Janssen et al., 2019). However, a recent systematic review by Barnett et al. (2021) called for longitudinal studies across childhood and into adolescence that include all the variables presented in the conceptual model by Stodden et al. (2008), including multiple time points and controlling for potential confounding factors.

Research has shown that children present markedly different developmental trajectories of actual motor competence (Coppens et al., 2019), physical activity behavior (Lounassalo et al., 2019), cardiorespiratory fitness (Raghuveer er al., 2020), and body weight status (Oluwagbemigun et al., 2019) over time. This is one reason why studies utilizing sophisticated person-oriented statistical methods are needed. Unlike traditional variable-oriented methods, person-oriented methods (e.g., latent profile analysis) use latent variables and enable the description of population heterogeneity for example in individuals' developmental differences (Ferguson, Moore & Hull, 2020). Another advantage of using person-oriented statistical methods, when investigating a whole theoretical model such as that of Stodden et al. (2008), is that they allow longitudinal analysis of hypothesized dynamic and synergistic relationships between variables. To date, only a few longitudinal studies have used person-oriented methodologies including latent variables. Jaakkola et al. (2020; 2021) and Estevan et al. (2021), for example, found that children with high actual and perceived motor competence and high physical fitness displayed higher levels of physical activity and were more likely than other children to have a healthy weight status in childhood. Furthermore, Jaakkola et al. (2020)

identified a profile in which children's levels of actual and perceived motor competence and fitness were significantly lower and who were less physically active than the two other profiles identified. Thus, these previous studies (Jaakkola et al., 2020; Jaakkola et al., 2021; Estevan et al., 2021) have provided support for the positive and negative spirals of engagement that direct the development of body weight over time in childhood and adolescence, as presented in the model of Stodden et al. (2008).

However, this one is the first study of children to apply latent profile analysis (LPA) utilizing all the variables in the model of Stodden et al. (2008) and, further, to use latent transition analysis (LTA) to examine to what extent children transition between the identified profiles from late childhood to adolescence. Moreover, this study includes sex as a covariate, because previous studies have shown gender differences in object control (Barnett et al., 2010) and cardiorespiratory fitness (Raghuveer et al., 2020), in which boys outperform girls. Thus, the aim of this study was to extend our understanding of the conceptual model of Stodden et al. (2008) using all the variables and implementing a longitudinal design with original collected data. The research questions were: 1) Can qualitatively distinct subgroups of children based on cardiorespiratory fitness, motor competence, perceived motor competence, physical activity, and weight status be identified? 2) Do these profiles remain stable over time?

Materials and methods

Participants and procedure

This three-year follow-up study was conducted in Finland during 2017-2020. Participants were recruited from 35 randomly selected elementary schools in four municipalities. All 5th graders were given the opportunity to participate, and a total of 1 162 (girls = 583, boys = 564, Mage = 11.27 ± 0.32 years) volunteered. These children accounted for 2 % of the Finnish population of that age, and all samples were representative of their local population. Data on actual motor competence, cardiovascular fitness, and anthropometric measurements (height and weight) were collected annually between August and October over four consecutive years (T0-T3) by trained researchers during physical education classes. The questionnaire on perceived motor competence was administered in the classroom setting. Accelerometers were used to collect device-based moderate-to-vigorous physical activity (MVPA). Participants were instructed to wear accelerometers for one week during the annual data collection periods (T0-T3). Verbal consents were obtained from the participating children and informed written consents from their guardian prior to the start of the study. The study was approved by the human research ethics committee of the local university.

Measurements

Actual motor competence. Actual motor competence was measured using three skill tests including object control and locomotor skills. The throw-catch test (Jaakkola et al., 2012) was used to assess participants' object control skills. A target square (1.5 x 1.5 meters) was marked on a wall at 90 centimeters above floor level. Throwing distance depended on the participant's grade and sex and ranged from 7 to 10 meters. Participants were instructed to throw a tennis ball with their desired hand directly at the target and to catch the ball after one bounce back from the floor with one or both hands. Participants were allowed 20 trials and the result was the number of successfully completed trials (i.e., the ball hit the target and was caught after one bounce back from the floor). This test is widely used in Finnish sport science studies (Jaakkola et al., 2021) and has shown acceptable test-retest reliability (ICC = .692, $p < .001$) in children and adolescents (Jaakkola et al., 2012). Locomotor skills were assessed by the 5-leap test (Jaakkola et al., 2012) and two-legged side-to-side jump test (Kiphard & Schilling, 2007). The 5-leap test consists of five consecutive strides with feet together at the start and end of the five leaps. Participants were allowed to start the strides with their desired leg. The test was performed twice, and the better result (i.e., the overall distance covered in meters rounded to two decimals) was recorded. In the two-legged side-to-side jump, the participant jumped from side-to side over a low wooden beam with legs in parallel continuously for 15 seconds as fast as possible. The test is performed twice, and the result is the sum of the number of successful jumps in each trial.

Perceived motor competence. Participants' perceived motor competence was assessed using the Finnish version of the sport competence dimension of the Physical Self-Perception Profile (PSPP) (Fox & Corbin, 1989). Each of the five items (i.e., good at sport, athletic ability, confidence to move, among the best when it comes to joining sport activities, among the first to join in sport activities) was preceded by the stem: "*What am I like*?" and rated on a five-point scale (e.g., 1 = *I'm among the best when it comes to athletic ability*, 5 = *I'm not among the best when it comes to athletic ability*). A previous study with Finnish children demonstrated acceptable construct validity (CFI = .98, TLI = .97, RMSEA = .074) and internal consistency (Cronbach's alpha = .90) (Gråstén, 2014).

Cardiorespiratory fitness. The 20-meter shuttle run test (Leger & Lambert, 1982) was used to assess participants' cardiorespiratory fitness. A 20-meter track was marked on the floor by two parallel lines and the running pace for each 20-meter shuttle was determined by the frequency of recorded beeps. Participants were instructed to run continuously up and down the 20-meter track in time to the beeps. The initial running velocity was 8.5 km/h for the first minute, after which it increased by 0.5 km/h for each successive minute. When participants were no longer able to keep pace with the beeps, they were instructed to terminate the test. The result was the number of completed shuttles.

Weight status. Participants' body mass index (BMI) was calculated using a weight (kg) and height (m) formula (kg/m^2). Body weight was measured to the nearest 0.1 kg using calibrated scales (Point Electronic Personal Scale), with the children wearing light clothing and barefoot. Height was measured to the nearest 0.1 cm using portable measuring equipment (measuring tape). Extended international body mass index cut-offs values (IOTF) were used to determine participants weight status (thinness, normal weight, overweight, obese) (Cole & Lobstein, 2012).

Device-measured MVPA. Participants' MVPA was measured using Actigraph wGT3X+ accelerometers. Participants were instructed to wear the device for seven consecutive days on their right hip at all times during their waking hours, except while bathing or doing water-based activities. Data were collected as raw accelerations at a frequency of 30 Hz and converted into 15-s epoch counts. Customized Visual Basic Macro for Excel software was used for data reduction. A valid day of physical activity monitoring included measured values ≥500 min/day for at least two weekdays and one weekend day between general waking hours (i.e., 7:00-23:00). Periods of 30 min of consecutive zero counts were defined as non-wear time, and values over 20 000 counts per minute (cpm) were considered spurious accelerations and discarded (Heil, Brage & Rothney, 2012). Cut points (Evenson et al., 2008) were used to calculate MVPA (≥2296 cpm).

Data analysis

Data were examined for normality, outliers, and missing values. Correlations and descriptive statistics including means and standard deviations were computed for the observed variables. In addition, Cronbach alphas were determined for the perceived competence scale. To conduct a latent transition analysis, a 5-step model was applied following the procedures of Nylund, Asparouhov & Muthén (2007) (cross-sectional data diagnosis and exploration using latent profile analysis (Step 1), testing for longitudinal measurement invariance (Step 2), defining latent statuses (Step 3), testing latent statuses for multiple-group latent transition analysis and transition probability invariance (Step 4), and testing latent transition analysis with the covariate sex (Step 5)).

In Step 1, to identify childhood movement profiles, a cross-sectional LPA was conducted for each time point (T0-T3). The explorative analyses were conducted for models including two to five profiles at each time point. Several indices were used to compere the models and thus to confirm the most reasonable model with optimal number of profiles. Statistical indicators included the Bayesian information criterion (BIC), the adjusted BIC (ABIC), Akaike's information criterion (AIC), entropy, and the adjusted Lo-Mendell-Rubin likelihood ratio test (ALMR-LTR). Models with low BIC, ABIC, and AIC indices and higher entropy were considered to show better fit to the data. In the ALMR-LTR, a p-value > .05 suggested that the k-pattern solution did not fit to the data any better than the k-1 solution (Nylund, Asparouhov & Muthén, 2007). Additionally, to avoid problematic models, profiles containing less than 1% or 5% of participants were identified and excluded. Once the most reasonable model was chosen, based on these several indices, a descriptive label was given to each profile and ANOVAs with post hoc were conducted to identify statistical differences in each variable between classes per time point.

In Step 2-4, the LTA, which is a longitudinal extension of the LPA method, was used to examine the stability of the profiles and the probabilities of changes in profiles over time. In Step 2, structural differences between the profiles at different time points were tested. Thus, to explore if the profile indicators provided an unbiased reflection of the same construct across time, longitudinal measurement invariance was tested by comparing the measurement invariance model (equal indicator means) with the measurement variance model (freely estimated profile indicator means). The Chi square (χ2) -test was conducted using the maximum likelihood estimator (MLR) with Satorra-Bentler scaling correction to evaluate the two models. In Step 3, the most reasonable solution was chosen for further analyses (i,e., if the models differed significantly, the measurement variance model was chosen) and the latent statuses were defined. In Step 4, the transition probability invariance was explored by fixing the transition probabilities to be equal over time and by comparing it to the freely estimated model. Finally, in Step 5, the covariate sex was added to the selected model. Results were considered statistically significant at the $p < .05$ level. Latent profile and latent transition analyses were performed by using Mplus version 8.2 and descriptive statistics, anova with post hoc and the missing completely at random (MCAR) test by using SPSS 22.0.

Results

Preliminary analysis

Tests of normality demonstrated that the data were approximately normally distributed ($p > .05$) and based on the standardized values (± 3.00) the data was free of outliers. As it was not possible to provide all the participants with accelerometers and the proportions of students completing all the measurements were lower at the later time points, missing values (9 651 out of 33 698) accounted for 28 % of the data. The Missing Completely at Random (MCAR) test indicated that the missing values ($\chi^2(9051) = 8494$, $p < .001$) were missing at random (MAR). Moreover, a closer examination of the data matrix revealed that the missing values did not represent any specific group or school. Consequently, the missing values were not imputed but were estimated through the mixture likelihood procedure, which has been shown to produce reliable parameter estimates and standard errors under MAR conditions (Hunt & Jorgensen, 2003).

Descriptive statistics

Descriptive statistics, including means, standard deviations, and proportion of students at each time point are shown in Table 1. A statistical power analysis suggested that to meet statistical constraints with a confidence level of 95% and a margin of error of $p < .05$, a minimum of 289 participants was required. Thus, the current sample size of 1 162 was adequate for the main analyses of this study. At baseline the participants' mean age was 11.27 ± 0.33 years and mean

BMI 18.88 ± 3.12 kg/m2. At baseline (T0) 4.4 % of the participants were thin, 73.2 % normal weight, 18.5 % overweight and 3.7 % obese. The Cronbach's alphas for the perceived competence scale were relatively high at each time point (T0 = .87, T1 = .90, T2 = .89, T3 = .89).

Latent profile analysis (Step 1)

Students were clustered into homogeneous profiles at each time point (T0-T3) based on actual motor competence, perceived motor competence, cardiorespiratory fitness, weight status, and MVPA. Statistical indices (AIC, BIC, aBIC, ALMR-LTR and entropy) showed that the three-profile model was the most reasonable at T0, T1 and T3. At each of these time points, the three-profile model produced more optimal statistical indicators than two-profile model, whereas four-profile model did not fit the data any better than three-profile model ($p > .05$). In addition, the three-profile models did not include classes containing less than 5 % of participants. At T2, the four-profile model indicated the best statistical fit but one of the classes contained less than 5 % of the participants, and therefore, the three-profile model was selected (Table 2). The selected 3-3-3-3-model comprised three latent profiles at each time-point (T0-T3).

Longitudinal measurement of invariance for the 3-3-3-3-model (Step 2)

Longitudinal measurement invariance was examined for the 3-3-3-3-model by comparing the measurement invariance model (equal indicator means) and the measurement variance model (freely estimated profile indicator means). The χ^2-test using the maximum likelihood estimator (MLR) with Satorra-Bentler scaling correction indicated that the full non-invariance model exhibited improved fit over the 3-3-3-3-model (Table 2). This result was expected given the large number of parameters and the developmental changes occurring over time in childhood (Putnick & Bornstein, 2016). Thus, the full non-invariance model was selected for subsequent transition analysis.

Definition of latent statuses (Step 3)

After careful examination of the models, the 3-3-3-3-model with freely estimated means was selected for further analysis. The next step included more specific reportage of the three clusters. Means and standard deviations of actual motor competence (locomotor and object control skills), perceived motor competence, cardiorespiratory fitness, MVPA and weight status prevalence were determined for each cluster and are presented in Table 3. Profile 3 was labelled normal weight with high movement (NW/MOVE+). The participants in this profile were mostly identified as normal weight or thin as less than 5 % was overweight or obese, and showed statistically significantly higher values in motor competence, cardiorespiratory fitness, MVPA and perceived motor competence at each time-point compared to their peers in the other two profiles. The profile 1 was labelled overweight/obese with low movement (OW-OB/MOVE-) as no children within this profile were identified as normal weight or thin, and the profile 2 was labelled normal weight with low movement (NW/MOVE-) as less than 4 % of the participants in this latter profile were overweight and none were identified as obese. The participants in the OW-OB/MOVE- profile were overweight and showed significantly lower values in locomotor competence and in the cardiorespiratory fitness measurements than their peers in the NW/MOVE- profile, although they showed significantly higher values in object control skills at T0, T1 and T3. No statistically significant differences were observed in MVPA or perceived motor competence between the OW-OB/MOVE- and NW/MOVE- profiles over time.

Latent status and transition probability invariance tests (Step 4)

The transition probability invariance result indicated that the model with transition probabilities fixed to be equal over time and the freely estimated model differed from each other. This result was expected given the large number of parameters and the developmental changes occurring over time in childhood (Putnick & Bornstein, 2016). As the freely estimated model allows for variation, it was chosen for further use. Thus, the results are based on a non-invariance model (i.e., the freely estimated model). Examination of the transition probabilities revealed that transition patterns were stable over time, indicating that participants remained in the clusters identified during the first measurement phase (Table 4).

Covariate effect of sex (Step 5)

To determine covariate effects of sex on status prevalence at T0-T3, sex was added to the 3-3-3-3 model as a covariate with free transition probabilities (Table 5). In a multinomial model, the analysis does not provide regression coefficients for the reference group. Significant covariate effects of sex on status prevalence were found for the memberships of the OW-OB/MOVE- and NW/MOVE- profile at T0 and NW/MOVE- profile at T2. The odds ratios indicated that girls were mostly likely to be in the NW/MOVE- profile at T0 and least likely to be in NW/MOVE+. At T2 girls were more likely to be in NW/MOVE- profile than in two others. There was no sample variance of sex at T1, indicating that girls and boys had an identical likelihood for cluster membership at T1, and thus sex effects were restricted.

Discussion

This study sought to profile children into homogeneous latent profiles and to explore their probabilities to transition between these profiles over three years from late childhood to early adolescence. The main finding based on actual and perceived motor competence, cardiorespiratory fitness, physical activity, and weight status was the identification of three latent profiles: OW-OB/MOVE-, NW/MOVE- and NW/MOVE+. This study also found that the profile memberships remained relatively stable over the three-year follow-up.

The participants in the NW/MOVE+ profile were normal weight and showed the highest values in all measurements, except in BMI. Compared to the other two profiles, their test results were significantly higher in actual and perceived motor competence, cardiorespiratory fitness, and

MVPA. Similar profiles were found by Estevan et al. (2021) and Jaakkola et al. (2020), both of whom reported one profile with high actual and perceived motor competence and high physical fitness. Estevan et al. (2021) also reported that this profile was characterized by the low membership of children with overweight/obesity and high engagement in physical activity. This profile demonstrates the positive spiral for engagement presented in the model of Stodden et al. (2008), positing that children with high actual and perceived motor competence and high cardiorespiratory fitness are more physically active and have a healthy weight status. Furthermore, according to Stodden et al. (2008), the children in this profile may have a lower risk for unhealthy weight development, as they have the tools to be physically active also later in life.

The participants in OW-OB/MOVE- and NW/MOVE- profiles had similar, although somewhat lower perceived motor competence and levels of MVPA, compared to their peers in the NW/MOVE+ profile. In addition, the participants in the OW-OB/MOVE- profile showed lower cardiorespiratory fitness and locomotor competence than those in the NW/MOVE- profile, but higher object control competence in T0, T1 and T3. As observed in previous studies (Moliner-Urdiales et al., 2011), children with overweight have a lower cardiorespiratory fitness than children with normal weight. Excessive body weight and/or fat mass increases the workload in the 20-meter shuttle run, which adversely affects test performance (Tomkinson et al., 2019). The participants in the OW-OB/MOVE- profile also showed significantly lower locomotor competence scores. However, poor performance in locomotor tasks such as jumping, and leaping may have less to do with motor coordination and more to do with the morphological limitations of overweight and obesity in transporting the body through space, and especially against gravity (Chivers et al., 2013; Webster et al., 2021). Overall, excess weight affects weight-bearing motor tasks, such as running and locomotion (Webster et al., 2021). In contrast, the children in the OW-OB/MOVE- profile showed significantly higher values for object control skills at the three time-points (T0, T1, T3) than their peers in the NW/MOVE- profile. This outcome contrasts somewhat with the findings of previous studies (D'Hondt et al., 2009; Gentier et al., 2013) comparing object control skills across different weight statuses, as they have concluded that children with obesity have lower scores in object control skills compared to their normal weight peers. However, D'Hondt et al. (2009) concluded that no differences in object control or motor skills in general were found between children with normal weight and overweight and thus suggested there may be certain cut-off from which movement difficulties appear. Also, previous studies have treated normal weight group as one homogeneous group (D'Hondt et al., 2009; Gentier et al., 2013), whereas this study showed that children with normal weight also have various levels of object control skills. Thus, children with normal weight may also have impaired object control competence, which may prevent them from being physically active in the future, as object control competence has been shown to be more strongly associated with physical activity levels than locomotor competence (Barnett et al., 2011). Moreover, according to Stodden et al. (2008), children in both the NW/MOVE- and OW-OB/MOVE- profiles may, owing to their low motor competence, be at higher risk for low engagement in physical activity, which in turn may lead to unhealthy weight development in the future.

The profile memberships identified in this study were relatively stable over time, suggesting that children in NW/MOVE- and OW-OB/MOVE- profiles with low actual and perceived motor competence, cardiorespiratory fitness, and physical activity in late childhood also tend to exhibit these characteristics in early adolescence. As in these profiles participants' level of actual and perceived motor competence remains relatively low, they are unlikely to be motivated to engage in physical activity either currently or later (Stodden et al., 2008; Robinson et al., 2015). Previous studies have also shown that weight status (Singh et al., 2008) and physical capabilities, such as physical fitness (True et al., 2021) and motor competence

(Jaakkola et al., 2021), tend to track from childhood to adolescence. Thus, it would be important to identify children with poor movement profiles as early as possible for example by systematic fitness and motor competence monitoring in schools and through actions and interventions in schools and communities seek to enhance children's motor competence and further engagement in physical activities.

Finally, the results indicated that at T0 and T2 girls were mostly likely to be in the NW/MOVE-profile than in the other two profiles. A previous finding that girls are less competent than boys in object control skills (Barnett et al., 2010) may, at least partially, explain this result. Girls have also been shown to be less physically active than boys (Guthold et al., 2020). Further conclusions on sex differences in profile membership cannot be drawn owing to the lack of social support variables in the current data, as it has been suggested social support is an important factor underlying participation in motor competence-related physical activities in school-aged children (Biddle et al., 2011).

The strengths of this study were the large number of participants, a longitudinal design with annual follow-ups, and the person-oriented statistical analyses. Moreover, the profile analyses included all the variables presented in the model of Stodden et al. (2008) and thereby providing further information on the model. However, the study has its limitations. Device-measured MVPA may be underestimated because water-based activities could not be recorded. While BMI is a widely used measure in tracking changes in adiposity, it is not unproblematic with children and adolescents due to maturational growth and its inability to differentiate muscle mass from fat (Nuttall, 2015). Also, the lack of maturation measurements is a notable limitation of this study, as maturation is characterized by several physiological and psychological changes that may over time influence an individual's BMI, actual motor competence, perceived motor competence and cardiorespiratory fitness developmental trajectories (Malina, Bouchard & Bar-Or, 2004). Perceived motor competence was assessed with the sport competence dimension of the Physical Self-Perception Profile (PSPP) by Fox & Corbin (1989), which is rather a measure of perceived sport/athletic competence than perceived motor competence. Therefore, caution should be exercised when comparing studies using different instruments to assess perceived motor competence (Estevan & Barnett, 2018).

The findings of this study extended our understanding of the variables included in the model of Stodden et al. (2008) and the role of weight status in this model from late childhood to early adolescence. To summarize, excessive body weight and/or fat mass is a burden which hinders performances in weight-bearing motor tasks. However, the fact that children with normal weight have very different movement profiles raises the concern that children with normal weight and a low movement profile may be at higher risk for unhealthy weight development in later life (Stodden et al., 2008; Robinson et al., 2015). Moreover, girls compared to boys were less likely to be in the high movement profile, which suggest that some gender differences can be seen in the development of physically active lifestyle. A suggestion for future studies is to repeat this study protocol in younger children and possibly follow them through adolescence. Moreover, future studies should include the examination of organized sport participation, as it seems to be important in this respect. To develop optimal overweight/obesity prevention programs, future studies should examine whether children with low movement profiles are at risk for low physical activity engagement and unhealthy weight development also in adulthood, so that resources can be targeted where they are most needed, such as children's motor competence development.

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Declaration of interest statement

The authors declare no competing financial or non-financial interests.

References

Barnett, L. M., Morgan, P. J., van Beruden, E., Ball, K., & Lubans, D. R. (2011). A Reverse Pathway? Actual and Perceived Skill Proficiency and Physical Activity. *Medicine and Science in Sports and Exercise*, 43(5), 898–904. https://doi.org/10.1249/mss.0b013e3181fdfadd

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2010). Gender differences in motor skill proficiency from childhood to adolescence. *Research Quarterly for Exercise and Sport*, 81(2), 162–170. https://doi.org/10.1080/02701367.2010.10599663

Barnett, L. M., Webster, E. K., Hulteen, R. M., de Meester, A., Valentini, N. C., Lenoir, M., Pesce, C., … Rodrigues, L. P. (2021). Through the Looking Glass: A Systematic Review of Longitudinal Evidence, Providing New Insight for Motor Competence and Health. *Sports Medicine*. 1-46. https://doi.org/10.1007/s40279-021-01516-8

Biddle, S. J. H., Atkin, A. J., Cavill, N., & Foster, C. (2011). Correlates of physical activity in youth: A review of quantitative systematic reviews. *International Review of Sport Exercise Psychology*, 4(1), 25-49. https://doi.org/10.1080/1750984X.2010.548528

Bouchard, C., & Shephard, R. J. (1994). Physical activity, fitness, and health: The model and key concepts. In: Bouchard, C., Shephard, R. J., Stephens, T. (eds.). Physical Activity, Fitness and Health. Champaign, IL: Human Kinetics.

Chivers, P., Larkin, D., Rose, E., Beilin, L., & Hands B. (2013). Low motor performance scores among overweight children: Poor coordination or morphological constraints? *Human Movement Science*, 32(5), 1127-1137. https://doi.org/10.1016/j.humov.2013.08.006.

Cole, T. J., & Lobstein, T. (2012). Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric Obesity*, 7(4), 284–294. https://doi.org/10.1111/j.2047-6310.2012.00064.x

Coppens, E., Bardid, F., Deconinck, F. J. A., Haerens, L., Stodden, D., D'Hondt, E., & Lenoir, M. (2019). Developmental Change in Motor Competence: A Latent Growth Curve Analysis. *Frontiers in Physiology*, 10, 1273. https://doi.org/10.3389/fphys.2019.01273

D'Hondt, E., Deforche, B., De Bourdeaudhuij, I. & Lenoir, M. (2009). Relationship between motor skill and body mass index in 5- to 10-year-old children. *Adapted Physical Activity Quarterly*, 26(1), 21-37. https://doi.org/10.1123/apaq.26.1.21

dos Santos, F. K., Prista, A., Gomes, T. N. Q. F., Santos, D., Damasceno, A., Madeira, A., … Maia, J. A. R. (2015). Body mass index, cardiorespiratory fitness and cardiometabolic risk factors in youth from Portugal and Mozambique. *International Journal of Obesity*, 39(10), 1467–1474. https://doi.org/10.1038/ijo.2015.110

Estevan, I. & Barnett, L. M. (2018). Considerations related to the definition, measurement and analysis of perceived motor competence. *Sports Medicine*, 48(12), 2685-2694. https://doi.org/10.1007/s40279-018-0940-2

Estevan, I., Menescardi, C., García-Massó, X., Barnett, L. M., & Molina-García, J. (2021). Profiling children longitudinally: A three-year follow-up study of perceived and actual motor competence and physical fitness. *Scandinavian Journal of Medicine & Science in Sports*, 31(S1), 35–46. https://doi.org/10.1111/sms.13731

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences*, 26(14), 1557–1565. https://doi.org/10.1080/02640410802334196

Ferguson, S. L., G. Moore, E. W., & Hull, D. M. (2020). Finding latent groups in observed data: A primer on latent profile analysis in Mplus for applied researchers. *International Journal of Behavioral Development*, 44(5), 458–468. https://doi.org/10.1177/0165025419881721

Fox, K. R., & Corbin, C. (1989). *The Physical self-perception profile: development and preliminary validation*. Journal of Sport and Exercise Psychology, 11(4), 408-430. https://doi.org/10.1123/jsep.11.4.408

Gentier, I., D'Hondt, E., Shultz, S., Deforche, B., Augustijn, M., Hoorne, S., … Lenoir, M. (2013). Fine and gross motor skills differ between healthy-weight and obese children. *Research in Developmental Disabilities*, 34(11), 4043-4051. https://doi.org/10.1016/j.ridd.2013.08.040

Goodway, J. D., Ozmun, J. C., & Gallahue, D. L. (2021). *Understanding motor development: infants, children, adolescents, adults* (Eighth edition). Jones & Bartlett Learning.

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Heil, D. P., Brage, S., & Rothney, M. P. (2012). Modeling Physical Activity Outcomes from Wearable Monitors. *Medicine and Science in Sports and Exercise*, 44(1 Suppl 1), S50–S60. https://doi.org/10.1249/MSS.0b013e3182399dcc

Hunt, L., & Jorgensen, M. (2003). Mixture model clustering for mixed data with missing information. *Computational Statistics & Data Analysis*, 41(3), 429–440. https://doi.org/10.1016/S0167-9473(02)00190-1

Jaakkola, T., Sääkslahti, A., Liukkonen, J., & Iivonen, S. (2012). Peruskoululaisten fyysisen toimintakyvyn seurantajärjestelmä [The system to develop and follow Finnish students' physical fitness and motor skills]. University of Jyväskylä: Faculty of Sport and Health Sciences.

Jaakkola, T., Yli-Piipari, S., Huhtiniemi, M., Salin, K., Hakonen, H., & Gråstén, A. (2021). Motor Competence and Health-related Fitness of School-Age Children: A Two-Year Latent Transition Analysis. *Medicine and Science in Sports and Exercise*, 53(12), 2645–2652. https://doi.org/10.1249/MSS.0000000000002746

Jaakkola, T., Yli-Piipari, S., Stodden, D. F., Huhtiniemi, M., Salin, K., Seppälä, S., … Gråstén, A. (2020). Identifying childhood movement profiles and tracking physical activity and sedentary time across 1 year. *Translational Sports Medicine*, 3(5), 480–487. https://doi.org/10.1002/tsm2.156

Janssen, X., Basterfield, L., Parkinson, K. N., Pearce, M. S., Reilly, J. K., Adamson, A. J., & Reilly, J. J. (2019). Non-linear longitudinal associations between moderate-to-vigorous physical activity and adiposity across the adiposity distribution during childhood and adolescence: Gateshead Millennium Study. *International Journal of Obesity*, 43(4), 744-750. https://doi.org/10.1038/s41366-018-0188-9

Jones, R. A., Okely, A. D., Caputi, P., & Cliff, D. P. (2010). Perceived and actual competence among overweight and non-overweight children. *Journal of Science and Medicine in Sport*, 13(6), 589–596. https://doi.org/10.1016/j.jsams.2010.04.002

Kiphard, E. J., & Schilling, F. (2007). Körperkoordinationstest für Kinder 2, überarbeitete und ergänzte Aufgabe. Weinham: Beltz Test.

Kolunsarka, I., Gråsten, A., Huhtiniemi, M., & Jaakkola, T. (2021). Development of Children's Actual and Perceived Motor Competence, Cardiorespiratory Fitness, Physical Activity, and

BMI. *Medicine and Science in Sports and Exercise*, *53*(12), 2653–2660. https://doi.org/10.1249/MSS.0000000000002749

Gråstén, A. (2014). Students' Physical Activity, Physical Education Enjoyment, and Motivational Determinants through a Three-Year School- Initiated Program. *Studies in Sport, Physical Education, and Health 205: University of Jyväskylä.*

Leger, L. A., & Lambert, J. (1982). A Maximal.Multistage 20-m Shuttle Run Test to Predict VO2 max*. *European Journal of Applied Physiology and Occupational Physiology*, 49(1), 1-12.

Lounassalo, I., Salin, K., Kankaanpää, A., Hirvensalo, M., Palomäki, S., Tolvanen, A., …. Tammelin, T. H. (2019). Distinct trajectories of physical activity and related factors during the life course in the general population: a systematic review. *BMC Public Health*, 19(1), 271. https://doi.org/10.1186/s12889-019-6513-y

Mahumud, R. A., Sahle, B. W., Owusu-Addo, E., Chen, W., Morton, R. L., & Renzaho, A. M. N. (2021). Association of dietary intake, physical activity, and sedentary behaviours with overweight and obesity among 282,213 adolescents in 89 low and middle income to high-income countries. *International Journal of Obesity,* 45. 2404-2418. https://doi.org/10.1038/s41366-021-00908-0

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed). Champaign, IL: Human Kinetics.

Meester, D., Barnett, L. M., Brian, A., Bowe, S. J., Jimenez-Diaz, J., Van Duyse , F., … Haerens, L. (2020). The Relationship Between Actual and Perceived Motor Competence in Children, Adolescents and Young Adults: A Systematic Review and Meta-analysis. *Sports Medicine*, *50*(11), 2001–2049. https://doi.org/10.1007/s40279-020-01336-2

Moliner-Urdiales, D., Ruiz, J. R., Vicente-Rodriguez, G., Ortega, F. B., Rey-Lopez, J. P., Espana-Romero, V., … Moreno, L. A. (2011). Associations of muscular and cardiorespiratory fitness with total and central body fat in adolescents: The HELENA Study. *British Journal of Sports Medicine*, 45(2), 101-108. http://dx.doi.org/10.1136/bjsm.2009.062430

Nuttall F. (2015). Body Mass Index: Obesity, BMI, and Health: A Critical Review. *Nutrition today,* 50(3):117-128. https://doi.org/10.1097/NT.0000000000000092

NCD Risk Factor Collaboration (NCD-RisC). (2020). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *The Lancet Child and Adolescent Health*, 4, 2627-2642. https://doi.org/10.1016/S0140-6736(17)32129-3

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *Structural Equation Modeling*, 14(4), 535–569. https://doi.org/10.1080/10705510701575396

Oluwagbemigun, K., Buyken, A. E., Alexy, U., Schmid, M., Herder, C., & Nöthlings, U. (2019). Developmental trajectories of body mass index from childhood into late adolescence and subsequent late adolescence–young adulthood cardiometabolic risk markers. *Cardiovascular Diabetology*, 18(1). https://doi.org/10.1186/s12933-019-0813-5

Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, 41, 71–90. https://doi.org/10.1016/j.dr.2016.06.004

Raghuveer, G., Hartz, J., Lubans, D., Takken, T., Wiltz, J., Mietus-Snyder, M., Perak, A., … Edwards, N. (2020). Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement From the American Heart Association. *Circulation, 142*(7), e101–e118. https://doi.org/10.1161/CIR.0000000000000866

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor Competence and its Effect on Positive Developmental Trajectories of Health. *Sports Medicine*, 45(9), 1273–1284. https://doi.org/10.1007/s40279-015-0351-6

Singh, A. S., Mulder, C., Twisk, J. W. R., van Mechelen, W., & Chinapaw, M. J. M. (2008). Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obesity Reviews*, 9(5), 474–488. https://doi.org/10.1111/j.1467-789X.2008.00475.x

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. *Quest*, 60(2), 290–306. https://doi.org/10.1080/00336297.2008.10483582

Tomkinson, G. R., Lang, J. J., Blanchard, J., Léger, L. A., & Tremblay MS. (2019). The 20-m Shuttle Run: Assessment and Interpretation of Data in Relation to Youth Aerobic Fitness and Health. *Pediatric Exercise Science*, 31(2), 152-163. https://doi.org/10.1123/pes.2018-0179

True, L., Martin, E. M., Pfeiffer, K. A., Siegel, S. R., Branta, C. F., Haubenstricker, J., & Seefeldt, V. (2021). Tracking of Physical Fitness Components from Childhood to Adolescence: A Longitudinal Study. *Measurement in Physical Education and Exercise Science*, 25(1), 22–34. https://doi.org/10.1080/1091367X.2020.1729767

Webster, E. K., Sur, I., Stevens, A., & Robinson, L. E. (2021). Associations between body composition and fundamental motor skill competency in children. *BMC Pediatrics*, 21(1), 444. https://doi.org/10.1186/s12887-021-02912-9