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Individual calibration of accelerometers in children and their health-related implications

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1 **Title Page**

2 **Title:** Individual calibration of accelerometers in children and their health-related
3 implications

4 **Running Title:** Individual PA calibration and health implications

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44

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61

62

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72 **Abstract**

73 This study compared children's physical activity (PA) levels, the prevalence of children
74 meeting current guidelines of ≥ 60 minutes of daily moderate to vigorous PA (MVPA), and
75 PA-health associations using individually calibrated (IC) and empirical accelerometer
76 cutpoints. Data from 75 (n = 32 boys) 10-12 year old children were included in this study.
77 Clustered cardiometabolic (CM) risk, directly measured cardiorespiratory fitness (CRF),
78 anthropometric and 7 day accelerometer data were included within analysis. PA data were
79 classified using Froude anchored IC, Evenson et al., 2008 (Ev) and Mackintosh et al., 2012
80 (Mack) cutpoints. The proportion of the cohort meeting ≥ 60 mins MVPA/day ranged from
81 37%-56% depending on the cutpoints used. Reported PA differed significantly across the
82 cutpoint sets. IC LPA and MPA were predictors of CRF (LPA: standardised $\beta = 0.32$, $p =$
83 0.002 , MPA: standardised $\beta = 0.27$ $p = 0.013$). IC MPA also predicted BMI Z-score
84 (standardised $\beta = -0.35$, $p = 0.004$). Ev VPA was a predictor of BMI Z-score (standardised β
85 $= -0.33$, $p = 0.012$). Cutpoint choice has a substantial impact on reported PA levels though no
86 significant associations with CM risk were observed. Froude IC cut points represent a
87 promising approach towards classifying children's PA data.

88 **Introduction**

89 Regular participation in physical activity (PA) in childhood is associated with reduced
90 cardiometabolic risk (Andersen, Riddoch, Kriemler, & Hills, 2011), improved bone health
91 (Boreham & McKay, 2011), reduced adiposity (McMurray & Ondrak, 2013), and improved
92 psychological well-being (Biddle & Asare, 2011). PA guidelines state that children should
93 accrue at least 60 minutes of daily moderate to vigorous PA (MVPA) to receive health benefits
94 (WHO, 2010). The accurate measurement of PA is essential to investigate the associations
95 between PA and health, estimate the prevalence of inactivity, and identify children in need of
96 intervention. Accelerometry is the most commonly used objective method for assessing free-
97 living PA in children, and has acceptable validity and reliability (Cain, Sallis, Conway, Van
98 Dyck, & Calhoun, 2013). Despite this, no consensus exists with regards to the treatment of
99 accelerometer data and inconsistent use of cutpoints presents challenges when quantifying the
100 prevalence of inactivity (Ekelund, Tomkinson, & Armstrong, 2011), making comparisons
101 between studies (Hislop, Bulley, Mercer, & Reilly, 2012) and establishing the relationship
102 between PA and health outcomes (Bailey, Boddy, Savory, Denton, & Kerr, 2013).

103

104 Previous research has compared the classification accuracy of published thresholds (PTs) in
105 youth using calibration studies, and recommended that researchers use Evenson's (Evenson,
106 Catellier, Gill, Ondrak, & McMurray, 2008) cutpoints to classify children's PA (Trost,
107 Loprinzi, Moore, & Pfeiffer, 2011). However, the empirical cutpoints examined by Trost et
108 al. (2011) applied universal cutpoints to all children, with only one age-specific cutpoint
109 included in the analysis (Freedson, Pober, & Janz, 2005). Such cutpoints fail to account for
110 wide variations in accelerometer counts observed between children when engaging in PA at
111 equivalent intensities (Rowlands, 2007). Subsequently researchers have proposed the use of
112 individually calibrated (IC) approaches to improve the classification of children's PA
113 (Mackintosh, Fairclough, Stratton, & Ridgers, 2012).

114

115 One method of deriving individual cutpoints, particularly when using hip-mounted
116 accelerometers, is to adjust cutpoints to account for limb length using relevant biomechanical
117 theory. The Froude (Fr) number (Minetti, 2001) offers one solution to the standardisation of
118 cutpoints for individuals, by taking the length of a given characteristic, in this case leg length,
119 into account. Froude numbers are calculated using the equation: $Fr = v^2/g * l$ where 'v' is the
120 speed, 'g' represents gravitational acceleration and 'l' is the length of the characteristic. The
121 theory of dynamic similarity suggests that geometrical bodies have similar gait dynamics if
122 the Fr number is kept constant (Alexander, 1989). For example, the Fr number of 0.25
123 represents optimum walking speed and Fr 0.5 is the point at which running occurs in most
124 bipedal bodies, including humans (Kram, Domingo, & Ferris, 1997). Therefore for a given Fr
125 number and related walking speed gait dynamics should be relatively consistent between
126 participants, which in turn allows for a simple method of creating individualised and
127 comparable thresholds. Despite its potential utility, few studies have utilised the Froude
128 approach to individually calibrate accelerometer cutpoints (Boddy et al., 2014). As PA is
129 positively associated with health, the potential to better examine these relationships with more
130 precise estimates of PA is important, especially as relationships between PA and variables
131 such as CRF and adiposity are often weaker than may be expected. To date no have examined
132 differences in reported PA or PA-health associations between IC and empirically derived
133 group level cutpoints. Therefore, the aims of this study were to compare children's physical
134 activity (PA) levels, the prevalence of children meeting current guidelines of 60 minutes of
135 daily moderate to vigorous PA (MVPA), and PA-health associations using individually
136 calibrated Fr (IC) and empirical accelerometer cutpoints.

137

138 **Methods**

139 *Participants and Settings*

140 The data for this analysis were taken from the REACH Year 6 study (Boddy et al., 2014).
141 Seventy-five children (n = 32 boys) 10-12 years of age agreed to take part in the study which
142 had ethical clearance from the respective institutional ethics committees. The study was

143 conducted in Liverpool, England (2010, n = 39) and Belfast, Northern Ireland (2011, n = 35).
144 Each participant attended one school-based blood sampling session and one laboratory testing
145 session. Participants also wore an accelerometer to quantify PA over seven days.

146

147

148 *Procedure and Measurements*

149 Anthropometrics: Stature, sitting stature to the nearest 0.1cm (Seca Ltd. Birmingham, UK)
150 and body mass to the nearest 0.1kg (Seca Ltd. Birmingham, UK) were assessed using standard
151 techniques (Lohman, Roche, & Martorell, 1988). Waist circumference was measured to the
152 nearest 0.1cm. Body mass index (BMI), BMI Z-scores (Cole, Freeman, & Preece, 1995) and
153 somatic maturation (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002) were calculated. High-
154 resolution ultrasound (Terason, t3000; Aloka, London, UK) was used to assess flow mediated
155 dilation (FMD) and % FMD calculated using the equation: ((Peak artery diameter - Baseline
156 artery diameter)/ Baseline artery diameter)*100) was calculated. Blood pressure (BP) was
157 measured on the left arm after 15mins rest in a supine position using an automated BP monitor
158 (Omron Healthcare UK Limited, Miton Keynes, UK).

159

160 Cardiorespiratory fitness assessment: After treadmill familiarisation, participants completed
161 an individually calibrated continuous, incremental (2mins stages) treadmill (both sites: HP
162 Cosmos, Traunstein, Germany) protocol to volitional exhaustion using online gas analysis
163 (Liverpool: Jaeger Oxycon Pro, Viasys Health Care, UK, Ulster: COSMED, Quark, Italy) to
164 measure peak oxygen uptake (VO₂peak). Treadmill speeds for the first two stages of the test
165 were anchored to Froude numbers 0.25 (MPA) and 0.5 (VPA) for each participant. For this
166 study leg length was used as the characteristic. An example equation to calculate treadmill
167 speed for an individual with a leg length of 0.67m for a Fr number of 0.25 would be: treadmill
168 speed (m/s) = $\sqrt{(0.25*(9.81* 0.67))}$, which would result in a speed of 1.28 m/s or 4.61 km/h.
169 Participants wore an ActiGraph accelerometer (ActiGraph GT1M, MTI Health Services,
170 Pensacola, FL) at the right hip and heart rate monitor (Polar Electro Oy, Kempele, Finland)

171 set to record using 5 second epochs throughout the treadmill protocol. The highest 15-second
172 average oxygen uptake was used to represent VO_2peak (ml/kg/min) for each participant.

173

174 Blood sampling: On a different day to the laboratory visits, children attended their school sites
175 to provide a fasting venous blood sample. Experienced phlebotomists obtained ~ 10ml of
176 venous blood following an overnight fast. Samples were taken between 8.30 and 10.30am.
177 After providing a sample children were given breakfast. Blood samples were transported to
178 the pathology laboratories at Alder Hey Children's Foundation NHS Trust or the Ulster
179 Hospital for analysis. Blood was analysed for triglycerides, cholesterol, high density
180 lipoprotein cholesterol (HDL-c), glucose, adiponectin, and high sensitivity C-reactive protein
181 (CRP) using assay methods that were standardised between sites. Blood markers were used in
182 combination with FMD%, blood pressure and waist circumference to calculate a clustered
183 cardiometabolic risk score by standardising individual risk components and summing them to
184 create a continuous clustered risk variable. This approach has been used in several similar
185 studies (Andersen, Hasselstrom, Gronfeldt, Hansen, & Karsten, 2004; Anderssen et al., 2007;
186 Boddy et al., 2014; Buchan, Young, Boddy, & Baker, 2014).

187

188 Physical activity assessment: Children wore an ActiGraph (ActiGraph GT1M) uniaxial
189 accelerometer on their right hip during waking hours for seven consecutive days. The monitors
190 recorded activity using 5 second epochs to account for the sporadic nature of children's
191 physical activity (Baquet, Stratton, Van Praagh, & Berthoin, 2007). Periods of 20 minutes of
192 consecutive zero counts (1 minute spike tolerance) were used to define a non-wear period and
193 these periods were subtracted from daily wear time (Catellier et al., 2005). Children were
194 included within analysis if they wore the monitor for a minimum of 9 hrs on any three days
195 (Mattocks et al., 2008).

196 PA data were classified into light (LPA), moderate (MPA), vigorous (VPA) and moderate to
197 vigorous PA (MVPA) intensities using three sets of intensity cutpoints: two sets of empirical
198 cutpoints: Evenson et al., 2008 (Ev) and Mackintosh et al., 2012 (Mack). The Mack

199 thresholds were generated from data derived from a field-based observational protocol with
200 children of the same age and from a similar geographical location as those included within
201 this study and were included to provide an additional comparison. PA was also classified using
202 individually calibrated (IC) cut points. Sedentary time was defined as ≤ 100 counts per minute
203 for all cut point sets (Fischer, Yildirim, Salmon, & Chinapaw, 2012). Individually calibrated
204 cut points were generated using the data from the VO_2 peak treadmill protocol. Froude 0.25
205 and 0.50 represent the thresholds for optimum walking speed and the transition between
206 walking and running. The average counts for the middle 90 seconds (18 epochs) of the two
207 Fr stages (Fr 0.25 and Fr 0.50) were used to represent MPA and VPA thresholds for each
208 individual. The middle 90 seconds were selected to avoid the transitional periods between the
209 Fr.25 (walking) and Fr.5 (running). To examine the energy cost associated with each Fr
210 threshold metabolic equivalents were calculated for Fr.25 and Fr.5 stages using the gas
211 analysis data (1 MET = 4.59 VO_2 ml/kg/min; (Ridley & Olds, 2008) and compared to the
212 energy costs outlined by Harrell et al. (2005). This gas analysis data was simply used to assess
213 the MET values associated with the Fr stages for each individual.

214

215 *Data analysis*

216 Differences in anthropometrics, clustered risk, VO_2 peak, sedentary time and PA components
217 (MPA, VPA, MVPA) were examined by sex using MANCOVA, controlling for accelerometer
218 wear time. The prevalence of those reaching ≥ 60 mins MVPA per day was calculated for each
219 cutpoint set. Differences in PA intensities were examined using repeated measures ANOVAs
220 by cutpoint. To investigate the association between PA components and health markers
221 (VO_2 peak, BMI Z-score, waist circumference, clustered cardiometabolic risk) multiple
222 regression was employed controlling for sex, maturation, BMI and wear time. For each
223 dependent variable three multiple regression models, one for each cutpoint, were created.
224 Where BMI was used as a dependent variable it was excluded as a covariate. All analyses
225 were completed using SPSS V21.0 (SPSS Inc, IBM). Alpha was set at $P \leq 0.05$.

226 **Results**

227 Unadjusted mean participant characteristics and adjusted mean anthropometric, VO₂peak,
228 sedentary time and PA values for boys and girls are illustrated in tables 1 and 2 respectively.
229 Boys were significantly less mature, had higher VO₂peak and accrued more LPA and MPA
230 than girls.

231

232 TABLE 1 ABOUT HERE

233 TABLE 2 ABOUT HERE

234

235 The IC cut points ranged from 1234-4476 counts per minute for MPA and 3192-9357 counts
236 per minute for VPA The mean oxygen consumption (VO₂ ml·kg⁻¹·min⁻¹) and MET values (1
237 MET = 4.59 VO₂ ml·kg⁻¹·min⁻¹) achieved during the treadmill stages Fr0.25 and Fr.5 were
238 20.1ml·kg⁻¹·min⁻¹ (SD = 4.2 ml·kg⁻¹·min⁻¹), 4.4 METs and 31.2 ml·kg⁻¹·min⁻¹ (SD = 7.4 ml·kg⁻¹·min⁻¹)
239 6.8 METs respectively. These values are proximal to those commonly used to
240 represent MPA (≥4 METS+) and VPA (≥6 METS) in the PA literature. Data from Harrell et
241 al (2005) calculated for children aged 8-12 years confirm that participants were working at an
242 intensity approximately equivalent to moderate intensity during Fr 0.25 (Harrell et al. (2005)
243 values: VO₂ = 18.3 ml·kg⁻¹·min⁻¹) and approaching high intensity activity during Fr 0.50
244 (Harrell et al. (2005) values: VO₂ = 38.5 ml·kg⁻¹·min⁻¹).

245

246 The proportion of children meeting ≥60mins/day MVPA varied depending on the cutpoints
247 used. According to the Mack cutpoints 56% met ≥60mins/day MVPA, whereas 49% and 37%
248 achieved 60mins according to Ev and IC cutpoints respectively.

249 The results of the repeated measures ANOVAs between cutpoint sets can be viewed in Table
250 3. Significantly higher MPA was reported using the Mack (MPA = 51.6 mins/day) cutpoints
251 in comparison to the Ev (MPA = 38.4 mins/day) and IC cutpoints (MPA = 44.3 mins/day). Ev
252 cutpoints (VPA = 25.9 mins/day) recorded higher VPA than Mack (17.8 mins/day) and IC

253 (13.0 mins/day). Significantly less LPA was observed using the Mack (195 mins/day)
254 cutpoints in comparison to IC (209 mins/day) and Ev (200.3 mins/day), the difference between
255 IC and Ev LPA was also statistically significant.

256

257 TABLE 3 ABOUT HERE

258

259 Results of multiple regression found that IC LPA and MPA were significant predictors of
260 VO_2 peak (R^2 for the model = 0.55, LPA: standardised beta = 0.32, $t = 3.24$, $p = 0.002$, MPA:
261 standardized beta = 0.27, $t = 2.57$, $p = 0.013$) IC MPA was also a significant predictor for BMI
262 Z-score (R^2 for the model = 0.31, standardised beta = -0.35, $t = -2.96$, $p = 0.004$). Ev VPA was
263 a significant predictor for BMI Z-score (R^2 for the model = 0.32, standardized beta = -0.33, t
264 = -2.59, $p = 0.012$), Mack data were not significant predictors for any health variables,
265 however Mack VPA approached statistical significance as a predictor for BMI Z-score (R^2 for
266 the model = 0.29, VPA standardized beta = -0.23, $t = -1.98$, $p = 0.052$). No significant PA-
267 clustered risk score associations were observed irrespective of cut point set used.

268

269 **Discussion**

270 The aims of this study were to compare children's physical activity (PA) levels, the prevalence
271 of children meeting current guidelines of 60 minutes of daily moderate to vigorous PA
272 (MVPA), and PA-health associations using individually calibrated Fr (IC) and empirical
273 accelerometer cutpoints. In this study the proportion of the cohort meeting current guidelines
274 for daily MVPA ranged from 37% - 56% depending upon the cut point used. A number of
275 studies have shown differences in PA prevalence depending on the choice of cut points used
276 to analyse data (Hislop et al., 2012; Reilly et al., 2008). For example, a review by Ekelund et
277 al. (2011) highlighted that the reported prevalence of children and young people meeting
278 current PA guidelines ranged across six studies from 1% and 100%, with authors suggesting
279 that the variability could be largely attributed to the different intensity cutpoints used between
280 studies. At a 4 MET intensity (approximate to MPA) recommended counts per minute have

281 ranged widely from 1400 to 3600 (Cain et al., 2013). In this study, IC cut points derived from
282 the treadmill-based protocol ranged from 1234-4476 for MPA, with a mean MET value of 4.4
283 (range 2.49-7.04 METs) and 3192-9357 for VPA (mean MET value of 6.8, range 3.83-12.33
284 METs). This demonstrates the substantial variation that exists in the biomechanical efficiency
285 of movement (e.g. stride length, stride pattern) between children of a similar age completing
286 the same activity, and provides support for the use of IC cut points that take account of
287 individual differences.

288

289 This study also revealed significant differences in the classification of LPA, MPA and VPA
290 depending upon the cutpoint used. The discrepancies in the classification of PA intensities
291 observed may be in part due to the differing methods used to define each of the cutpoint
292 thresholds. For example, the IC cut points used in this study were derived from the application
293 of biomechanical theory, which is in contrast to the empirical cut points derived from
294 laboratory based (Ev) or field-based (Mack) energy expenditure. Although it is well
295 documented that the application of different cut points results in differences in estimates of
296 activity intensity (Troost et al., 2011), to date, none of the published papers have compared the
297 classification of activity intensity between IC and empirical cut points. Our findings suggest
298 that researchers should be cautious about the universal application of cut points which fail to
299 account for individual differences between participants, particularly with evidence suggesting
300 wide variations in step counts between children when engaging in PA at equivalent intensities
301 (Rowlands, 2007). The application of more specific cutpoints may provide an opportunity to
302 reduce sample size requirements within studies due to better estimates of primary outcome
303 measures.

304

305 Despite calls for raw data processing techniques to remove the reliance on proprietary counts
306 based data, this approach still requires the use of cutpoints or acceleration thresholds to
307 classify raw acceleration signals, therefore the findings of this study apply in the raw data
308 analysis context. To remove the requirement of cutpoints, pattern recognition or machine

309 learning approaches to classify accelerometer data have been proposed Despite the potential
310 utility of this approach the majority of PA research conducted to date using accelerometers
311 still utilises proprietary counts data and apply group level thresholds to the data, therefore the
312 IC approach proposed within this paper is recommended. The range in prevalence and
313 classification of PA resulting from the application of different cut points underscores the need
314 for a consensus on accelerometer thresholds to quantify PA intensity. The array of thresholds
315 used by researchers makes comparison between studies problematic, leading to conflicting
316 conclusions (Hislop et al., 2012). The inconsistent use of these thresholds is also a major issue
317 when attempting to quantify the prevalence of inactivity (Ekelund et al., 2011), has impacted
318 upon PA policy making for children (Bailey et al., 2013) and the relationships between PA
319 and health outcomes (Bailey et al., 2013). For example, in their comparison of three published
320 thresholds (Chu, McManus, & Yu, 2007; Rowlands, Thomas, Eston, & Topping, 2004;
321 Vanhelst et al., 2010) Bailey et al. (2013) reported a range of different associations between
322 PA and health outcomes such as blood pressure, waist circumference, cardiorespiratory fitness
323 and metabolic markers such as glucose and triglycerides. In our study, although the estimates
324 of the intensity of PA differed according to thresholds used, relationships detected with the
325 clustered cardiometabolic risk score were consistent. However, the IC cut points had the
326 strongest associations with VO_2 peak, an important independent predictor of cardiometabolic
327 risk (Andersen et al., 2011). This may be due to the methods utilised to create the IC cutpoints
328 and the treadmill-based VO_2 peak protocol. Whether the approach of individually calibrating
329 PA thresholds according to limb length is as effective at predicting energy expenditure across
330 a range of different activities warrants further investigation. Furthermore, the empirical
331 cutpoints used in this study were created using field-based protocols that included a range of
332 typical daily activities. The differences described between these methods and the IC approach
333 may relate to the protocols used to generate the cutpoints, rather than the accuracy of the
334 cutpoints per se.

335

336 When compared to the use of a portable metabolic unit (Ev) or PA observation (Mack), it
337 appears that the treadmill-based calibration protocol used in this study was more effective in
338 accounting for individual differences in biomechanical efficiency of movement (e.g limb
339 length, stride length/frequency) by matching the accelerometer counts to changes in speed and
340 resulting PA intensity. Whereas in previous research, the observed relationships between CRF
341 and PA in children have been weaker than expected, for example weak-moderate standardized
342 regression coefficients (0.14-0.33) between aerobic fitness and PA have been
343 reported (Kristensen et al., 2010), the present findings suggest that IC cut points highlight
344 stronger associations between children's PA and CRF than are often reported. Moreover, there
345 is a growing body of evidence that links CRF to cardiometabolic disease risk in children
346 (Anderssen et al., 2007) (Boddy et al., 2014). Therefore, our findings have important
347 implications for researchers investigating the associations between activity status, CRF and
348 health, and practitioners referring inactive individuals for lifestyle intervention.

349

350 Strengths and Limitations: This is the first study to examine differences in reported PA, and
351 PA-health relationships between Fr IC and empirically derived cut points. The generic
352 cutpoint method is less time consuming than completing laboratory calibration studies
353 involving multiple activities and portable calorimetry or observation. Despite this, the
354 individual calibration approach used within this study does not take into account movement
355 patterns other than walking and running, and although the majority of children's activity is
356 ambulatory the method may not accurately classify other types of movements completed by
357 children. The method also did not merge the VO_2 data from the fitness assessment that would
358 have provided energy expenditure data. This was purposeful to allow the examination of the
359 thresholds based on the Fr number alone, rather than a more complex hybrid threshold
360 approach. An evolution of this method could be proposed that utilises VO_2 data to examine
361 whether the precision of the thresholds is improved, however this was beyond the scope and
362 aims of the current study. In addition, the Fr number could result in non-ecological walking
363 patterns which are not representative of 'usual' walking speeds. It is important to note that

364 maturational factors may influence metabolic efficiency and therefore energy expenditure
365 within this population. The influence of maturation on energy expenditure was not explored
366 within this study, mainly because of the repeated measures nature of the analysis when
367 comparing thresholds, however warrants consideration when working with populations within
368 this age range. This study used a range of established and emerging risk factors to provide a
369 robust estimate of cardiometabolic risk. However, the participants involved in this study were
370 healthy children, which may account for the lack of associations observed between the PA
371 data and cardiometabolic risk scores. Stronger PA-health associations may be apparent in a
372 population exhibiting greater cardiometabolic risk. The treadmill measure of VO_2 peak is
373 considered the reference standard, though standardised protocols were used, data were taken
374 using different gas analysis systems in Liverpool and Ulster (Oxycon Pro and COSMED)
375 which may influence comparability between the VO_2 peak estimates.

376

377 *Conclusion*

378 This study has demonstrated that the application of different intensity thresholds has an impact
379 when determining the proportion of children meeting current daily PA guidelines. To make
380 accurate evidence based recommendations, a consensus on appropriate accelerometer
381 thresholds for quantifying PA intensity is needed. IC cut points provide evidence of a stronger
382 association between children's PA and CRF than is often reported. This finding has important
383 implications for researchers and practitioners investigating the associations between activity
384 status, CRF and health and referring inactive individuals for lifestyle intervention. Additional
385 research is needed with larger cohorts to fully examine the potential of using IC cut points to
386 classify children's PA.

387

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493

494 Table 1. Raw mean [SE] participant characteristics by sex

Variable	Boys (n = 32)	Girls (n = 43)
Age (years)	10.47 [0.57]	10.5 [0.75]
Maturation offset (years)	-2.64 [0.71]	-0.95 [0.68]
BMI Z-score	0.65 [0.86]	0.53 [1.24]
Waist circumference (cm)	64.4 [6.4]	65.7 [9.57]
VO ₂ peak (ml/kg/min)	45.55 [9.71]	40.81 [8.7]
Diastolic BP (mmHg)	63 [6.2]	62.1 [6.7]
Systolic BP (mmHg)	103.6 [11.9]	102.3 [12.1]
FMD %	8.39 [3.24]	8.54 [4.26]
C-Reactive Protein (mg/L)	0.38 [0.29]	0.94 [1.32]
Triglycerides (mmol/L)	0.64 [0.2]	0.78 [0.28]
Cholesterol (mmol/L)	4.17 [0.67]	4.21 [0.54]
HDL-C (mmol/L)	1.59 [0.31]	1.49 [0.38]
Glucose (mmol/L)	4.71 [0.34]	4.63 [0.3]
Adiponectin (µg/mL)	10.58 [5.4]	11.14 [6.78]
Clustered CM risk	0.18 [4.01]	-0.38 [3.71]
Sedentary Time (mins/day)	440.4 [41]	458.8 [41.2]

IC LPA (mins/day)	220 [46]	200.7 [33]
IC MPA (mins/day)	52.4 [36.3]	38.3 [24.7]
IC VPA (mins/day)	14.2 [9.7]	12.2 [17.7]
IC MVPA (mins/day)	66.6 [37.5]	50.4 [31.9]
Accelerometer wear time (mins/day)	716.8 [49.2]	716.6 [116.9]

495

496 Table 2. Mean values [SE] for boys and girls adjusted for wear time (MANCOVA
 497 output, n = 61).

Variable	Boys	Girls	P value
Age (years)	10.45 [.13]	10.49 [.12]	.833
Maturation offset (years)	-2.63 [.14]	-0.89 [.13]	< 0.001
BMI Z-score	0.62 [.21]	0.70 [.18]	.776
Waist circumference (cm)	64.0 [1.6]	67.0 [1.5]	.173
VO₂peak (ml/kg/min)	46.39 [1.61]	39.28 [1.44]	.002
Clustered CM risk	-0.047 [.75]	-0.282 [.67]	.816
Sedentary Time (mins/day)	438.6 [7.7]	457.8 [6.9]	.069
IC LPA (mins/day)	221.5 [7.4]	196.3 [6.6]	.014
IC MPA (mins/day)	53.5 [5.9]	37.4 [5.3]	.047
IC VPA (mins/day)	14.0 [3.1]	12.6 [2.8]	.741
IC MVPA (mins/day)	67.5 [7.0]	50.1 [6.2]	.066

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499

500 **Table 3. Adjusted mean [SE] physical activity across the three cutpoint sets**

Activity Component	Individually Calibrated		Mackintosh et al. 2012		Evenson et al., 2008	
	(IC) Minutes/day		(Mack) Minutes/day		(Ev) Minutes/day	
	Mean	SE	Mean	SE	Mean	SE
VPA	13.0 ^{*†}	1.7	17.8 [†]	1.7	25.9	2.0
MPA	44.3 ^{^^}	3.6	51.6 [^]	2.4	38.4	1.8
LPA	209.0 [‡]	4.1	195.0 [†]	3.7	200.3	3.8

501

502 ^{*}Ev > IC ($p < 0.001$), [†]Mack > IC ($p < 0.001$), [†]Ev > Mack ($p < 0.001$), ^{^^}Mack > IC

503 ($p = 0.005$) [^]Mack > Ev ($p < 0.001$), [‡]IC > Mack ($p < 0.01$) and IC > Ev ($p = 0.006$).

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