

1 THIS IS A NON-FINAL VERSION OF AN ARTICLE PUBLISHED IN FINAL
2 FORM IN Medicine and Science in Sports and Exercise

3 Moving forward with backwards compatibility: Translating wrist accelerometer data

4 Short title: Translating wrist accelerometer data

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26 **Abstract**

27 **Purpose:** To provide a means for calibrating raw acceleration data from wrist-worn
28 accelerometers in relation to past estimates of children's moderate-to-vigorous
29 physical activity (MVPA) from a range of cut-points applied to hip-worn ActiGraph
30 data. **Methods:** This is a secondary analysis of three studies with concurrent 7-day
31 accelerometer wear at the wrist (GENEActiv) and hip (ActiGraph) in 238 children
32 aged 9-12 years. The time spent above acceleration (ENMO) thresholds of 100, 150,
33 200, 250, 300, 350 and 400 mg from wrist acceleration data (≤ 5 s epoch) was
34 calculated for comparison to MVPA estimated from widely used children's hip-worn
35 ActiGraph MVPA cut-points (Freedson/Trost 1100 counts per minute (cpm); Pate
36 1680 cpm; Evenson 2296 cpm; Puyau 3200 cpm) with epochs of ≤ 5 , 15 and 60 s.
37 **Results:** The optimal ENMO thresholds for alignment with MVPA estimates from
38 ActiGraph cut-points determined from 70% of the sample and cross-validated with
39 the remaining 30% were: Freedson/Trost = ENMO 150+ mg, irrespective of
40 ActiGraph epoch ($ICC \geq 0.65$); Pate = ENMO 200+ mg, irrespective of ActiGraph
41 epoch ($ICC \geq 0.67$); Evenson = ENMO 250+ mg for ≤ 5 s and 15 s epochs ($ICC \geq 0.69$)
42 and ENMO 300+ mg for 60 s epochs ($ICC = 0.73$); Puyau = ENMO 300+ mg for ≤ 5 s
43 epochs ($ICC = 0.73$), ENMO 350+ mg for 15 s epochs ($ICC = 0.73$), ENMO 400+ mg
44 for 60 s epochs ($ICC = 0.65$). Agreement was robust with cross-validation $ICCs = 0.62-$
45 0.71 and means within $17.8 \pm 4.9\%$ of MVPA estimates from ActiGraph cut-points,
46 except Puyau 60 s epochs ($ICC = 0.42$). **Conclusion:** Incremental ENMO thresholds
47 enable children's acceleration data measured at the wrist to be simply and directly
48 compared, at a group level, to past estimates of MVPA from hip-worn ActiGraphs
49 across a range of cut-points.

50 **Keywords:** Physical activity, children, MVPA, ActiGraph, GENEActiv, cut-point

51 **Introduction**

52 Objective measures of physical activity, specifically uniaxial hip-worn
53 accelerometers, were introduced into national surveys in the US (National Health and
54 Nutrition Examination Survey, NHANES) in 2003 (29), Canada (Canada Health
55 Measures Survey) in 2007 (7,8) and the UK (Health Survey for England) in 2008
56 (17). Also in 2008, the International Children’s Accelerometry Database (ICAD) was
57 initiated: a compilation of accelerometer-derived estimates of children’s physical
58 activity from a wide range of studies, settings, and countries (28). The accelerometers
59 employed in these surveys and studies converted accelerations into proprietary counts
60 stored in 5-60 s epochs and time accumulated in moderate-to-vigorous physical
61 activity (MVPA) was subsequently estimated.

62
63 Over the past decade there have been rapid developments in accelerometry resulting
64 in the commercial availability of triaxial microelectromechanical (MEMS)
65 accelerometers that continuously sample and store raw accelerations at up to 100 Hz,
66 such as the ActiGraph GT3X+ and the GENEActiv. There has also been a move to 24
67 h wear protocols with wrist-wear to maximize compliance (2,9,14) and facilitate
68 measurement of the full spectrum of physical behaviours (physical activity, sedentary
69 behavior and sleep) (6). As a result, since 2011, wrist-worn ActiGraph GT3X+
70 monitors that collect and store raw accelerations at 100 Hz have been used in
71 NHANES (30). Other large-scale adult (2,9,21) and children’s (9,10,20,34) studies
72 are also employing 24 h wrist-worn accelerometer protocols using the GENEActiv.

73
74 As the ActiGraph GT3X+ and the GENEActiv store raw accelerations rather than
75 proprietary counts, their data should, theoretically, be comparable. Output from the

76 GENEActiv and the Actigraph GT3X+, when processed and calibrated identically
77 using the open source package GGIR (32,33) in R [<http://cran.r-project.org>], have high
78 agreement for acceleration magnitudes >50-80 mg, indicative of light activity and
79 MVPA, although not for lower acceleration magnitudes indicative of sedentary time
80 (27).

81

82 Advances in measurement methods (e.g. self-report to objective measurement) and/or
83 measurement technologies (e.g. proprietary count uniaxial accelerometers to raw
84 acceleration triaxial accelerometers) bring reduced bias, improved precision and
85 enhanced measurement opportunities (30), but at a cost of limited comparability to
86 past data. There is a wealth of MVPA data on children estimated from uniaxial hip-
87 worn ActiGraphs (28,29) and it is desirable to use these data to: contextualize future
88 estimates of MVPA; map trends in physical activity; compare effectiveness of past
89 and present interventions; and understand the clinical significance of intervention
90 changes in PA, by contextualizing current data with the extant historical evidence on
91 the impact of physical activity on health. To complicate comparisons further, hip-
92 worn ActiGraph data have been analyzed using an extensive range of cut-points
93 leading to widely varying estimates of MVPA even for the same dataset (4,5,15).

94

95 The purpose of this study is to provide a means for quickly and simply comparing raw
96 acceleration data from wrist-worn accelerometers at a group level to past estimates of
97 children's MVPA from a range of cut-points applied to hip-worn ActiGraph data. To
98 do this, we used data from three studies that have concurrent 7-day accelerometer
99 wear at the wrist (GENEActiv) and hip (ActiGraph) to determine and cross-validate
100 the acceleration magnitudes most closely associated with established MVPA cut-

101 points. As the GENEActiv and ActiGraph GT3X+ have high agreement for
102 accelerations indicative of light activity and MVPA (27), the results will be applicable
103 to studies measuring raw triaxial accelerations at the wrist in children with either the
104 ActiGraph GT3X+ or the GENEActiv.

105

106 **Methods**

107

108 This is a secondary data analysis using data from three studies: 1) 58 children, aged
109 10-12 years, recruited from primary schools in South Australia (26); 2) 129 children,
110 aged 9-10 years, recruited from primary schools in Liverpool, UK (12); 3) 81
111 children, aged 9-11 years, recruited from one primary school in Liverpool, UK. The
112 appropriate university research ethics committee approved each study. Written
113 informed consent and assent were obtained from the parents/guardians and children,
114 respectively. Height was measured to the nearest 0.1 cm and body mass to the nearest
115 0.1 kg.

116

117 **Assessment of activity**

118

119 Free-living physical activity was measured by concurrent wear of the GENEActiv on
120 the non-dominant wrist and the ActiGraph GT3X+ positioned above the right hip, on
121 an elasticated belt worn around the waist, for seven consecutive days. In study 1,
122 children were requested to wear both monitors day and night, removing the hip-worn
123 ActiGraph for water-based activities only. In studies 2 and 3, children were requested
124 to wear both monitors at all times except when sleeping or during water-based
125 activities.

126

127 Accelerometers

128

129 The GENEActiv is a triaxial accelerometry-based activity monitor with a dynamic
130 range of +/- 8g (Gravity Estimator of Normal Everyday Activity, ActivInsights Ltd,
131 Cambridgeshire, UK). The ActiGraph GT3X+ is a triaxial accelerometry-based
132 activity monitor with a dynamic range of +/- 6 g (ActiGraph LLC, Pensacola, FL,
133 USA). Study 1: The GENEActivs were initialized to collect data at 87.5 Hz and data
134 uploaded using GENEActiv PC software version 2.2. The ActiGraphs were initialized
135 to collect data at 80 Hz and data uploaded using Actilife version 6.5.3. Data were
136 collected between April and December 2012. Studies 2 and 3: The GENEActivs and
137 ActiGraphs were both initialized to collect data at 100 Hz and data uploaded using
138 GENEActiv PC software version 2.2 and Actilife version 6.11.4, respectively. Study
139 2 data were collected between January and May 2014 and study 3 data were collected
140 in January and February 2015.

141

142 Data processing

143

144 Wrist-worn GENEActiv (raw acceleration) GENEActiv .bin files were analysed with
145 R-package GGIR version 1.2-0 (<http://cran.r-project.org>) (32,33). Signal processing in
146 GGIR includes the following steps: 1. Autocalibration using local gravity as a
147 reference (32); 2. Detection of sustained abnormally high values; 3. Detection of non-
148 wear; 4. Calculation of the average magnitude of dynamic acceleration, i.e. the vector
149 magnitude of acceleration corrected for gravity (Euclidean Norm minus 1 g, ENMO)
150 over user-defined s epochs:

151 ENMO = $\sum \sqrt{x^2 + y^2 + z^2} - g$ with negative values set to zero. In study 1,
152 ENMO was averaged over 5 s epochs; in studies 2 and 3, ENMO was averaged over 1
153 s epochs. As studies applying GGIR to wrist accelerometer data have used both 1 s
154 (12) and 5 s epochs (9), inclusion of both epochs increases the generalizability of the
155 findings.

156

157 Files were excluded from all analyses if post-calibration error was greater than 0.02 g
158 (9) and individual days were classified as invalid and excluded if wear-time was
159 insufficient (16 h for the 24 h protocol in study 1, 10 h for the waking wear protocol
160 in studies 2 and 3). Detection of non-wear has been described in detail previously
161 (See ‘Procedure for non-wear detection’ in supplementary document to van Hees et
162 al. (33)). In brief, non-wear is estimated based on the standard deviation and value
163 range of each axis, calculated for 60 min windows with 15-min moving increments. If
164 for at least 2 out of the 3 axes the SD is less than 13 mg or the value range is less than
165 50 mg the time window is classified as non-wear. The default non-wear setting was
166 used, i.e. invalid data were imputed by the average at similar timepoints on different
167 days of the week

168

169 The distribution of time spent across ENMO levels in 50 mg resolution (0-50 mg, 50-
170 100 mg..... ≥ 400 mg) was calculated using the argument ‘ilevels’ from the GGIR
171 package. The time spent above thresholds of 100, 150, 200, 250, 300, 350 and 400 mg
172 was calculated for comparison to widely used hip-worn ActiGraph MVPA cut-points.

173

174 Hip-worn ActiGraph (counts)

175

176 Data were analyzed using Actilife version 6.13.0. The raw.gt3x files were
177 summarized into uniaxial (vertical) proprietary counts in 1 s, 5 s, 15 s and 60 s
178 epochs, resulting in four ActiGraph files for analysis per participant. Non-wear was
179 defined as 60 min of consecutive zero counts, with an allowance for 1-2 min of counts
180 between 0 and 100 (29). Individual days were classified as invalid and excluded if
181 wear-time was insufficient (16 h for the 24 h protocol in study 1, 10 h for the waking
182 wear protocol in studies 2 and 3).

183

184 Each file was analyzed with four widely-used MVPA cut-points: very low (1100 cpm
185 (counts per minute), approximately equivalent to the cut-point for an 11 y old (3
186 METs) using the age-specific criteria of the Freedson group, published by Trost et al.
187 (31)); low (1680 cpm, Pate et al. (23)); medium (2296 cpm, Evenson et al. (11)); high
188 (3200 cpm, Puyau et al. (24)). This resulted in 16 outputs per participant: MVPA
189 classified using very low, low, medium and high cut-points, with each cut-point
190 applied to data integrated into 1 s, 5 s, 15 s and 60 s epochs.

191

192 Data analysis

193

194 For each participant, days were only included if classified as valid for both the wrist-
195 worn GENEActiv and hip-worn ActiGraph; therefore to be included a participant
196 needed a minimum of one day where both the ActiGraph and GENEActiv recorded
197 sufficient wear time. The daily means for all output variables were taken for each
198 participant. For data from study 1, GENEActiv 5 s epoch outputs were compared to
199 the ActiGraph 5 s, 15 s and 60 s epoch outputs. For data from studies 2 and 3, the
200 GENEActiv 1 s epoch files were compared to the ActiGraph 1 s, 15 s and 60 s

201 epochs. The 5 s data from study 1 and the 1 s data from studies 2 and 3 were
202 designated a ≤ 5 s epoch.
203
204 Descriptive statistics (mean \pm SD) were calculated for all variables. Data from studies
205 1 and 2 (approximately 70% of the total sample) were analyzed with data from study
206 3 reserved for cross validation. The wrist-worn GENEActiv ENMO thresholds (100+,
207 150 +, 200+, 250+, 300+, 350+, 400+ mg) which most closely approximated time
208 accumulated in each of the hip-worn ActiGraph MVPA cut-points (very low, low,
209 medium, high) for each epoch length (≤ 5 s, 15 s, 60 s) were examined with a series of
210 limits of agreement (LoA) analyses (3) and intra-class correlations (ICC, single
211 measures, absolute agreement) with 95% confidence intervals (CI).

212
213 For each hip-worn ActiGraph MVPA cut-point / epoch combination, the wrist-worn
214 ENMO threshold with the closest agreement was selected and the agreement between
215 these optimal pairings tested in the independent cross-validation sample. The
216 distributions for each of the optimal pairings were illustrated on kernel density plots
217 (bandwidth = 10) for the total sample (data from studies 1, 2 and 3 combined).

218

219 **Results**

220

221 Demographic data, by study, are presented in Table 1. The final sample size was 238
222 (Test sample N = 159, Cross-validation sample N = 79) with 30 participants excluded
223 due to no days of concurrent valid wear for both monitors. Figure 1 shows the time
224 recorded in each of the intensity categories by the hip-worn ActiGraph (very low,
225 low, medium and high MVPA cut-points) and the wrist-worn GENEActiv (100+,

226 150+, 200+, 250+, 300+, 350+, 400+ mg ENMO thresholds) by epoch (ActiGraph ≤ 5
227 s, 15 s, 60 s; GENEActiv ≤ 5 s) for the total sample.

228

229 Test sample

230

231 The agreement between each wrist-worn GENEActiv ENMO threshold and each hip-
232 worn ActiGraph MVPA cut-point is shown for each epoch length in Table 2. The
233 ENMO threshold with the highest agreement for each ActiGraph MVPA cut-point /
234 epoch combination is highlighted in bold in Table 2. The optimal wrist-worn ENMO
235 thresholds for comparison to hip-worn ActiGraph MVPA cut-points were:

- 236 • very low MVPA ActiGraph cut-points (1100 cpm, Trost et al. (31))
 - 237 ○ ENMO 150+ mg, irrespective of the ActiGraph epoch ($ICC \geq 0.65$,
 - 238 mean bias (ENMO – ActiGraph) = -2.9 to -18.0 min, (-2.7 to -14.9%
 - 239 of mean MVPA));
- 240 • low MVPA ActiGraph cut-points (1680 cpm, Pate et al. (23))
 - 241 ○ ENMO 200+ mg, irrespective of the ActiGraph epoch ($ICC \geq 0.67$,
 - 242 mean bias = -4.1 to -10.7 min (-5.4 to -13.0% of mean MVPA));
- 243 • medium MVPA cut-points (2296 cpm, Evenson et al. (11))
 - 244 ○ ENMO 250+ mg for ≤ 5 s and 15 s epochs ($ICC \geq 0.69$, mean bias = -
 - 245 3.0 to -7.3 min (-5.4 to -12.0% of mean MVPA))
 - 246 ○ ENMO 300+ mg for 60 s epochs ($ICC = 0.73$, mean bias = -5.0 min (-
 - 247 10.6% of mean MVPA));
- 248 • high MVPA cut-points (3200 cpm, Puyau et al. (24))
 - 249 ○ ENMO 300+ mg for ≤ 5 s epochs ($ICC = 0.73$, mean bias = +1.8 min
 - 250 (+4.7% of mean MVPA))

- 251 ○ ENMO 350+ mg for 15 s epochs (ICC = 0.73, mean bias = +2.7 min
252 (+8.7% of mean MVPA))
- 253 ○ ENMO 400+ mg for 60 s epochs (ICC = 0.65, mean bias = +6.5 min
254 (+28.6% of mean MVPA)).

255

256 Cross-validation

257

258 The agreement of each of these optimal pairings of wrist-worn ENMO threshold and
259 hip-worn ActiGraph MVPA cut-point was tested in the cross-validation sample
260 (Table 3, Figure 2). Agreement was robust with ICC's similar to the test sample for
261 15 s epochs (very low, low and medium MVPA cut-points, mean bias = $|4.9| \pm 0.9\%$
262 of mean MVPA) and $\approx 0.01-0.11$ lower than the test sample (0.61 to 0.71, mean bias =
263 $|8.9| \pm 4.8\%$ of mean MVPA) for other MVPA cut-point / epoch combinations, except
264 for the high MVPA cut-point / 60 s epoch where the ICC was considerably reduced
265 (0.42). The mean biases and 95% limits of agreement were also similar in magnitude
266 to the test sample. However, the values of the mean bias for specific pairings were not
267 consistent between the test sample and the cross-validation sample.

268

269 The distribution of the ActiGraph and ENMO data for each of the optimal pairings is
270 shown on kernel density plots for the total sample, Figure 3. The columns represent
271 cut-points (left to right: very low, low, medium, high) and the rows represent
272 ActiGraph epochs (top to bottom: ≤ 5 s, 15 s, 60 s). The agreement statistics for the
273 total sample are shown in Supplemental Digital Content 1.

274

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276

277

278 **Discussion**

279

280 Rapid progress in accelerometer technology has led to changes in the data collected
281 and study protocols followed, with a shift from uniaxial proprietary count outcomes
282 collected using accelerometers worn at the hip to triaxial raw accelerations measured
283 using wrist-worn accelerometers (30). We have developed a quick and simple method
284 to facilitate the comparison of group level estimates of children's MVPA from
285 uniaxial hip-worn count-based ActiGraphs to triaxial raw acceleration data measured
286 at the wrist processed using the open source R-package, GGIR (32,33). The method
287 was developed using the GENEActiv wrist-worn accelerometer, but evidence
288 suggests it will also be applicable to raw acceleration measured at the wrist using the
289 ActiGraph and processed in GGIR (27).

290

291 Mean biases for optimal pairings of ENMO thresholds and ActiGraph MVPA cut-
292 points were relatively low (test sample: mean bias = $19.4 \pm 4.2\%$ of mean MVPA;
293 cross-validation sample: mean bias = $17.8 \pm 4.9\%$ of mean MVPA) indicating good
294 group level agreement, excluding high ActiGraph MVPA cut-points assessed using a
295 60 s epoch where mean bias was high relative to the low means (29% in the test
296 sample, 60% in the cross-validation sample). Similarly, the ICC's for optimal pairings
297 were all between 0.61 and 0.76 in the test and cross-validation sample, indicating
298 good agreement (13), with the exception of the high ActiGraph MVPA cut-points
299 assessed using a 60 s epoch in the cross-validation sample (ICC = 0.42). The 95%
300 limits of agreement were moderate to large indicating that individual level

301 comparisons are not advised. The MVPA recorded in the cross-validation sample was
302 lower than the test samples, in particular when applying high cut-points with a 60 s
303 epoch (Figures 1 and 2); this may have contributed to the lower robustness for the
304 high cut-point/60 s epoch combination. Hildebrand et al. (16) developed an MVPA
305 threshold of approximately 200 mg for use with wrist-worn ActiGraph and
306 GENEActiv accelerometers. Based on the current findings, MVPA determined by
307 applying the 200 mg threshold to wrist-worn accelerometer data should compare best
308 to MVPA determined from low cut-points (23) applied to hip-worn ActiGraph data,
309 irrespective of epoch. Overall, the cross-validation suggests that agreement may be
310 closest when comparing ENMO 150+, 200+ and 250+ thresholds to MVPA estimated
311 from ActiGraph 15 s epoch data processed using very low, low and medium cut-
312 points, respectively.

313

314 The potential for application of these comparisons is extensive. By 2010, over 46000
315 physical activity datasets from hip-worn ActiGraphs had been collated in the ICAD,
316 approximately 19000 from children aged 9-12 y, (28). More recently, the
317 International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)
318 collected data on 6000 children, aged 9-11 y from 12 countries across five diverse
319 regions of the world using hip-worn ActiGraphs (18). The latter study collected
320 triaxial raw acceleration data using ActiGraph GT3X+ and has developed novel
321 analytical tools for application to the raw acceleration data, e.g. to determine sleep
322 duration (1), but as the hip was the measurement site these data have also been
323 summarized in proprietary counts and analyzed using count cut-points (19). Since
324 NHANES moved to assessing physical activity using triaxial raw acceleration data
325 measured at the wrist for the NHANES cycles 2011-2012 and 2013-2014 (30), many

326 other large studies have also used wrist-worn accelerometers. For example, data have
327 already been collected in: ≈ 4000 children, aged 9-11 y, in the Child Health
328 Checkpoint (Melbourne, Australia (34)); ≈ 1800 girls, aged 11-14 y, in Girls Active
329 (Leicester, UK (10)); ≈ 1000 children, aged 8-11 y in the Cork Children's Lifestyle
330 Study (Ireland (20)); and ≈ 4000 children aged 7 y in the Pelotas Birth cohort (Brazil
331 (9)). The comparisons presented will facilitate interpretation of these data in relation
332 to past estimates of children's MVPA, e.g. from NHANES, ICAD and ISCOLE.

333

334 The data collated for this study came from three different sources and were collected
335 using two differing protocols. Study 1 took place in South Australia, used a 24 h wear
336 protocol and summarized the GENEActiv ENMO data in 5 s epochs. Studies 2 and 3
337 took place in the UK, used a waking time only protocol and summarized the ENMO
338 data in 1 s epochs. While the results were similar across studies and the cross-
339 validation (study 3 data) showed the agreement statistics were robust, these
340 differences limit the internal validity of the study. However, the external validity is
341 enhanced, as results are applicable to ENMO data collected in 1 s and 5 s epochs
342 using either a waking or 24 h protocol. Given the outcome of interest was MVPA it is
343 not surprising that the use of a waking or 24 h protocol did not impact on the results.

344

345 ActiGraph epochs of ≤ 5 s, 15 s and 60 s were considered, whereas ENMO data were
346 only summarized into ≤ 5 s epochs. The use of longer epochs in the past was due to
347 the memory limitations of accelerometers (30). Accelerations were integrated onboard
348 the accelerometer and stored in epochs, normally 60 s epochs, to ensure one week of
349 data could be stored before downloading the data. Due to technological progress
350 onboard memory is no longer a problem and raw acceleration data collected at 100 Hz

351 can be stored for one week. Therefore it is unlikely that epochs longer than the default
352 5 s epoch in GGIR will be used, particularly when assessing children's activity where
353 the typical sporadic activity patterns are best captured using short epochs (22). It
354 should be noted that the participants in this study were from a relatively narrow age
355 range and the results cannot be generalized beyond the 9-12 y age group tested.

356

357 In summary, this study indicates that, in 9-12 y old children, time accumulated above
358 the appropriate incremental ENMO threshold has good agreement at a group level
359 with a range of widely used very low to high ActiGraph MVPA cut-points. It is
360 important to note this is a simple pooled-data comparison study that enables group
361 level comparisons, but individual level comparisons are not advised. We recommend
362 that when processing triaxial raw acceleration wrist accelerometer data using GGIR,
363 the times accumulated above ENMO thresholds ranging from ≥ 100 to ≥ 400 mg, or in
364 incremental acceleration bins (e.g. 9), are presented. As well as providing an activity
365 profile, this will enable the reader to quickly and simply compare the findings to past
366 estimates of children's MVPA from hip-worn ActiGraph data across a range of
367 widely used cut-points.

368

369 **Acknowledgements**

370

371 Study 1 was funded by the University of South Australia and Studies 2 and 3 were
372 funded by Liverpool John Moores University. AR is with the National Institute for
373 Health Research (NIHR) Diet, Lifestyle & Physical Activity Biomedical Research
374 Unit based at University Hospitals of Leicester and Loughborough University, the
375 National Institute for Health Research Collaboration for Leadership in Applied Health

376 Research and Care – East Midlands (NIHR CLAHRC – EM) and the Leicester
377 Clinical Trials Unit. The views expressed are those of the authors and not necessarily
378 those of the NHS, the NIHR or the Department of Health. DPC is funded by an
379 Australian Research Council (ARC) Discovery Early Career Researcher Award
380 (DE140101588). The results of the present study do not constitute endorsement by the
381 authors or the American College of Sports Medicine of the products described in this
382 article. The results of the study are presented clearly, honestly, and without
383 fabrication, falsification, or inappropriate data manipulation. There are no conflicts of
384 interest.

385 **References**

386

- 387 1. Barreira TV, Schuna JM, Jr., Mire EF, et al. Distinguishing children's
388 nocturnal sleep using 24-hour waist accelerometry. *Med Sci Sports Exerc*
389 2015; 47: 937–943.
- 390 2. Bell JA, Hamer M, van Hees VT, Singh-Manoux, A, Kivimäki, Sabia S.
391 Healthy obesity and objective physical activity. *Am Soc Nutr* 2015 doi:
392 10.3945/ajcn.115.110924.
- 393 3. Bland JM, Altman GA. Statistical methods for assessing agreement between
394 two methods of clinical measurement. *Lancet*. 1986;1(8476)307-310.
- 395 4. Bornstein DB, Beets MW, Byun W et al. Equating accelerometer estimates of
396 moderate-to-vigorous physical activity: in search of the Rosetta Stone. *J Sci*
397 *Med Sport* 2011; 14: 404-410.
- 398 5. Brazendale K, Beets MW, Bornstein DB et al. Equating accelerometer
399 estimates among youth: The Rosetta Stone 2. *J Sci Med Sport* 2016; 19: 242-
400 249.
- 401 6. Buman, M.P., Hu, F., Newman, E., Smeaton, A.F., Epstein, D.R. Behavioral
402 periodicity detection from 24 h wrist accelerometry and associations with
403 cardiometabolic risk and health-related quality of life. *BioMed Research Int*
404 2016; 2016:4856506. doi: 10.1155/2016/4856506. Epub 2016 Jan 31.
- 405 7. Colley RC, Garriguet D, Janssen I, Craig, C.L., Clarke, J., Tremblay, M.S.
406 Physical activity of Canadian adults: Accelerometer results from the 2007 to
407 2009 Canadian Health Measures Survey. *Health Reports* (Statistics Canada,
408 Catalogue 82-003) 2011; 22(1): 7-14.

- 409 8. Colley, R.C., Garriguet, D., Janssen, I., Craig, C.L., Clarke, J., Tremblay, M.S.
410 Physical activity of Canadian children and youth: Accelerometer results from
411 the 2007 to 2009 Canadian Health Measures Survey. *Health Reports*
412 (Statistics Canada, Catalogue no. 82-003). 2011; 22(1): 15-23.
- 413 9. da Silva ICM, van Hees VT, Ramires VV et al. Physical activity levels in
414 three Brazilian birth cohorts as assessed with raw triaxial wrist accelerometry.
415 *Int J Epidemiol.* 2014;43(6):1959-1968.
- 416 10. Edwardson CL, Harrington DM, Yates T et al. A cluster randomized
417 controlled trial to investigate the effectiveness and cost effectiveness of the
418 ‘Girls Active’ intervention: a study protocol. *BMC Public Health* 2015
419 15:526. doi: 10.1186/s12889-015-1886-z.
- 420 11. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of
421 two objective measures of physical activity for children. *J Sports Sci.*
422 2008;26:1557–65.
- 423 12. Fairclough SJ, Noonan R, Rowlands AV, van Hees V, Knowles Z, Boddy LM.
424 Wear compliance and activity in children wearing wrist and hip mounted
425 accelerometers. *Med Sci Sports Exerc.* 2016; 48: 243-253. doi:
426 10.1249/MSS.0000000000000771.
- 427 13. Fleiss J. *The Design and Analysis of Clinical Experiments.* New York: John
428 Wiley & Sons, 1986, p1-31.
- 429 14. Freedson PS, John D. Comment on “‘Estimating Activity and Sedentary
430 Behaviour from an Accelerometer on the Hip and Wrist’”. *Med Sci Sports*
431 *Exerc.* 2013; 45(5): 962 – 963

- 432 15. Guinhouya BC, Samouda H, de Beaufort C. Level of physical activity among
433 children and adolescents in Europe: a review of physical activity assessed
434 objectively by accelerometry. *Public Health* 2013; 127: 301-311.
- 435 16. Hildebrand M, Van Hees VT, Hansen BH, Ekelund U. Age-Group
436 Comparability of Raw Accelerometer Output from Wrist- and Hip-Worn
437 Monitors. *Med Sci Sport Exerc.* 2014; 46(9): 1816-1824. doi: 10.1249/MSS.
438 0000000000000289.
- 439 17. Joint Health Surveys Unit, National Centre for Social Research and University
440 College London Research Department of Epidemiology and Public Health.
441 *The Health Survey for England 2008. Volume 1: Physical Activity and Fitness.*
442 Leeds, United Kingdom: NHS Information Centre for Health and Social Care;
443 2009. ([http://www.hscic.gov.uk/catalogue/PUB00430/heal-surv-phys-acti-fitn-](http://www.hscic.gov.uk/catalogue/PUB00430/heal-surv-phys-acti-fitn-eng-2008-rep-v2.pdf)
444 [eng-2008-rep-v2.pdf](http://www.hscic.gov.uk/catalogue/PUB00430/heal-surv-phys-acti-fitn-eng-2008-rep-v2.pdf)). (Accessed March 31, 2016).
- 445 18. Katzymarzyk PT, Barreira TV, Broyles ST et al. The International Study of
446 Childhood Obesity, Lifestyle and the Environment (ISCOLE): design and
447 methods. *BMC Public Health* 2013 13:900. doi: 10.1186/1471-2458-13-900.
- 448 19. Katzymarzyk PT, Barreira TV, Broyles ST et al. Relationship between
449 lifestyle behaviors and obesity in children ages 9–11: Results from a 12-
450 country study. *Obesity* 2015; 23:1696-1702. doi: 10.1002/oby.21152
- 451 20. Keane E, Kearney PM, Perry IJ, Browne GM, Harrington JM. Diet, physical
452 activity, lifestyle behaviours, and prevalence of childhood obesity in Irish
453 children: the Cork Children’s Lifestyle Study Protocol. *JMIR Res Protoc* 2014
454 3(3) e44. doi: 10.2196/resprot.3140

- 455 21. Kearney PM, Harrington JM, McCarthy VJC, Fitzgerald AP, Perry I. Cohort
456 Profile: The Cork and Kerry Diabetes and Heart Disease Study. *Int J*
457 *Epidemiol* 2013; 42:1253-1262.
- 458 22. Nilsson A, Ekelund U, Yngve A, Sjostrom M. Assessing physical activity
459 among children with accelerometers using different time sampling intervals
460 and placements. *Ped Exerc Sci* 2002; 14: 87–96.
- 461 23. Pate RR, Almeida MJ, McIver KL et al. Validation and calibration of an
462 accelerom-eter in preschool children. *Obesity* 2006; 14(11): 2000–2006.
- 463 24. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of
464 physical activity monitors in children. *Obes Res.* 2002; 10(3): 150–7.
- 465 25. Rowlands, A.V., Olds, T.S., Hillsdon, M. et al. Assessing sedentary behaviour
466 with the GENEActiv: Introducing the Sedentary Sphere. *Med Sci Sport Exerc.*
467 2014; 46: 1235-1247.
- 468 26. Rowlands AV, Rennie K, Kozarski R et al. Children’s physical activity
469 assessed with wrist- and hip-worn accelerometers. *Med Sci Sport Exerc.*
470 2014; 46: 2308-2316. DOI: 10.1249/MSS.0000000000000365.
- 471 27. Rowlands AV, Yates T, Davies M, Khunti K, Edwardson CL. Raw
472 accelerometer data analysis with GGIR R-package: Does accelerometer brand
473 matter? *Med Sci Sport Exerc.* 2016. In press.
- 474 28. Sherar L, Griew P, Esliger D et al. International children’s accelerometry
475 database (ICAD): Design and methods. *BMC Public Health* 2011; 11:485. doi:
476 10.1186/1471-2458-11-485
- 477 29. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M.
478 Physical activity in the United States measured by accelerometer. *Med Sci*
479 *Sport Exerc.* 2008; 40: 181-188.

- 480 30. Troiano, R.P., McClain, J.J., Brychttta, R.J., Chen, K.Y. Evolution of
481 accelerometer methods for physical activity research. *Br J Sports Med* 2014;
482 48: 1019-1023.
- 483 31. Trost SG, Pate RR, Sallis JF, et al. Age and gender differences in objectively
484 measured physical activity in youth. *Med Sci Sports Exerc.* 2002; 34: 350–5.
- 485 32. van Hees VT, Fang Z, Langford J et al. Auto-calibration of accelerometer data
486 for free-living physical activity assessment using local gravity and
487 temperature: an evaluation on four continents. *J Appl Physiol.* 2014; 117(7):
488 738-744. doi: 10.1152/jappphysiol.00421.2014.
- 489 33. van Hees VT, Gorzelniak L, Dean León EC et al. Separating Movement and
490 Gravity Components in an Acceleration Signal and Implications for the
491 Assessment of Human Daily Physical Activity. *PLoS ONE.* 2013; 8(4):
492 e61691. doi: 10.1371/journal.pone.0061691.
- 493 34. Wake M, Clifford S, York E et al. Introducing Growing Up in Australia's
494 Child Health CheckPoint: A physical health and biomarkers module for the
495 Longitudinal Study of Australian Children. *Fam Matters* 2014; 94: 15-23
- 496

497 **Figure legends**

498 Figure 1. Time recorded above each of the intensity thresholds by the hip-worn
499 ActiGraph (very low, low, medium and high MVPA count cut-points) and the wrist-
500 worn GENEActiv (100+, 150+, 200+, 250+, 300+, 350+, 400+ mg ENMO
501 thresholds) by epoch (ActiGraph ≤ 5 s, 15 s, 60 s; GENEActiv ≤ 5 s) for the total
502 sample. Boxplot shows the median (dark line), 25th and 75th percentiles (box), lowest
503 and highest values within 1.5 times the inter-quartile range (whiskers) and outliers
504 (circles).

505

506 Figure 2. The time recorded above each of the intensity thresholds by the hip-worn
507 ActiGraph (very low (a), low (b), medium (c) and high (d) MVPA count cut-points)
508 and the wrist-worn GENEActiv acceleration threshold by epoch (ActiGraph ≤ 5 s, 15
509 s, 60 s; GENEActiv ≤ 5 s) for each of the optimal pairings in the cross-validation
510 sample. Boxplots show the median (dark line), 25th and 75th percentiles (box), lowest
511 and highest values within 1.5 times the inter-quartile range (whiskers) and outliers
512 (circles).

513

514 Figure 3. Kernel density plots showing the distribution of time recorded above each of
515 the intensity thresholds by the hip-worn ActiGraph and the wrist-worn GENEActiv
516 for each of the optimal pairings (total sample). The columns represent cut-points (left
517 to right: very low, low, medium, high) and the rows represent ActiGraph epochs (top
518 to bottom: ≤ 5 s, 15 s, 60 s)

519

520 **List of Supplemental Digital Content**

521 Supplemental Digital Content 1. Docx

522 Table 1. Participant characteristics (mean \pm standard deviation (SD))

Study	Valid N (boys)	Age (y)	Height (cm)	Mass (kg)
1	51 (26)	11.3 \pm 0.6	148.7 \pm 6.8	44.1 \pm 11.2
2	108 (42)	10.0 \pm 0.3	139.1 \pm 7.6	35.4 \pm 8.5
1 & 2 (Test sample)	159 (68)	10.4 \pm 0.7	142.2 \pm 8.6	38.3 \pm 10.3
3 (Cross-validation sample)	79 (5)	10.3 \pm 0.6	142.1 \pm 7.8	36.9 \pm 8.6
Total sample	238 (103)	10.4 \pm 0.7	142.2 \pm 8.3	37.8 \pm 9.7

523

524 Table 2. Agreement between each hip-worn ActiGraph cut-point and each wrist-worn GENEActiv ENMO threshold by epoch length in the test sample
525 (N=159)

HIP ActiGraph cut-point	WRIST GENEActiv ENMO ^e (mg)	ActiGraph ≤5 s epoch			ActiGraph 15 s epoch			ActiGraph 60 s epoch		
		ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^g (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)
Very low ^a	100+	0.29 (-0.09, 0.62)	55.9	59.6	0.43 (-0.10, 0.72)	42.8	58.7	0.47 (-0.08, 0.75)	40.7	61.6
	150+	0.71 (0.62, 0.78)	-2.9	43.9	0.67 (0.33, 0.82)	-15.9	44.1	0.65 (0.31, 0.81)	-18.0	49.5
	200+	0.36 (-0.10, 0.69)	-34.6	39.6	0.30 (-0.08, 0.65)	-47.7	41.8	0.31 (-0.09, 0.65)	-49.8	49.4
	250+	0.18 (-0.06, 0.49)	-53.0	39.4	0.16 (-0.05, 0.46)	-66.0	43.4	0.18 (-0.06, 0.48)	-68.1	52.2
	300+	0.11 (-0.04, 0.36)	-64.3	40.0	0.10 (-0.04, 0.35)	-77.3	45.3	0.12 (-0.05, 0.37)	-79.4	54.9
	350+	0.08 (-0.03, 0.28)	-71.8	40.8	0.08 (-0.03, 0.28)	-84.9	47.1	0.09 (-0.04, 0.30)	-87.0	57.1
	400+	0.06 (-0.03, 0.23)	-77.2	41.7	0.06 (-0.03, 0.23)	-90.3	48.7	0.07 (-0.04, 0.24)	-92.4	59.0
Low ^b	100+	0.16 (-0.06, 0.44)	80.4	61.6	0.18 (-0.06, 0.49)	79.8	60.9	0.17 (-0.06, 0.47)	86.4	63.0
	150+	0.53 (0.01, 0.77)	21.6	41.2	0.59 (0.05, 0.81)	21.0	40.6	0.53 (-0.07, 0.79)	27.6	42.7
	200+	0.67 (0.41, 0.80)	-10.1	32.7	0.71 (0.44, 0.83)	-10.7	33.5	0.75 (0.67, 0.81)	-4.1	36.4
	250+	0.37 (-0.09, 0.70)	-28.5	30.1	0.41 (-0.10, 0.73)	-29.1	32.5	0.51 (-0.06, 0.77)	-22.5	36.1
	300+	0.22 (-0.06, 0.55)	-39.8	29.6	0.25 (-0.07, 0.59)	-40.4	33.3	0.33 (-0.10, 0.66)	-33.8	37.5
	350+	0.15 (-0.04, 0.44)	-47.3	29.9	0.18 (-0.06, 0.49)	-47.9	34.5	0.23 (-0.08, 0.56)	-41.3	39.0

	400+	0.11 (-0.04, 0.36)	-52.7	30.6	0.13 (-0.05, 0.41)	-53.3	35.9	0.18 (-0.07, 0.47)	-46.7	40.5
Medium ^c	100+	0.09 (-0.04, 0.29)	101.6	65.9	0.09 (-0.04, 0.31)	105.8	65.5	0.08 (-0.04, 0.28)	115.2	66.9
	150+	0.26 (-0.09, 0.59)	42.8	43.1	0.27 (-0.08, 0.60)	47.1	42.2	0.21 (-0.06, 0.54)	56.4	43.3
	200+	0.63 (0.30, 0.79)	11.1	31.7	0.61 (0.09, 0.82)	15.3	31.1	0.48 (-0.10, 0.77)	24.7	32.0
	250+	0.69 (0.48, 0.80)	-7.3	26.4	0.76 (0.69, 0.82)	-3.0	26.7	0.73 (0.59, 0.82)	6.4	27.7
	300+	0.46 (-0.10, 0.76)	-18.6	24.3	0.58 (0.00, 0.81)	-14.4	25.6	0.73 (0.61, 0.81)	-5.0	26.6
	350+	0.30 (-0.08, 0.65)	-26.1	23.6	0.41 (-0.10, 0.73)	-21.9	25.7	0.58 (0.10, 0.79)	-12.5	26.9
	400+	0.22 (-0.06, 0.55)	-31.5	23.6	0.30 (-0.08, 0.64)	-27.3	26.4	0.45 (-0.08, 0.73)	-17.9	27.6
High ^d	100+	0.05 (-0.03, 0.17)	122.0	71.3	0.04 (-0.03, 0.16)	130.4	72.1	0.03 (-0.02, 0.13)	139.5	73.9
	150+	0.12 (-0.05, 0.37)	63.3	47.1	0.10 (-0.05, 0.33)	71.7	47.8	0.07 (-0.04, 0.27)	80.7	49.6
	200+	0.28 (-0.09, 0.61)	31.6	33.4	0.21 (-0.07, 0.54)	40.0	34.1	0.15 (-0.05, 0.43)	49.0	35.6
	250+	0.54 (0.03, 0.77)	13.2	25.7	0.40 (-0.10, 0.71)	21.6	27.3	0.26 (-0.08, 0.59)	30.7	27.6
	300+	0.73 (0.65, 0.80)	1.8	21.5	0.60 (0.12, 0.80)	10.3	22.3	0.40 (-0.10, 0.71)	19.3	23.2
	350+	0.69 (0.46, 0.81)	-5.7	19.3	0.73 (0.64, 0.80)	2.7	20.2	0.54 (-0.02, 0.78)	11.8	20.8
	400+	0.55 (-0.04, 0.80)	-11.1	18.3	0.72 (0.64, 0.80)	-2.6	19.2	0.65 (0.36, 0.79)	6.5	19.5

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527

^aVery low = 1100 cpm, approximately equivalent to the 3 MET cut-point, age 11 y, age-specific criteria of the Freedson group, published by Trost et al. (31)
^bLow = 1680 cpm, Pate et al. (23)

528 ^cMedium = 2296 cpm, Evenson et al. (11)
529 ^dHigh = 3200 cpm, Puyau et al. (24)
530 ^eENMO = Euclidean Norm Minus One, the vector magnitude of acceleration corrected for gravity
531 ^fICC = Intra-class correlation coefficient
532 ^g95% CI = 95% confidence interval
533 ^hLoA = Limits of agreement
534 The ENMO threshold with the highest agreement for each ActiGraph count cut-point / epoch combination is highlighted in bold.
535

536 Table 3. Cross-validation sample: Agreement between the hip-worn ActiGraph and wrist-worn GENEActiv for the optimal ENMO threshold for each
 537 ActiGraph count cut-point / epoch combination (N = 79)

ActiGraph cut-point HIP	GENEActiv	ActiGraph ≤ 5 s epoch			ActiGraph 15 s epoch			ActiGraph 60 s epoch		
	ENMO ^e (mg) WRIST	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^g (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)
Very low ^a	150+	0.63 (0.46, 0.75)	7.0	39.4	0.71 (0.57, 0.80)	-5.9	39.1	0.69 (0.55, 0.80)	-6.2	42.6
Low ^b	200+	0.66 (0.51, 0.77)	-3.8	31.0	0.71 (0.58, 0.80)	-3.0	31.2	0.69 (0.55, 0.80)	5.3	32.8
Medium ^c	250+	0.64 (0.49, 0.76)	-3.6	25.7	0.70 (0.57, 0.80)	2.0	13.1			
	300+							0.69 (0.56, 0.79)	2.2	23.8
High ^d	300+	0.62 (0.46, 0.74)	2.7	21.5						
	350+				0.61 (0.33, 0.76)	5.5	18.7			
	400+							0.42 (-0.04, 0.69)	9.7	18.2

538
 539 ^aVery low = 1100 cpm, approximately equivalent to the 3 MET cut-point, age 11 y, age-specific criteria of the Freedson group, published by Trost et al. (31)
 540 ^bLow = 1680 cpm, Pate et al. (23)
 541 ^cMedium = 2296 cpm, Evenson et al. (11)
 542 ^dHigh = 3200 cpm, Puyau et al. (24)
 543 ^eENMO = Euclidean Norm Minus One, the vector magnitude of acceleration corrected for gravity
 544 ^fICC = Intra-class correlation coefficient
 545 ^g95% CI = 95% confidence interval
 546 ^hLoA = Limits of agreement
 547

548 Supplementary Table. Agreement between each hip-worn ActiGraph cut-point and each wrist-worn GENEActiv ENMO threshold by epoch length in
549 the total sample (N = 238)

HIP ActiGraph cut-point	WRIST GENEActiv ENMO ^e (mg)	ActiGraph ≤5 s epoch			ActiGraph 15 s epoch			ActiGraph 60 s epoch		
		ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^g (+/- min)	ICC ^f (95% CI ^g)	Mean bias (G-AG, min)	95% LoA ^h (+/- min)
Very low ^a	100+	0.27 (-0.09, 0.60)	57.5	59.6	0.36 (-0.10, 0.68)	44.5	57.1	0.44 (-0.09, 0.73)	43.0	59.6
	150+	0.70 (0.63, 0.76)	0.4	43.4	0.68 (0.57, 0.76)	-12.6	43.4	0.67 (0.45, 0.79)	-14.1	48.5
	200+	0.39 (-0.10, 0.70)	-30.5	38.6	0.34 (-0.10, 0.66)	-43.5	40.9	0.33 (-0.09, 0.66)	-45.0	48.0
	250+	0.19 (-0.06, 0.51)	-48.4	38.0	0.18 (-0.06, 0.48)	-61.4	42.2	0.18 (-0.06, 0.49)	-62.9	50.4
	300+	0.12 (-0.04, 0.39)	-59.4	38.5	0.12 (-0.05, 0.37)	-72.4	44.0	0.12 (-0.05, 0.37)	-73.9	52.8
	350+	0.09 (-0.04, 0.29)	-66.8	39.3	0.08 (-0.04, 0.29)	-79.8	45.7	0.09 (-0.04, 0.30)	-81.3	54.8
	400+	0.064 (-0.03, 0.24)	-72.0	40.2	0.07 (-0.04, 0.24)	-85.0	47.3	0.07 (-0.04, 0.25)	-86.5	56.6
Low ^b	100+	0.15 (-0.06, 0.43)	79.9	80.0	0.16 (-0.06, 0.46)	79.9	59.5	0.16 (-0.05, 0.45)	87.1	61.1
	150+	0.50 (-0.02, 0.75)	22.9	41.1	0.54 (-0.01, 0.78)	22.8	40.5	0.48 (-0.09, 0.76)	29.9	42.6
	200+	0.68 (0.51, 0.78)	-8.0	32.7	0.71 (0.54, 0.80)	-8.2	33.4	0.74 (0.68, 0.80)	-1.0	36.3
	250+	0.39 (-0.10, 0.71)	-25.9	29.7	0.42 (-0.10, 0.73)	-26.0	32.1	0.54 (0.01, 0.77)	-18.9	35.6
	300+	0.23 (-0.06, 0.56)	-36.9	29.0	0.25 (-0.07, 0.59)	-37.1	32.6	0.35 (-0.10, 0.67)	-29.9	36.6
	350+	0.15 (-0.05, 0.45)	-44.3	29.2	0.18 (-0.06, 0.48)	-44.4	33.7	0.25 (-0.09, 0.57)	-37.3	37.9

	400+	0.11 (-0.04, 0.37)	-49.5	29.7	0.13 (-0.05, 0.40)	-49.7	34.9	0.19 (-0.08, 0.49)	-42.5	39.3
Medium ^c	100+	0.08 (-0.04, 0.28)	99.9	66.1	0.08 (-0.04, 0.29)	104.6	64.0	0.07 (-0.03, 0.26)	114.4	65.5
	150+	0.25 (-0.09, 0.57)	42.8	42.9	0.25 (-0.08, 0.58)	47.4	42.1	0.19 (-0.06, 0.51)	57.3	43.4
	200+	0.60 (0.25, 0.77)	11.8	31.7	0.59 (0.10, 0.79)	16.5	33.4	0.43 (-0.10, 0.74)	26.3	32.5
	250+	0.68 (0.53, 0.78)	-6.1	26.4	0.74 (0.67, 0.79)	-1.4	26.7	0.69 (0.45, 0.81)	8.5	27.9
	300+	0.47 (-0.09, 0.75)	-17.1	24.0	0.55 (-0.02, 0.79)	-12.4	25.3	0.73 (0.66, 0.78)	-2.6	26.5
	350+	0.31 (-0.08, 0.65)	-24.5	23.2	0.38 (0.10, 0.71)	-19.8	25.2	0.61 (0.25, 0.78)	-9.9	26.5
	400+	0.22 (-0.06, 0.55)	-29.7	23.1	0.28 (-0.08, 0.61)	-24.9	25.7	0.48 (-0.03, 0.73)	-15.2	27.0
High ^d	100+	0.04 (-0.03, 0.17)	119.1	71.4	0.04 (-0.03, 0.15)	128.0	70.5	0.03 (-0.02, 0.12)	137.1	72.7
	150+	0.11 (-0.05, 0.36)	62.0	46.5	0.10 (-0.05, 0.31)	70.9	47.3	0.07 (-0.04, 0.24)	79.9	49.5
	200+	0.26 (-0.09, 0.58)	31.1	33.3	0.21 (-0.08, 0.52)	39.9	33.4	0.13 (-0.05, 0.40)	49.0	36.0
	250+	0.51 (0.02, 0.75)	13.2	25.7	0.40 (-0.09, 0.69)	22.1	26.3	0.23 (-0.08, 0.55)	31.1	28.0
	300+	0.71 (0.64, 0.77)	2.1	21.5	0.60 (0.30, 0.76)	11.0	22.1	0.35 (-0.10, 0.67)	20.1	23.4
	350+	0.68 (0.48, 0.79)	-5.2	19.2	0.70 (0.63, 0.76)	3.7	19.9	0.48 (-0.06, 0.75)	12.7	20.8
	400+	0.54 (-0.03, 0.78)	-10.5	18.1	0.65 (0.48, 0.76)	-1.6	18.7	0.59 (0.22, 0.36)	7.5	19.3

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551

^aVery low = 1100 cpm, approximately equivalent to the 3 MET cut-point, age 11 y, age-specific criteria of the Freedson group, published by Trost et al. (31)
^bLow = 1680 cpm, Pate et al. (23)

552 ^cMedium = 2296 cpm, Evenson et al. (11)

553 ^dHigh = 3200 cpm, Puyau et al. (24)

554 ^eENMO = Euclidean Norm Minus One, the vector magnitude of acceleration corrected for gravity

555 ^fICC = Intra-class correlation coefficient

556 ^g95% CI = 95% confidence interval

557 ^hLoA = Limits of agreement

558 The ENMO threshold with the highest agreement for each ActiGraph count cut-point / epoch combination in the test sample is highlighted in bold.

559

560





