

1 Original Article

2 Title: Real world, real people: Can we assess walking on a treadmill to establish step count
3 recommendations in adolescents?

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Abstract

Background: It is currently not known how much walking should be advocated for good health in an adolescent population. Step count recommendations for minimum time in moderate intensity activity have been translated predominantly from treadmill walking. The aim of this study was to compare the energy cost of walking on a treadmill with overground walking in adolescent girls. **Method:** Twenty six adolescent girls undertook resting metabolic measurements for individual determination of one MET using indirect calorimetry. Energy expenditure was subsequently assessed during treadmill and overground walking at slow, moderate and fast walking speeds for 4 – 6 minutes. Treadmill step rates were matched overground using a metronome. **Result:** The energy cost of treadmill walking was found to be significantly greater than and not equivalent to overground walking at 133step·min⁻¹ (equivalent to the fast walking pace) $\dot{V}O_2$ 3.90 [2.78 to 5.01] $P<0.001$, MAPE =18.18%, METs 0.77[0.54 to 1.00] $P<0.001$, MAPE =18.16%. The oxygen cost per step ($\dot{V}O_2$ ml· step⁻¹) was significantly greater and not equivalent on the treadmill at 120 and 133step·min⁻¹, 0.43 [0.12 to 0.56] $P<0.05$, MAPE =10.12%, 1.40[1.01 to 1.76] $P<0.001$, MAPE =17.64% respectively. **Conclusion:** The results suggest that there is a difference in energy cost per step of walking on a treadmill and overground at the same step rate. This should be considered when utilising the treadmill in energy expenditure studies. Studies which aim to provide step recommendations should focus on overground walking where most walking activity is adopted.

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Introduction

44 Adolescent girls are insufficiently active which has serious implications for their current
45 and future health (7, 41). Walking is recognised as an effective way of implementing regular,
46 health enhancing physical activity into the daily routine of the general population (27) and in an
47 adolescent population walking is a convenient alternative to active play and sports participation.
48 In order to promote walking, researchers have sought to identify the required step count and step
49 rate to achieve a health-enhancing number of steps and intensity of walking (1, 3, 24, 30, 35).

50 In adults 10,000 steps/day is considered sufficient to maintain health and this is
51 considered equivalent to normal habitual activity (7,000 steps) plus 30 min of moderate intensity
52 activity (3,000-4,000 steps) (33). There is conflicting evidence with regard to the number of
53 steps required for health in children. Tudor-Locke et al (33) reported that 12,000 and 15,000
54 steps/day were sufficient for good health for girls and boys respectively whereas Duncan,
55 Schofield and Duncan (9) reported 13,000 (girls) and 16,000 (boys) steps·day⁻¹. Although
56 useful, these recommendations are appropriate for children but not for adolescents and whilst
57 identifying the number of steps recommended is important, it is also pertinent to establish the
58 step rate so that walking can be undertaken at a level of intensity beneficial for health. Step rate
59 corresponding to moderate intensity walking in adults has been investigated in at least five prior
60 studies (1, 3, 24, 30, 35). These studies were conducted in well controlled laboratory conditions
61 on a treadmill (1, 24, 35), overground (3) and using both treadmill and overground (30). From
62 these studies it has been suggested that a step rate of ≥ 100 steps·min⁻¹ is associated with
63 moderate to vigorous intensity walking in adults and therefore recommended for health.

64 With regard to the stepping rate required to promote moderate intensity walking in
65 adolescent girls there is limited data. Seven youth studies have provided data on step rate that
66 reflect intensity of walking (11, 12, 14, 17, 22, 26, 34). While five studies have investigated
67 walking on a treadmill (11, 12, 22, 26, 34) only one has investigated walking overground (17)
68 and one has cross-validated treadmill walking overground (although treadmill step rate data were
69 used) (14). Further only three of these studies (14, 26, 34) have directly assessed walking
70 intensity (energy expenditure). However, it should also be noted that two of these studies (14,
71 34) have used estimated resting energy expenditure in participants under 18yrs to calculate
72 METs. It is therefore difficult to accurately extrapolate step rate corresponding to moderate and
73 moderate to vigorous intensity walking, due to the different intensity markers used and lack of
74 direct assessment of energy expenditure.

75 A major limitation with several of these studies is the assumption that treadmill walking
76 is equivalent in energy cost to overground walking. There are clear advantages to using a
77 treadmill to assess walking, for example walking is not limited by space or environmental
78 conditions, and speed can more easily be controlled. However, in adults, there is evidence to
79 suggest that treadmill walking may overestimate the energy cost of walking overground (4, 6).
80 For example, individuals tend to adopt an unnatural and less energy efficient walking pattern on
81 a treadmill (4, 6). Consequently, the recommendation of 100 steps·min⁻¹ may be an
82 underestimation of the stepping rate associated with moderate intensity walking overground in
83 adults. It is not known if walking on a treadmill accurately replicates walking overground in
84 adolescent girls. Thus, in order to undertake studies to identify step guidelines in an adolescent
85 population based on treadmill studies, it is important to first determine whether treadmill and
86 overground walking are similar in terms of energy cost for the same step rate. The aim of this

87 study was therefore to compare the energy cost of walking on a treadmill with overground
88 walking in adolescent girls.

89 **Methods**

90 A convenience sample of twenty-six adolescent girls aged between 12-15 yrs (mean \pm SD
91 age = 14.01 \pm 0.56 yrs) took part in the study which was given ethics approval by the institution's
92 research ethics committee. Data were collected from each participant on the same day, in the
93 following order: a) anthropometric and resting metabolic rate measurements; b) three 6-min
94 treadmill walking trials; c) three overground walking trials lasting a minimum of 4 min.

95 *Measures*

96 *Anthropometry*

97 Stature and body mass were measured using a seca portable stadiometer and seca 761 flat
98 scales (seca, Birmingham, UK) respectively. Measurements were made according to the
99 procedures recommended by the International Society for Advancement of Kinanthropometry.
100 Measurements were repeated twice, and the mean was taken as the true measurement.

101 *Metabolic measures*

102 Gas exchange variables and heart rate were measured and displayed online using the
103 Oxycon mobile portable metabolic cart (MS-CPX, Viasys Healthcare, Hoehberg, Germany). The
104 participants breathed through an appropriately sized tight-fitting mask (Hans Rudolph ING,
105 USA) with the total dead space volume, including turbine, of 120ml. The gas analyser, volume
106 sensor and turbine were calibrated according to the manufacturer's specifications before each

107 test. Oxygen uptake ($\dot{V}O_2$) was measured continuously on a breath-by-breath basis and averaged
108 over 5 seconds for data analysis.

109 *Step count measures*

110 Step counts were measured by real-time direct observation, using a hand tally counter
111 (observed by two researchers). This method is considered to be an accurate way of directly
112 measuring steps and is often used as a criterion measure against which other step measurement
113 methods are compared (24, 30).

114 **Experimental protocol**

115 For the assessment of resting metabolic rate, $\dot{V}O_2$ was measured over a 20-min period
116 while the participant sat quietly watching a DVD. $\dot{V}O_2$ was subsequently assessed during
117 treadmill and overground walking trials. During the treadmill trials, participants completed three
118 6 minute controlled trials at 2, 3 and 4 mph respectively. The treadmill incline was set at 0%,
119 which is deemed appropriate at walking speeds <6.5mph as there is no wind resistance (19).
120 Following a \approx 4minute warm up where participants practiced stepping onto and off the treadmill
121 at all speeds, the participants were fitted with a heart rate monitor and the Oxycon metabolic
122 system (weighing 1.2 kg), held by a harness, which slipped over the girls' shoulders and clipped
123 into place securely without restricting movement. The participants were then asked to stand on
124 the treadmill with a foot on either side of the belt, while it was set to the appropriate speed.
125 Following a 5 second countdown, the participant stepped onto the treadmill and began walking.
126 The event marker on the metabolic cart was pressed immediately prior to and following each
127 trial, for later reference in the $\dot{V}O_2$ data. Treadmill speed was calibrated using a digital
128 tachometer, twice during the first minute of each treadmill walking trial. Step rate was measured

129 using two methods; total observed step count over the 6 minute trial, measured by hand tally and
130 a 60 second stride rate taken during the fifth minute of each trial, which allowed an overground
131 stride rate (stepping speed) to be prescribed. A 5-s countdown was given to each participant
132 indicating when she should step off the treadmill. Within each trial, heart rate was recorded
133 during the last 15 seconds of each minute, for determination of steady state (defined as a change
134 of less than 5 beats per min) (2). An average of 5 minutes of static rest was taken between trials
135 and 20 minutes between each walking mode (treadmill and overground).

136 Following the treadmill walking trials, participants completed three overground walking
137 trials on a 34m indoor oval track, which was marked out. The treadmill step rate obtained from
138 the 60-s hand tally count was prescribed for the overground walking trials to replicate the
139 treadmill speed. This was accomplished by setting a clip-on metronome to the treadmill step rate
140 and asking each participant to match their step rate to the metronome. Total number of steps
141 were measured, using real time direct observation hand tally count by means of a researcher
142 walking behind each participant counting steps taken. For logistical reasons, the overground
143 walking trials were not limited to 6 minutes, as a complete number of laps had to be taken in
144 order to provide a known distance from which the average walking speed could be calculated.
145 Participants started and finished each trial at the same point and were informed by the researcher
146 halfway round the last lap to stop at the finish line. In order to obtain steady state data, the
147 participant walked for between 4 and 6 minutes. As with the treadmill trials the event marker on
148 the metabolic cart was pressed immediately prior to and following each trial, for later reference
149 in the $\dot{V}O_2$ data, and heart rate data were recorded during the last 15 seconds of each minute of
150 the trials, to determine steady state.

151

152 **Data analysis**

153 Hand tally counts observed from the two researchers were compared and an average
154 taken if an exact match was not observed. Where step rate overground did not match the
155 prescribed step rate (± 10 steps \cdot min $^{-1}$), data were excluded from further analysis ($n=5$). One MET
156 was calculated individually as the mean $\dot{V}O_2$ for 5 min between the 10th and 14th min of the 20-
157 min seated period using the Weir equation (39). For each walking trial (treadmill and
158 overground), $\dot{V}O_2$ was determined for the final 2 min, and subsequently converted into METs.
159 Oxygen cost per step was calculated for each walking trial. Descriptive statistics were expressed
160 as mean \pm standard deviation for the dependent variables. Differences in treadmill and
161 overground response variables ($\dot{V}O_2$ and METs) were tested using a factorial repeated measures
162 analysis of variance (ANOVA) and Bonferroni corrected post hoc pairwise comparisons. Partial
163 eta-squared values (η^2_p) are reported as effect size estimates. The magnitude of the effect size for
164 the partial eta-squared is 0.01 (small), 0.06 (medium), and 0.14 (large) (5). Agreement between
165 the treadmill and overground response variables was also tested. Pearson correlations tested
166 relative accuracy and initial agreement was obtained by Mean absolute percent error (MAPE).
167 Equivalence testing using the TOST method was used to determine group level agreement
168 (8,32). It is important with this testing approach to specify appropriate equivalence zones (8).
169 However, there is no conclusive standard (21), therefore the equivalence zone was set at 10%.
170 This is in line with prior studies (20, 21, 31, 40) which have used this method of analysis within
171 physical activity research. All analyses were conducted using PASW Statistics version 18.0.0
172 (IBM Corp., Somers, NY). With exception of the Equivalence analyses which were conducted
173 using Jamovi (18) version 0.8. Statistical significance was set at $p < 0.05$.

174

175 **Results**

176 Twenty-one participants successfully completed all overground walking trials at the
177 prescribed step rate to replicate treadmill walking speed. Five participants were excluded from
178 further analysis as their step rate overground did not match the prescribed step rate (± 10
179 steps \cdot min $^{-1}$). There were no significant differences in physical characteristics and other outcome
180 variables measured, between those participants that were not included and those included in the
181 final analysis. Participants' physical characteristics and resting measures are presented in table 1.

182 [Table 1]

183 **Treadmill and overground response parameters**

184 Table 2 presents response parameters during each walking trial. The results of the
185 ANOVA show a significant main effect of condition (treadmill and overground walking) $F(1,$
186 $19) = 10.74, P < 0.01, \eta^2_p = 0.58$; speed $F(2, 38) = 243.15 P < 0.01 \eta^2_p = 0.96$ and interaction $F(2,$
187 $38) = 71.16 P < 0.01 \eta^2_p = 0.78$ on $\dot{V}O_2$ (ml \cdot kg $^{-1}\cdot$ min $^{-1}$) and a significant main effect of condition F
188 $(1, 19) = 10.94, P < 0.01, \eta^2_p = 0.36$ speed $F(2, 38) = 125.75 P < 0.01, \eta^2_p = 0.86$ and interaction F
189 $(2, 38) = 70.91 P < 0.01, \eta^2_p = 0.78$ on METs. Significant differences between treadmill and
190 overground walking were apparent at step rates (steps \cdot min $^{-1}$) equivalent to the fast walking speed
191 only. Despite matching step rate (steps \cdot min $^{-1}$), walking speed at slow and fast pace was
192 significantly different between conditions. The overground walking pace was significantly faster
193 than treadmill walking in the slow walking trials and significantly slower in the fast walking
194 trials.

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196

197 Treadmill and Overground agreement

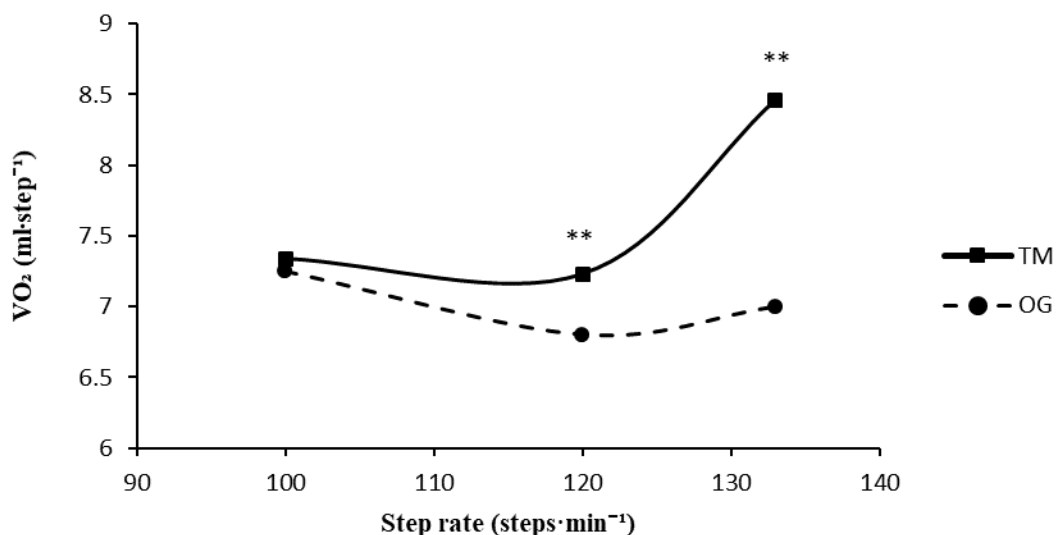
198 Treadmill $\dot{V}O_2$ were moderately correlated with overground $\dot{V}O_2$ at all walking speeds
 199 (slow, moderate and fast) respectively ($r = 0.54, P=0.01, r = 0.64, P <0.001, r = 0.54, P =0.01$).
 200 Treadmill METs were moderately correlated with overground METs ($r=0.59 P<0.001$) at the
 201 slow walking speed and strongly correlated ($r = 0.81, P <0.001, r = 0.77, P <0.001$) at the
 202 moderate and fast walking speed. The MAPE was 10.92%, 8.8%, 18.18% and 10.95%, 9.25%,
 203 18.16% for $\dot{V}O_2$ and METs at slow, moderate and fast walking speeds respectively. Table 3
 204 presents the 10% equivalence zones and the associated 95% CI mean difference for each
 205 response variable. Treadmill walking was deemed equivalent to overground walking at 10% for
 206 $\dot{V}O_2$ and METs at slow and moderate walking speeds. Treadmill walking required a significantly
 207 greater energy cost and was not equivalent in terms of $\dot{V}O_2$ and METs when compared to
 208 overground walking during the fast walking trials.

209 [Table 2]

210 [Table 3]

211 Oxygen Cost per Step

212 Figure 1 presents the oxygen cost per step, ($\dot{V}O_2$ ml· step⁻¹) during each walking trial.
 213 Results of the ANOVA show a significant main effect of condition (treadmill and overground
 214 walking) $F(1, 20) = 10.99, P <0.01, \eta^2_p=0.35$ speed $F(2,40) = 22.98 P <0.01, \eta^2_p=0.53$ and
 215 interaction $F(2, 40) = 44.99 P <0.01, \eta^2_p=0.69$ on $\dot{V}O_2$ (ml·step⁻¹). The oxygen cost per step
 216 was significantly greater and not equivalent to overground (Table 3) during the moderate and fast
 217 treadmill walking trials.



218

219 **Figure 1.** Comparison of the oxygen cost per step for the mean step rates during each walking
 220 trial for treadmill and overground walking.

221 TM = treadmill; OG = overground

222 **significantly higher than overground walking ($p < 0.01$)

223

224 Discussion

225 In order to determine whether walking can be assessed on a treadmill to establish step
 226 rate recommendations, the current study has compared the energy cost for equivalent step rates
 227 during treadmill and overground walking in a group of adolescent girls. The results suggest that
 228 the energy cost of walking on a treadmill is greater than and not equivalent to walking
 229 overground at step rates thought to be representative of moderate to vigorous intensity walking in
 230 the youth population (11, 17, 26, 34). Although the energy cost for equivalent step rates were
 231 compared, rather than walking speed per se, the results of the current study are consistent with
 232 the findings of Parvataneni, Ploeg, Olney and Brouwer (28), Dal et al., (6) and Berryman et al.,
 233 (4) who observed a greater metabolic energy cost during treadmill walking when compared to

234 overground walking at both pre-selected (4) and self-selected (6, 28) walking speeds in adults (6)
235 and older adults (4, 28).

236

237 **Step rate, Speed, Energy Cost Relationship**

238 The mechanisms underlying the higher metabolic energy cost observed during treadmill
239 walking in comparison to overground walking are complex and not well understood (4). Holt,
240 Hamill and Andres (15) suggested that when individuals walk overground in a natural setting
241 (i.e. real world setting) they adopt a preferred walking speed and step rate (frequency) to
242 minimise the metabolic energy cost and maintain energy efficiency. Based on this hypothesis it
243 has been suggested that the relationship between oxygen cost and step rate gives a U-shaped
244 curve when walking speed is kept constant (15,16). Further Rose, Ralston and Gamble (29)
245 suggested that during self-selected walking overground an individual's arms, legs and trunk are
246 coordinated in such a manner that keeps vertical displacement to a minimum, thus maximizing
247 metabolic economy. Therefore, when individuals are forced to walk at a slower or faster pace
248 (e.g. on a treadmill), energy efficiency is reduced. While step rate to match walking speed
249 between the two modes (treadmill and overground) was prescribed rather than self-selected in
250 the current study, a mismatch in walking speed for the same step rate was observed during the
251 slow and fast walking trials between the two modes (i.e. during the slow walking trial the girls
252 walked faster overground than on the treadmill, but slower overground during the fast walking
253 trial). This suggests that the girls adopted a more energy efficient walking pattern overground, by
254 adjusting their gait (stride length) to a more natural, comfortable walking speed to match the
255 prescribed step rate overground and may account for the large effect sizes observed for
256 $\dot{V}O_2$, METs, $\dot{V}O_2$ ml·step⁻¹. It also suggests that the treadmill may have forced the girls into

257 walking at an unnatural and less energy efficient rhythm. Similarly, Dal et al., (6) who compared
258 self-selected walking speed between the two modes reported that young adults tended to walk
259 faster overground which was more energy efficient and resulted in a more advantageous position
260 regarding the U-shaped curve than the slower self-selected pace observed on a treadmill (4). It
261 has also been suggested that adopting a slower walking speed may increase the relative intensity
262 (23, 25, 37). Dal et al. (6) also suggested that slower self-selected treadmill walking speeds may
263 be attributed to additional balance and coordination being required during treadmill walking,
264 which may explain the higher energy costs observed (i.e. increased muscle force requirement)
265 (4). However, 10 minutes of treadmill familiarisation has been suggested to reduce these
266 additional energy requirements (6, 36). Although treadmill familiarisation was less than the
267 recommended period of 10 minutes in the current study, all the girls regularly used the treadmill
268 during physical education lessons and therefore this was not considered a likely contributor to
269 the observed difference.

270

271 **Optimal walking speed and step rate**

272 Interestingly during the moderately paced walking trial in the current study, walking
273 speed was the same for both the treadmill and overground trials (approximately 3mph). This is
274 consistent with the findings of Berryman et al. (4) who found that an optimal speed of
275 approximately 3mph (2.98mph) was the same for both treadmill and overground in older adults.
276 They suggested that this walking speed may be the best compromise regarding the ability to use
277 the elastic energy and maintain stability. These findings also support the hypothesis that there is
278 a preferred rhythmical human behaviour (15,16). Further studies which have aimed to establish
279 step based recommendations with regard to moderate intensity walking have also indicated little

280 difference in step rate at moderate intensity walking speeds between the two modes (14, 30).
281 Rowe et al., (30) and Harrington et al., (14) compared and cross validated treadmill walking
282 overground respectively and concluded that the replication of prior treadmill step rates to
283 overground supports the use of treadmill step recommendations for practical situations.
284 However, the focus of these studies was step rate associated intensity rather than the energy cost
285 per se and despite this agreement in walking speed/step rate between the two modes, in the
286 current study the oxygen cost per step was still significantly greater on the treadmill at step rates
287 equivalent to the moderate walking speed. This illustrates that although 3 mph and 120
288 steps·min⁻¹ may be a comfortable and economical walking speed (optimal speed and step rate)
289 for adolescent girls, the treadmill artificially elevates the energy cost per step. This indicates that
290 the step rate/speed relationship is different on a treadmill and overground in adolescent girls, as
291 has been previously demonstrated in adults (38) and further illustrates the problem with using the
292 treadmill to infer step based recommendations.

293

294 **Implication for step based recommendations**

295 While the intended application of any step based recommendation is overground walking
296 in a real world setting, the treadmill is often utilised as a matter of convenience. From the current
297 study it is clear that treadmill walking does not replicate walking overground under controlled
298 conditions and therefore increased oxygen cost per step observed on the treadmill may lead to an
299 underestimation of the step rate required to achieve moderate intensity activity in overground
300 walking. It is also acknowledged that under such controlled conditions ecological validity is
301 reduced (24). However, oxygen cost per step examined within the current study is a higher
302 resolution than has previously been reported (1, 3,14, 24, 20, 34). While this may be useful for

303 scientific research purposes, physical activity and allied health professional, to better understand
304 the complex nature of the energy cost of walking, it may not be useful for general health
305 recommendations per se. Further there is little known about the energy cost and step rate
306 equivalence with regard to other overground walking conditions such as walking on other
307 surfaces e.g. grass, gravel paths and pavement with curbs under free living conditions. Further
308 research is required into natural and moderate intensity walking speed and step rates over such
309 surfaces. This may be particularly important with regard to implementing step based
310 recommendations and walking interventions.

311

312 **Strengths and Limitations**

313 The current study had several strengths. It is the only study to compare the energy cost of
314 treadmill and overground walking with regard to step rate ($\text{steps}\cdot\text{min}^{-1}$) and step rate associated
315 intensity in youth. The energy cost of walking was assessed using indirect calorimetry (METS
316 derived from oxygen uptake) during both the treadmill and overground walking trials. Therefore,
317 MET values derived are ‘true’ MET values, rather than estimated. Resting metabolic rate was
318 representative of 1 MET and therefore 3 MET is approximately moderate intensity. The mean
319 resting energy expenditure of $5.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ is also similar to values reported elsewhere (10,
320 13). Step rates have also been derived from real time direct observation rather than pedometer
321 counts. However, it should be noted that video verification of the observed step count was not
322 conducted and is considered to be a limitation of the study. Further limitations of this study are
323 that the results may not be generalisable or extend to other populations.

324 Furthermore, walking speeds were constant and not self-selected or randomised. Overground
325 step rate was prescribed from treadmill step rate at the set speeds of 2.0, 3.0 and 4.0 mph.
326 Despite these measures, some of the girls naturally adjusted to a self-selected speed overground.
327 To overcome this limitation, it may have been more appropriate to allow the girls to walk at self-
328 selected speeds overground, and subsequently match this speed to the treadmill. It is also
329 acknowledged that the influence of different anthropometric indices on step-rate associated
330 intensity previously reported (3, 17, 20) have not been reported within the current study and
331 although these findings cannot be generalised to adolescent girls, within whom growth and
332 maturation are prevalent, it is considered a limitation of the current study.

333

334

335 **Conclusion**

336 The results of the current study suggest that at step rates representative of moderate to vigorous
337 intensity activity (fast walking speed), the metabolic cost of treadmill walking is statistically
338 different and not statistically equivalent to walking overground. Further when expressed as the
339 high resolution oxygen cost per step, ($\dot{V}O_2$ ml·step⁻¹) the current study suggests treadmill
340 walking overestimates (statistically different from) and is not statistically equivalent to walking
341 overground at moderate and fast walking speeds. Step count recommendations translated from
342 treadmill walking may therefore underestimate the step rate required to promote health
343 enhancing overground walking. Consequently, studies that aim to explore the step rate that
344 corresponds to moderate to vigorous intensity activity should focus on overground walking, as
345 this would generalise more accurately to real-life walking behaviour.

346

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448 **Table 1.** Physical characteristics

Variable	Mean±SD	Range
Age (yrs)	14.0±0.5	12.9-15.0
Height (cm)	160.73±5.80	150.30-178.20
Weight (kg)	52.52±10.27	37.00-75.00
BMI	20.27±3.57	15.92-29.07
Resting $\dot{V}O_2$ (ml·kg ⁻¹ ·min ⁻¹)	5.40±0.85	3.39-7.25

449 $\dot{V}O_2$ = Oxygen uptake

450

451 **Table 2.** Dependent variables at each speed comparing treadmill with overground walking

Variable	Treadmill walking			Overground walking		
	Slow	Moderate	Fast	Slow	Moderate	Fast
Walking trial	Slow	Moderate	Fast	Slow	Moderate	Fast
Walking speed(m·s⁻¹)	0.89±0.0#	1.34±0.0	1.78±0.0**	1.12±0.16	1.36±0.15	1.59±0.17
Step Rate	100±7	120±6	133±6	100±6	120±5	133±7
$\dot{V}O_2$(ml·kg⁻¹·min⁻¹)	13.72±1.50	16.27±1.52	21.85±2.16**	13.90±2.04	16.01±2.17	17.95±2.77
METs	2.63±0.35	3.15±0.54	4.23±0.79**	2.66±0.42	3.08±0.50	3.46±0.68
$\dot{V}O_2$ (ml·step⁻¹)	7.34±1.30	7.23±1.44**	8.46±1.45**	7.25±1.38	6.80±1.22	7.00±1.19

452 $\dot{V}O_2$ = Oxygen uptake; MET= metabolic equivalent.453 **significantly higher than overground walking ($p < 0.01$), # significantly lower than overground walking ($p < 0.01$)

454

455 **Table 3.** Group level agreement of treadmill and overground response variables

Variable	Treadmill walking						Overground walking					
	Slow		Moderate		Fast		Slow		Moderate		Fast	
Walking trial	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
$\dot{V}O_2$ (ml·kg ⁻¹ ·min ⁻¹)	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Equivalence region (10%)	12.34	15.09	14.64	17.89	19.66##	24.03##	12.51	15.29	14.40	17.61	16.15	19.74
95% CI mean difference	13.02	14.39	15.57	16.95	20.86	22.82	12.94	14.85	15.02	16.99	16.68	19.20
METs	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Equivalence region (10%)	2.36	2.89	2.83	3.46	3.8##	4.65##	2.39	2.92	2.77	3.38	3.11	3.80
95% CI mean difference	2.47	2.78	2.90	3.39	3.87	4.59	2.46	2.85	2.84	3.31	3.15	3.76
$\dot{V}O_2$ (ml·step ⁻¹)	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Equivalence region (10%)	6.60	8.07	6.50##	7.95##	7.61##	9.30##	6.52	7.97	6.12	7.48	6.30	7.70
95% CI mean difference	6.35	7.30	7.52	8.60	6.12	7.21	6.24	7.28	6.35	7.42	6.24	7.25

456 $\dot{V}O_2$ = Oxygen uptake; MET= metabolic equivalent.

457 ## Not equivalent at 10% to Overground walking

458