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2 and Weight Status in Schoolchildren: Latent Profile and Transition Analyses

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4

5 **Abstract**

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

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

21 **Introduction**

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

30 The conceptual model of Stodden et al. (2008) titled “A Developmental Perspective on the
31 Role of Motor Skill Competence in Physical Activity” has been widely used to explain physical
32 activity and weight development from childhood to adolescence (Robinson et al., 2015). It
33 postulates motor competence (i.e., fundamental movement skills: locomotor, object control,
34 and stability skills) (Goodway, Ozmun & Gallahue, 2021) as a driver of physical activity, and
35 (self-)perceived motor competence (De Meester et al., 2020) and health-related fitness (i.e.,
36 cardiorespiratory fitness and muscular fitness) (Bouchard & Shephard, 1994) as mediators
37 between actual motor competence and physical activity engagement. According to the model,
38 reciprocal and dynamic relationships between these variables form either a positive spiral of
39 engagement or negative spiral of disengagement that directs the development of body weight
40 over time in childhood and adolescence. The model suggests that children with high actual and
41 perceived motor competence and high health-related fitness can continue physical activity
42 engagement for longer periods, which in turn gives them more possibilities for the further
43 development of motor competence. Thus, they have the skills and confidence to be physically
44 active, and thus enhanced possibilities to maintain a healthy weight status. In contrast, low
45 actual and perceived motor competence and low health-related fitness may have the opposite

46 outcomes. This in turn may lead to an unhealthy weight status, further straining the
47 aforementioned variables (Stodden et al., 2008). The hypothetical theoretical relationships
48 between the variables in the model have been demonstrated in many studies (Robinson et al.,
49 2015). Overweight/obesity has consistently been associated with poor actual motor
50 competence (Barnett et al., 2021), low cardiorespiratory fitness (Kolunsarka et al., 2021), low
51 perceived motor competence (Jones et al, 2010) and low physical activity engagement (Janssen
52 et al., 2019). However, a recent systematic review by Barnett et al. (2021) called for
53 longitudinal studies across childhood and into adolescence that include all the variables
54 presented in the conceptual model by Stodden et al. (2008), including multiple time points and
55 controlling for potential confounding factors.

56 Research has shown that children present markedly different developmental trajectories of
57 actual motor competence (Coppens et al., 2019), physical activity behavior (Lounassalo et al.,
58 2019), cardiorespiratory fitness (Raghuv eer al., 2020), and body weight status
59 (Oluwagbemigun et al., 2019) over time. This is one reason why studies utilizing sophisticated
60 person-oriented statistical methods are needed. Unlike traditional variable-oriented methods,
61 person-oriented methods (e.g., latent profile analysis) use latent variables and enable the
62 description of population heterogeneity for example in individuals' developmental differences
63 (Ferguson, Moore & Hull, 2020). Another advantage of using person-oriented statistical
64 methods, when investigating a whole theoretical model such as that of Stodden et al. (2008), is
65 that they allow longitudinal analysis of hypothesized dynamic and synergistic relationships
66 between variables. To date, only a few longitudinal studies have used person-oriented
67 methodologies including latent variables. Jaakkola et al. (2020; 2021) and Estevan et al. (2021),
68 for example, found that children with high actual and perceived motor competence and high
69 physical fitness displayed higher levels of physical activity and were more likely than other
70 children to have a healthy weight status in childhood. Furthermore, Jaakkola et al. (2020)

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

77 However, this one is the first study of children to apply latent profile analysis (LPA) utilizing
78 all the variables in the model of Stodden et al. (2008) and, further, to use latent transition
79 analysis (LTA) to examine to what extent children transition between the identified profiles
80 from late childhood to adolescence. Moreover, this study includes sex as a covariate, because
81 previous studies have shown gender differences in object control (Barnett et al., 2010) and
82 cardiorespiratory fitness (Raghuveer et al., 2020), in which boys outperform girls. Thus, the
83 aim of this study was to extend our understanding of the conceptual model of Stodden et al.
84 (2008) using all the variables and implementing a longitudinal design with original collected
85 data. The research questions were: 1) Can qualitatively distinct subgroups of children based on
86 cardiorespiratory fitness, motor competence, perceived motor competence, physical activity,
87 and weight status be identified? 2) Do these profiles remain stable over time?

88 **Materials and methods**

89 *Participants and procedure*

90 This three-year follow-up study was conducted in Finland during 2017-2020. Participants were
91 recruited from 35 randomly selected elementary schools in four municipalities. All 5th graders
92 were given the opportunity to participate, and a total of 1 162 (girls = 583, boys = 564, Mage
93 = 11.27 ± 0.32 years) volunteered. These children accounted for 2 % of the Finnish population
94 of that age, and all samples were representative of their local population. Data on actual motor

95 competence, cardiovascular fitness, and anthropometric measurements (height and weight)
96 were collected annually between August and October over four consecutive years (T0-T3) by
97 trained researchers during physical education classes. The questionnaire on perceived motor
98 competence was administered in the classroom setting. Accelerometers were used to collect
99 device-based moderate-to-vigorous physical activity (MVPA). Participants were instructed to
100 wear accelerometers for one week during the annual data collection periods (T0-T3). Verbal
101 consents were obtained from the participating children and informed written consents from
102 their guardian prior to the start of the study. The study was approved by the human research
103 ethics committee of the local university.

104 *Measurements*

105 *Actual motor competence.* Actual motor competence was measured using three skill tests
106 including object control and locomotor skills. The throw-catch test (Jaakkola et al., 2012) was
107 used to assess participants' object control skills. A target square (1.5 x 1.5 meters) was marked
108 on a wall at 90 centimeters above floor level. Throwing distance depended on the participant's
109 grade and sex and ranged from 7 to 10 meters. Participants were instructed to throw a tennis
110 ball with their desired hand directly at the target and to catch the ball after one bounce back
111 from the floor with one or both hands. Participants were allowed 20 trials and the result was
112 the number of successfully completed trials (i.e., the ball hit the target and was caught after one
113 bounce back from the floor). This test is widely used in Finnish sport science studies (Jaakkola
114 et al., 2021) and has shown acceptable test-retest reliability (ICC = .692, $p < .001$) in children
115 and adolescents (Jaakkola et al., 2012). Locomotor skills were assessed by the 5-leap test
116 (Jaakkola et al., 2012) and two-legged side-to-side jump test (Kiphard & Schilling, 2007). The
117 5-leap test consists of five consecutive strides with feet together at the start and end of the five
118 leaps. Participants were allowed to start the strides with their desired leg. The test was
119 performed twice, and the better result (i.e., the overall distance covered in meters rounded to

120 two decimals) was recorded. In the two-legged side-to-side jump, the participant jumped from
121 side-to side over a low wooden beam with legs in parallel continuously for 15 seconds as fast
122 as possible. The test is performed twice, and the result is the sum of the number of successful
123 jumps in each trial.

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

133 *Cardiorespiratory fitness.* The 20-meter shuttle run test (Leger & Lambert, 1982) was
134 used to assess participants' cardiorespiratory fitness. A 20-meter track was marked on the floor
135 by two parallel lines and the running pace for each 20-meter shuttle was determined by the
136 frequency of recorded beeps. Participants were instructed to run continuously up and down the
137 20-meter track in time to the beeps. The initial running velocity was 8.5 km/h for the first
138 minute, after which it increased by 0.5 km/h for each successive minute. When participants
139 were no longer able to keep pace with the beeps, they were instructed to terminate the test. The
140 result was the number of completed shuttles.

141 *Weight status.* Participants' body mass index (BMI) was calculated using a weight (kg)
142 and height (m) formula (kg/m^2). Body weight was measured to the nearest 0.1 kg using
143 calibrated scales (Point Electronic Personal Scale), with the children wearing light clothing and
144 barefoot. Height was measured to the nearest 0.1 cm using portable measuring equipment

145 (measuring tape). Extended international body mass index cut-offs values (IOTF) were used to
146 determine participants weight status (thinness, normal weight, overweight, obese) (Cole &
147 Lobstein, 2012).

148 *Device-measured MVPA.* Participants' MVPA was measured using Actigraph
149 wGT3X+ accelerometers. Participants were instructed to wear the device for seven consecutive
150 days on their right hip at all times during their waking hours, except while bathing or doing
151 water-based activities. Data were collected as raw accelerations at a frequency of 30 Hz and
152 converted into 15-s epoch counts. Customized Visual Basic Macro for Excel software was used
153 for data reduction. A valid day of physical activity monitoring included measured values ≥ 500
154 min/day for at least two weekdays and one weekend day between general waking hours (i.e.,
155 7:00-23:00). Periods of 30 min of consecutive zero counts were defined as non-wear time, and
156 values over 20 000 counts per minute (cpm) were considered spurious accelerations and
157 discarded (Heil, Brage & Rothney, 2012). Cut points (Evenson et al., 2008) were used to
158 calculate MVPA (≥ 2296 cpm).

159 *Data analysis*

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

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

183 In Step 2-4, the LTA, which is a longitudinal extension of the LPA method, was used to
184 examine the stability of the profiles and the probabilities of changes in profiles over time. In
185 Step 2, structural differences between the profiles at different time points were tested. Thus, to
186 explore if the profile indicators provided an unbiased reflection of the same construct across
187 time, longitudinal measurement invariance was tested by comparing the measurement
188 invariance model (equal indicator means) with the measurement variance model (freely
189 estimated profile indicator means). The Chi square (χ^2) -test was conducted using the
190 maximum likelihood estimator (MLR) with Satorra-Bentler scaling correction to evaluate the
191 two models. In Step 3, the most reasonable solution was chosen for further analyses (i.e., if the
192 models differed significantly, the measurement variance model was chosen) and the latent
193 statuses were defined. In Step 4, the transition probability invariance was explored by fixing

194 the transition probabilities to be equal over time and by comparing it to the freely estimated
195 model. Finally, in Step 5, the covariate sex was added to the selected model. Results were
196 considered statistically significant at the $p < .05$ level. Latent profile and latent transition
197 analyses were performed by using Mplus version 8.2 and descriptive statistics, anova with post
198 hoc and the missing completely at random (MCAR) test by using SPSS 22.0.

199 **Results**

200 *Preliminary analysis*

201 Tests of normality demonstrated that the data were approximately normally distributed ($p >$
202 $.05$) and based on the standardized values (± 3.00) the data was free of outliers. As it was not
203 possible to provide all the participants with accelerometers and the proportions of students
204 completing all the measurements were lower at the later time points, missing values (9 651 out
205 of 33 698) accounted for 28 % of the data. The Missing Completely at Random (MCAR) test
206 indicated that the missing values ($\chi^2(9051) = 8494, p < .001$) were missing at random (MAR).
207 Moreover, a closer examination of the data matrix revealed that the missing values did not
208 represent any specific group or school. Consequently, the missing values were not imputed but
209 were estimated through the mixture likelihood procedure, which has been shown to produce
210 reliable parameter estimates and standard errors under MAR conditions (Hunt & Jorgensen,
211 2003).

212 *Descriptive statistics*

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

218 BMI 18.88 ± 3.12 kg/m². At baseline (T0) 4.4 % of the participants were thin, 73.2 % normal
219 weight, 18.5 % overweight and 3.7 % obese. The Cronbach's alphas for the perceived
220 competence scale were relatively high at each time point (T0 = .87, T1 = .90, T2 = .89, T3 =
221 .89).

222 *Latent profile analysis (Step 1)*

223 Students were clustered into homogeneous profiles at each time point (T0-T3) based on actual
224 motor competence, perceived motor competence, cardiorespiratory fitness, weight status, and
225 MVPA. Statistical indices (AIC, BIC, aBIC, ALMR-LTR and entropy) showed that the three-
226 profile model was the most reasonable at T0, T1 and T3. At each of these time points, the three-
227 profile model produced more optimal statistical indicators than two-profile model, whereas
228 four-profile model did not fit the data any better than three-profile model ($p > .05$). In addition,
229 the three-profile models did not include classes containing less than 5 % of participants. At T2,
230 the four-profile model indicated the best statistical fit but one of the classes contained less than
231 5 % of the participants, and therefore, the three-profile model was selected (Table 2). The
232 selected 3-3-3-3-model comprised three latent profiles at each time-point (T0-T3).

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

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

242 *Definition of latent statuses (Step 3)*

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

262 *Latent status and transition probability invariance tests (Step 4)*

263 The transition probability invariance result indicated that the model with transition
264 probabilities fixed to be equal over time and the freely estimated model differed from each
265 other. This result was expected given the large number of parameters and the developmental
266 changes occurring over time in childhood (Putnick & Bornstein, 2016). As the freely estimated

267 model allows for variation, it was chosen for further use. Thus, the results are based on a non-
268 invariance model (i.e., the freely estimated model). Examination of the transition probabilities
269 revealed that transition patterns were stable over time, indicating that participants remained in
270 the clusters identified during the first measurement phase (Table 4).

271 *Covariate effect of sex (Step 5)*

272 To determine covariate effects of sex on status prevalence at T0-T3, sex was added to the 3-3-
273 3-3 model as a covariate with free transition probabilities (Table 5). In a multinomial model,
274 the analysis does not provide regression coefficients for the reference group. Significant
275 covariate effects of sex on status prevalence were found for the memberships of the OW-
276 OB/MOVE- and NW/MOVE- profile at T0 and NW/MOVE- profile at T2. The odds ratios
277 indicated that girls were mostly likely to be in the NW/MOVE- profile at T0 and least likely to
278 be in NW/MOVE+. At T2 girls were more likely to be in NW/MOVE- profile than in two
279 others. There was no sample variance of sex at T1, indicating that girls and boys had an
280 identical likelihood for cluster membership at T1, and thus sex effects were restricted.

281 **Discussion**

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

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

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

301 The participants in OW-OB/MOVE- and NW/MOVE- profiles had similar, although somewhat
302 lower perceived motor competence and levels of MVPA, compared to their peers in the
303 NW/MOVE+ profile. In addition, the participants in the OW-OB/MOVE- profile showed
304 lower cardiorespiratory fitness and locomotor competence than those in the NW/MOVE-
305 profile, but higher object control competence in T0, T1 and T3. As observed in previous studies
306 (Moliner-Urdiales et al., 2011), children with overweight have a lower cardiorespiratory fitness
307 than children with normal weight. Excessive body weight and/or fat mass increases the
308 workload in the 20-meter shuttle run, which adversely affects test performance (Tomkinson et
309 al., 2019). The participants in the OW-OB/MOVE- profile also showed significantly lower
310 locomotor competence scores. However, poor performance in locomotor tasks such as
311 jumping, and leaping may have less to do with motor coordination and more to do with the
312 morphological limitations of overweight and obesity in transporting the body through space,
313 and especially against gravity (Chivers et al., 2013; Webster et al., 2021). Overall, excess
314 weight affects weight-bearing motor tasks, such as running and locomotion (Webster et al.,
315 2021). In contrast, the children in the OW-OB/MOVE- profile showed significantly higher

316 values for object control skills at the three time-points (T0, T1, T3) than their peers in the
317 NW/MOVE- profile. This outcome contrasts somewhat with the findings of previous studies
318 (D'Hondt et al., 2009; Gentier et al., 2013) comparing object control skills across different
319 weight statuses, as they have concluded that children with obesity have lower scores in object
320 control skills compared to their normal weight peers. However, D'Hondt et al. (2009)
321 concluded that no differences in object control or motor skills in general were found between
322 children with normal weight and overweight and thus suggested there may be certain cut-off
323 from which movement difficulties appear. Also, previous studies have treated normal weight
324 group as one homogeneous group (D'Hondt et al., 2009; Gentier et al., 2013), whereas this
325 study showed that children with normal weight also have various levels of object control skills.
326 Thus, children with normal weight may also have impaired object control competence, which
327 may prevent them from being physically active in the future, as object control competence has
328 been shown to be more strongly associated with physical activity levels than locomotor
329 competence (Barnett et al., 2011). Moreover, according to Stodden et al. (2008), children in
330 both the NW/MOVE- and OW-OB/MOVE- profiles may, owing to their low motor
331 competence, be at higher risk for low engagement in physical activity, which in turn may lead
332 to unhealthy weight development in the future.

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

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

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

354 The strengths of this study were the large number of participants, a longitudinal design with
355 annual follow-ups, and the person-oriented statistical analyses. Moreover, the profile analyses
356 included all the variables presented in the model of Stodden et al. (2008) and thereby providing
357 further information on the model. However, the study has its limitations. Device-measured
358 MVPA may be underestimated because water-based activities could not be recorded. While
359 BMI is a widely used measure in tracking changes in adiposity, it is not unproblematic with
360 children and adolescents due to maturational growth and its inability to differentiate muscle
361 mass from fat (Nuttall, 2015). Also, the lack of maturation measurements is a notable limitation
362 of this study, as maturation is characterized by several physiological and psychological changes
363 that may over time influence an individual's BMI, actual motor competence, perceived motor
364 competence and cardiorespiratory fitness developmental trajectories (Malina, Bouchard & Bar-
365 Or, 2004). Perceived motor competence was assessed with the sport competence dimension of

366 the Physical Self-Perception Profile (PSPP) by Fox & Corbin (1989), which is rather a measure
367 of perceived sport/athletic competence than perceived motor competence. Therefore, caution
368 should be exercised when comparing studies using different instruments to assess perceived
369 motor competence (Estevan & Barnett, 2018).

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

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388 **Declaration of interest statement**

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

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