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Associations of age, body size, and maturation with physical activity intensity in different laboratory tasks in children

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25 **ABSTRACT**

26 We investigated the associations of age, sex, body size, body composition, and maturity with
27 measures of physical activity (PA) intensity in children. PA intensity was assessed using $\dot{V}O_2$
28 as % of $\dot{V}O_{2\text{reserve}}$ or $\dot{V}O_2$ at ventilatory threshold (VT), muscle activity measured by textile
29 electromyography, mean amplitude deviation (MAD) measured by accelerometry, and
30 metabolic equivalent of task (MET) during laboratory activities. Age, stature, and skeletal
31 muscle mass were inversely associated with $\dot{V}O_2$ as % of $\dot{V}O_{2\text{reserve}}$ and $\dot{V}O_2$ as % of $\dot{V}O_2$ at
32 VT, during walking or running on a treadmill for 4, 6, and 8 km/h (Spearman $r=-0.645$ to -
33 0.358 , $p<0.05$). Age was inversely associated with MAD during walking on treadmill for 4
34 km/h ($r=-0.541$, $p<0.05$) and positively associated with MAD during running on a treadmill
35 for 8 km/h, playing hopscotch, and during self-paced running ($r=0.368$ to 0.478 , $p<0.05$). Fat
36 mass was positively associated with $\dot{V}O_2$ as % of $\dot{V}O_{2\text{reserve}}$ and $\dot{V}O_2$ as % of $\dot{V}O_2$ at VT and
37 waist circumference was positively associated with $\dot{V}O_2$ as a % of $\dot{V}O_{2\text{reserve}}$ and muscle
38 activity during stair climbing ($r=0.416$ to 0.519 , $p<0.05$). Fixed accelerometry cut-offs used
39 to define PA intensities should be adjusted for age, sex, body size, and body composition.

40

41 **Key words:** child; physical activity; accelerometry; electromyography; body composition

42 **Disclosure statement:** No potential conflict of interest was reported by the authors.

43 **Data availability statement:** The datasets generated during and/or analysed during the
44 current study are available from the corresponding author on reasonable request.

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50 INTRODUCTION

51 Accelerometry has become the preferred device-based method to assess volume and intensity
52 of habitual physical activity (PA) ¹. Higher levels of moderate-to-vigorous intensity physical
53 activity (MVPA) and vigorous PA (VPA) assessed by accelerometry have been consistently
54 associated with lower levels of adiposity, cardiometabolic risk, arterial stiffness, and higher
55 cardiorespiratory fitness in children and adolescents ^{1,2}.

56

57 Cut-offs defining light PA, moderate PA, and vigorous PA in children and adolescents have
58 been created using specific calibration activities ³⁻⁵. These calibration activities have been
59 used to investigate the point of acceleration magnitude separating e.g. slow walking as light
60 PA from brisk walking and climbing up and down the stairs as moderate PA ³⁻⁵. Although
61 some of these calibration studies have measured oxygen uptake ($\dot{V}O_2$) during the calibration
62 activities, PA intensity cut-offs have been mainly created using subjective criteria based on
63 calibration activities rather than physiological responses ³⁻⁵. Furthermore, converting
64 accelerometry metrics to metabolic equivalents of tasks (METs) and utilising commonly used
65 MET-based cut-offs for PA intensities have been suggested to improve comparability
66 between studies ⁶. However, physiological rationale for the usage of METs in the assessment
67 of PA intensity is lacking ⁷ and fixed MET-based cut-offs have been found to underestimate
68 PA intensity and volume in unfit and obese adults⁸ and to misclassify PA intensity in children
69 ⁹.

70

71 Growth and maturation are dominant biological processes during childhood and adolescence
72 characterised by increased body size, sexually dimorphic changes in body composition, and
73 morphological and functional changes in cardiorespiratory, neuromuscular, and metabolic
74 systems ^{10,11}. Exercise capacity also increases with increasing age and advancing maturity ¹⁰.

75 Nevertheless, none of the previous calibration studies have taken body size, maturation, or
76 body composition into account in the proposed cut-offs^{3-5,12}. Furthermore, previous large
77 scale PA studies in paediatric populations have used the same fixed accelerometry cut-offs
78 for the assessment of PA intensity for children and adolescents with age of the participants
79 varying from 3 to 18 years¹³⁻¹⁷. However, because of growth and maturation and
80 accompanying changes in locomotor economy^{18,19}, using the same cut-offs in children and
81 adolescent with different ages, body sizes, and body compositions may lead to large errors in
82 the estimation of PA prevalence and the associations of PA with health and wellbeing.
83 Nevertheless, some evidence also suggests that the same accelerometer cut-offs could be
84 applied for adolescents and adults²⁰. Furthermore, some studies suggest that muscle activity
85 measured by electromyography (EMG) could provide a direct and useful measure of PA
86 intensity in children²¹, but the knowledge on the associations of age, sex, body size, body
87 composition, and maturity with muscle activity in different PA intensity calibration activities
88 is limited. Therefore, research on the role of age, growth, and maturation on the PA intensity
89 during the calibration activities is warranted.

90

91 Available and commonly used acceleration magnitude cut-offs utilised to define PA intensity
92 in children and youth^{3-5,12} are based on several different methods and calibration tasks.
93 However, these fixed PA intensity cut-offs provide absolute values which are used to define
94 light PA, moderate PA, and vigorous PA in children and adolescents without consideration
95 whether proposed PA intensity cut-offs describe the same intensity among children with
96 different body sizes and body compositions or among different age- and maturation groups.
97 Therefore, we investigated the associations of age, sex, body size, body composition,
98 estimated years from the peak height velocity (YPHV), and pubertal status with acceleration
99 magnitude and MET-based PA intensity in children. We further investigated whether age,

100 sex, body size, body composition, estimated years from the peak height velocity (YPHV),
101 and pubertal status were associated with individualised measures of PA intensity defined
102 using $\dot{V}O_{2\text{reserve}}$, ventilatory threshold (VT), and muscle activity.

103

104 **METHODS**

105 **Participants**

106 This study was based on the laboratory phase of the Children's Physical Activity Spectrum
107 (CHIPASE) study²². A total of 35 children (21 girls, 14 boys) aged 7–11 years were recruited
108 from local schools by leaflets and word of mouth advertisement to participate in the study.
109 Volunteering children were accepted into to the study sample in the order of enrolment. The
110 applicability of the children was checked by the research staff and children were included if
111 they were apparently healthy and were able to perform the physical activities at moderate and
112 vigorous intensities. Children with chronic conditions or disabilities were excluded from the
113 study. The number of participants in the current data analyses varied from 27 to 35
114 participants with acceptable data quality. Most missing data was from the activity where the
115 participants were asked to run around an indoor track at self-paced speed (27 participants
116 with acceptable METs data). The study protocol was approved by the Ethics Committee of
117 the University of Jyväskylä. All children gave their assent and their parents/caregivers gave
118 their written informed consents. The study was conducted in agreement with the Declaration
119 of Helsinki.

120

121 Based on the main research question of the CHIPASE Study, a sample size of 30 was
122 estimated to provide sufficient statistical power for differentiating METs between sitting
123 (1.33 ± 0.24) and standing (1.59 ± 0.37) based on the data of Mansoubi et al.²³ with 80%
124 power and 5% α -error level.

125

126

127 Study protocol

128 The participants visited the laboratory on three occasions. At the first visit, research staff
129 explained the research protocol to children and their parents. They were also familiarised to
130 the laboratory environment and measurement equipment. At the second visit, children arrived
131 at the laboratory in the morning after 10-12 hour overnight fast for assessment of
132 anthropometrics, body composition, and resting $\dot{V}O_2$. At the third visit, children were asked
133 to perform following activities for 4.5 minutes in a random order interspersed with 1-minute
134 rest: sitting quietly, sitting while playing a mobile game, standing quietly, standing while
135 playing a mobile game, playing hopscotch, walking up and down the stairs, and walking or
136 running on a treadmill at 4, 6, and 8km/h. They were also asked to walk and run around an
137 indoor track at self-chosen speed for 4.5 minutes. At the end of the third visit, children
138 performed maximal cardiopulmonary exercise test on a bicycle ergometer.

139

140 Assessments*141 Body size and body composition*

142 Stature was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body mass
143 (BM), skeletal muscle mass (SMM), fat mass (FM), fat free mass, and body fat percentage
144 were measured by InBody 770 bioelectrical impedance device (Biospace Ltd., Seoul, Korea).
145 Body mass index (BMI) was calculated by dividing body weight with body height squared
146 and body mass index standard deviation score (BMI-SDS) was computed using the Finnish
147 references ²⁴. Waist circumference (WC) was measured to the nearest 0.1 cm using a
148 unstretchable measuring tape at mid-distance between the top of the iliac crest and the bottom

149 of the rib cage. Hip circumference (HC) was measured at the widest circumference over the
150 great trochanter.

151

152 *Years from peak height velocity and pubertal status*

153 Years from peak height velocity and pubertal status (YPHV) was estimated using a sex-
154 specific formula described by Mirwald et al. ²⁵. Pubertal status was assessed according to
155 self-reported genital development in boys and breast development in girls on the basis of the
156 five-stage criteria described by Tanner ²⁶. We defined those at Stage I as pre-pubertal and
157 those at Stage II as those who had entered puberty.

158

159 *Oxygen uptake*

160 Mobile metabolic cart (Oxycon mobile, CareFusion Corp, USA) was calibrated and dead
161 space was adjusted to 78 mL for the petite size of the face mask following the manufacturer's
162 recommendations. $\dot{V}O_2$, carbon dioxide production ($\dot{V}CO_2$) and respiratory exchange ratio
163 (RER) were collected breath by breath and computed in non-overlapping 1 second epoch
164 lengths. Resting $\dot{V}O_2$ was determined as the mean value between the 15th and 25th minute of
165 30 minutes of supine rest when the steady state was reached. When steady state was not
166 observed between 15th and 25th minute, the steady state was visually selected for further
167 analysis. In physical activities, $\dot{V}O_2$ was averaged over 2 minutes from the 3rd and 4th
168 minutes of each task when plateau in $\dot{V}O_2$ and $\dot{V}CO_2$ was observed ²². $\dot{V}O_2$ reserve as a
169 percentage of $\dot{V}O_{2peak}$ during different physical activities was calculated as ($\dot{V}O_2$ during PA
170 task / ($\dot{V}O_{2peak}$ - $\dot{V}O_2$ during rest)) x 100. $\dot{V}O_2$ at VT was determined individually by two
171 exercise physiologists using modified V-slope method and any disagreements were solved by
172 these two exercise physiologists. $\dot{V}O_2$ at VT was verified utilising the equivalents for $\dot{V}_E /$
173 $\dot{V}CO_2$ and $\dot{V}_E / \dot{V}O_2$.

174

175 *Accelerometry*

176 Movement was measured by triaxial accelerometer (X6-1a, Gulf Coast Data Concepts Inc.,
177 Waveland, USA). We used raw acceleration data in actual g-units, with range up to 6g, 16-bit
178 A/D conversion, and sampling at 40 Hz. The resultant acceleration of the triaxial
179 accelerometer signal was calculated from $\sqrt{x^2 + y^2 + z^2}$, where x, y and z are the
180 measurement sample of the raw acceleration signal in x-, y-, and z-directions. The X6-1a
181 accelerometer has been shown to produce congruent results with the ActiGraph GT3X
182 accelerometer in children²⁷. Mean amplitude deviation (MAD) was calculated from the
183 resultant acceleration in non-overlapping 1 s epoch. MAD was calculated as the mean
184 distance of data points about the mean ($\frac{1}{n} \sum_{i=1}^n |r_i - \bar{r}|$ where n is the number of samples in
185 the epoch, r_i is the i^{th} resultant sample within the epoch and \bar{r} is the mean resultant value of the
186 epoch)^{20,28}. The mean of the 1 s MAD values (g) calculated in 2 minute epochs for each
187 activity and in 10 minute epoch for lying down are reported as the outcomes.

188

189 *Textile electromyography*

190 Textile EMG electrodes embedded into elastic garments were used to assess muscle activity
191 from the quadriceps and the hamstring muscles and has been described in detail previously²².
192 Four different sizes of EMG shorts (120, 130, 140, and 150 cm) with zippers located at the
193 inner sides of short legs and adhesive elastic band in the hem ensured proper fit in every
194 child. The conductive area of the electrodes over the muscle bellies of the left and the right
195 quadriceps was $9 \times 2 \text{ cm}^2$ (length \times width) in all short sizes, while the corresponding sizes for
196 the hamstring muscles were $6 \times 2 \text{ cm}^2$ in sizes of 120, 130, and 140 cm and $6.5 \times 2 \text{ cm}^2$ in
197 size of 150 cm. The conductive area of the reference electrodes was $11 \times 2 \text{ cm}^2$, and they
198 were located longitudinally over the iliotibial band. Water or electrode gel (Parker

199 Laboratories Inc., Fairfield, NJ, USA) was used on the electrode surfaces to minimize the
200 skin-electrode impedance.

201

202 In the signal analysis, EMG data were identified from different activities in the certain time
203 windows simultaneously according to the steady state in respiratory gases. Individual EMG
204 activities were normalised channel by channel to EMG amplitude measured during self-paced
205 walking. The normalised EMG data were averaged for quadriceps from right and left side and
206 hamstring muscles from right and left side, then the mean amplitude of the average
207 normalised data was computed as the intensity of muscle activity level for each activity.

208

209 **Statistical methods**

210 Basic characteristics between girls and boys were compared using Student's t-test for
211 normally distributed continuous variables and Mann-Whitney U-test for skewed continuous
212 variables and χ^2 - test for categorical variables. We investigated the correlations of age,
213 stature, weight, BMI, BMI-SDS, FM, SMM, YPHV, and pubertal status to $\dot{V}O_2$ as a % of
214 $\dot{V}O_{2\text{reserve}}$, $\dot{V}O_2$ as a % of $\dot{V}O_2$ at VT, MAD, METs, and muscle activity during different
215 activities using Spearman correlation coefficients. Differences in $\dot{V}O_2$ as a % of $\dot{V}O_2$
216 reserve, $\dot{V}O_2$ as a % of $\dot{V}O_2$ at VT, MAD, METs, and muscle activity between girls and boys
217 and between prepubertal and those who had entered clinical puberty were investigated using
218 Kruskal-Wallis test. Student's t-test, the Mann-Whitney U-test, the χ^2 test, and the Kruskal-
219 Wallis tests were performed using the SPSS Statistics, Version 23.0 (IBM Corp., Armonk,
220 NY, USA). The data were visualised and Spearman correlations were performed by the
221 GraphPad Prism, version 8.0.2 (Graph Pad Software, Inc., San Diego, CA, USA). The data
222 were analysed using non-parametric tests because the assumptions to use parametric were not
223 met for some variables. Because of the large number of statistical analyses, we utilised

224 Benjamini–Hochberg false discovery rate (FDR) procedure and Bonferroni correction for multiple
225 testing in the correlation analyses. Correction for multiple testing was performed for each PA
226 intensity indicator. We used false discovery rate of 0.1 in the Benjamini-Hochberg procedure.
227 Furthermore, with the Bonferroni correction the threshold for statistical significance was
228 computed dividing the p -value of 0.05 by the number of variables used in each analysis
229 resulting in the corrected critical value of 0.006.

230

231 **RESULTS**

232 **Basic characteristics and the associations between the measures of age, body size,** 233 **composition, and maturation**

234 Girls were lighter, had lower BMI, and had less FM and SMM than boys (Table 1). Girls
235 were also closer to their estimated PHV than boys (Table 1). Age and the measures of body
236 size and body composition were strongly and positively correlated (Supplementary Table).
237 YPHV was positively correlated to age, stature, SMM, and HC. Children who had entered to
238 puberty were taller (mean=143.9 (SD=8.2) vs. 135.3 (8.9) cm) and heavier (37.1 (6.5) vs.
239 30.7 (6.3) kg), and had more SMM (16.2 (2.4) vs. 13.1 (2.7) kg) than pre-pubertal children
240 (all $p<0.05$).

241

242 **Associations of sex, age, body size, and maturation with physical activity intensity**

243 *Girls vs. boys*

244 Girls operated at higher intensity relative to their $VO_{2\text{reserve}}$ during running on a treadmill for
245 8 km/h and during self-paced walking than boys (Figure 1). Girls had lower muscle activity
246 (i.e. lower EMG signal normalised for EMG signal during self-paced walking) during
247 walking on a treadmill for 6 km/h, walking up and down the stairs, and during playing
248 hopscotch. Girls also had higher MET during running on a treadmill for 8 km/h and during

249 playing hopscotch than boys. However, girls had lower MAD during walking up and down
250 the stairs than boys.

251

252 *Age*

253 Age was inversely associated with $\dot{V}O_2$ as a % of $\dot{V}O_{2\text{reserve}}$ and $\dot{V}O_2$ as a % of $\dot{V}O_2$ at VT,
254 during walking or running on a treadmill for 4, 6, and 8 km/h (Table 2). Age was also
255 inversely associated with MAD during walking on a treadmill for 4 km/h and positively
256 associated with MAD during running on a treadmill for 8 km/h and during self-paced
257 running. The effect of correction for multiple testing using Benjamini-Hochberg FDR and
258 Bonferroni is demonstrated in Table 2.

259

260 *Body size and body composition*

261 Stature and SMM were inversely associated with $\dot{V}O_2$ as a % of $\dot{V}O_{2\text{reserve}}$ and $\dot{V}O_2$ as a % of
262 $\dot{V}O_2$ at VT, during walking or running on a treadmill for 4, 6, and 8 km/h (Table 2).
263 Furthermore, FM was positively associated with $\dot{V}O_2$ as a % of $\dot{V}O_{2\text{reserve}}$ and $\dot{V}O_2$ as a % of
264 $\dot{V}O_2$ at VT and WC with $\dot{V}O_2$ as a % of $\dot{V}O_{2\text{reserve}}$ and muscle activity during climbing up
265 and down the stairs. The effect of correction for multiple testing using Benjamini-Hochberg
266 FDR and Bonferroni is demonstrated in Table 2.

267

268 *Maturity*

269 Children who had entered puberty operated at lower intensity relative to their VT and they
270 had lower MET-values during walking on a treadmill for 4 km/h than their pre-pubertal peers
271 (Figure 2). YPHV was inversely associated with $\dot{V}O_2$ as a % of $\dot{V}O_2$ at VT during walking
272 or running on a treadmill for 4, 6, and 8 km/h and MAD during walking on a treadmill for 4
273 km/h but positively with MAD during running on a treadmill for 8 km/h (Table 2). The effect

274 of correction for multiple testing using Benjamini-Hochberg FDR and Bonferroni is
275 demonstrated in Table 2.

276

277 There were also other but inconsistent associations between the measures of age, maturation,
278 body size, body composition, and the measures of PA intensity (Table 2).

279

280 **DISCUSSION**

281 We found that older children and those who were taller and had more SMM operated at lower
282 PA intensity level relative to their $\dot{V}O_{2\text{reserve}}$ and VT during walking or running on a treadmill
283 for 4, 6, and 8 km/h. We also found that children with higher levels of adiposity operated at
284 higher intensity level relative to their $\dot{V}O_{2\text{reserve}}$ and VT during climbing up and down the
285 stairs than leaner children. Furthermore, boys operated at lower intensity level relative to
286 their $\dot{V}O_{2\text{reserve}}$ during running on a treadmill and self-paced walking than girls, but the sex-
287 differences in METs and muscle activity were heterogenous. The associations of age, body
288 size, and body composition with PA intensity estimated by MAD or METs were inconsistent
289 and weak, suggesting that they were not able to capture physiological PA intensity. Finally,
290 79% and 37% of statistically significant associations remained significant after Benjamini-
291 Hochberg FDR or Bonferroni corrections for multiple testing, respectively. The most robust
292 associations even after corrections for multiple testing were those of stature and SMM with
293 $\dot{V}O_{2\text{reserve}}$ and VT during walking or running on a treadmill for 4, 6, and 8 km/h.

294

295 Previous calibration studies have defined light PA as walking on a treadmill for ~3–4 km/h,
296 MPA as stair climbing and walking on a treadmill for ~5–6 km/h, and VPA as running on a
297 treadmill for ~6.5–8 km/h^{13–15}. We found that older children and those who were taller and
298 had more SMM and who were more mature performed constant speed activities on treadmill

299 at lower physiological intensity level than other children. Nevertheless, we found no marked
300 differences in other more self-paced tasks, such as playing hopscotch and self-paced walking
301 and running, used to assess light PA, moderate PA, or vigorous PA in children. For example,
302 age or stature were not associated with $\dot{V}O_{2\text{reserve}}$ and VT during climbing up and down the
303 stairs, which has been previously considered moderate intensity PA. Reasons for our findings
304 may be that constant treadmill speeds require more effort from younger and smaller children
305 than from older and taller children because of lower required step frequency ¹⁹, better
306 walking and running economy ^{18,29} and ability to store elastic energy ³⁰, and increased
307 cardiorespiratory capacity ³¹ with increasing age and stature. Because climbing up and down
308 the stairs and other activities in our study were performed at a self-paced speed, it is possible
309 that children adapted their effort to fit their fitness level. Nevertheless, we found a positive
310 association between adiposity and PA intensity during climbing up and down the stairs that
311 could be due to excess inert mass that must be carried during climbing up and down the stairs
312 ³².

313

314 We found no consistent associations of age and stature with muscle activity during treadmill
315 activities suggesting that differences in muscle activity during constant speed treadmill
316 walking and running are not a factor of body size or body composition children. These results
317 correspond to our earlier observations that muscle strength is not associated with PA intensity
318 during treadmill walking and running (Haapala et al. unpublished observation). Furthermore,
319 a large interindividual variability in muscle activity in different activities in children ²², may
320 explain our observations. However, we observed that boys, older children, and who were
321 taller, heavier, and had more FM had higher muscle activity during playing hopscotch.
322 Furthermore, children with higher WC and HC had higher muscle activity during climbing up
323 and down the stairs and playing hopscotch. Adults have been found to exhibit larger muscle

324 activity especially during eccentric activities³⁰ and playing hopscotch and climbing up and
325 down the stairs include strong eccentric phases. Therefore, it is possible that the observed
326 associations reflect increased muscle activity in boys and older, taller, and heavier children
327 during eccentric phase.

328

329 Despite significant associations between body size and body composition with $\dot{V}O_{2\text{reserve}}$ and
330 VT, we found inconsistent and mixed associations of body size and composition with PA
331 intensity measured by MAD and METs. Interestingly, we observed higher MAD in older and
332 taller children during running on a treadmill and during self-paced running, although older
333 and taller children had lower $\dot{V}O_{2\text{reserve}}$ and VT during those activities. Therefore, these
334 results suggest that MAD overestimate PA intensity especially in higher intensity activities
335 among older and taller children. However, while the exact reason for these findings is
336 unclear, it is possible that older and taller children modify their walking and running styles
337 between slower and faster treadmill speeds as some previous evidence suggests that there are
338 natural differences in walking and running mechanics between children and adolescents with
339 varying ages³³. Finally, in line with previous studies in adults^{8,34}, METs were not able to
340 differentiate physiological differences in PA intensity in children with different body sizes
341 and compositions.

342

343 The strengths of the present study include a valid and simultaneous assessment of different
344 measures of PA intensity such as $\dot{V}O_2$, muscle activity by EMG, and accelerometry during
345 different activities. The assessment of different PA intensity indicators allowed us to form
346 more complete picture of PA intensity during the activities. We also assessed of $\dot{V}O_{2\text{peak}}$ and
347 VT, body size, and body composition using valid methodology. Nevertheless, we had some
348 missing data due to malfunction of the devices or poor data quality in some tasks which may

349 influence the results. $\dot{V}O_{2\text{peak}}$ and VT were assessed during a maximal cycle ergometer test
350 and $\dot{V}O_{2\text{peak}}$ was adjusted using the data from treadmill running or self-paced running if
351 higher $\dot{V}O_2$ was observed during those tasks. Therefore, it is possible that we have
352 underestimated true $\dot{V}O_{2\text{max}}$ in some participants and this may have had a minor effect on
353 $\dot{V}O_{2\text{reserve}}$ estimation. Furthermore, we estimated APHV and assessed pubertal status using
354 self-reports instead of measuring circulating sex steroids or using clinical examination of
355 secondary sex-characteristics. In addition, the increasing error in the estimation of APHV
356 with increasing time to PHV could have an effect on the estimated maturity status in our
357 sample of relatively young children. Further studies on the effect of maturation on PA
358 intensity utilising more accurate methods, such as skeletal age, in the assessment of maturity
359 are warranted. Because of relatively small sample size, we were not able to study whether age
360 or maturity groups modified the observed associations of body size and composition with PA
361 intensity in different tasks. Finally, the relatively large number of analyses increases the
362 possibility that some statistically significant associations were observed by chance.

363

364 **CONCLUSION**

365 In conclusion, we found inverse association of age, stature, and SMM with PA intensity
366 defined using $\dot{V}O_{2\text{reserve}}$ and VT. However, MADs and METs did not reliably capture these
367 associations and our results suggest that PA intensity estimated by MAD may overestimate
368 PA intensity in older and taller children. Therefore, our results suggest that studies validating
369 accelerometry or muscle activity cut-offs used to define PA intensities should be adjusted for
370 age, sex, body size, and body composition. Further studies on the role of these adjustments of
371 the prevalence of children meeting the PA recommendations are warranted.

372

373

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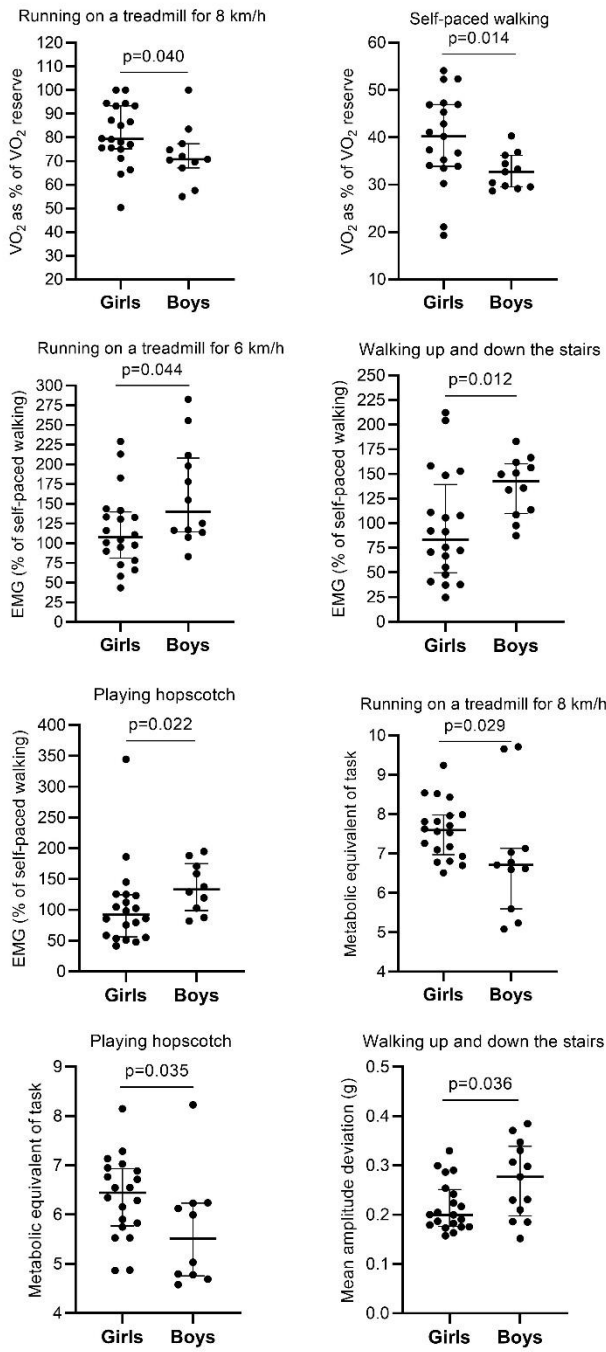
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501 **Figure legends**

502 **Figure 1.** Differences in the measures of physical activity intensity between girls and boys.

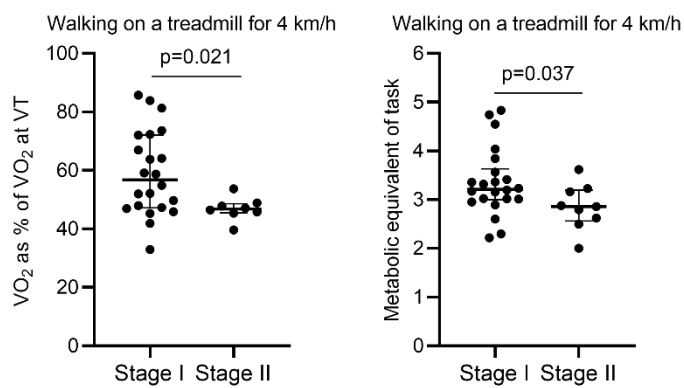


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506 **Figure 2.** Differences in the measures of physical activity intensity between prepubertal and
507 pubertal children.



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