1 **Accelerometry assessed sedentary behaviour and physical activity levels during the segmented school day**

2 **in 10-14 year-old children: the HAPPY study**

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9 Abstract

10 The school day offers several different time periods that provide varying opportunities for sedentary time (SED)

11 and engagement in physical activity (PA), yet little is known about the PA and sedentary behaviour patterns of

12 boys and girls during these times. The volume, intensity and temporal distribution of SED and PA undertaken

13 by 135 schoolchildren aged 10-14 years, during different segments of the school day: a) school transport, b)

14 morning recess, c) lunch break, d) class time, and e) after school, was explored using tri-axial accelerometry. PA

15 was categorised into SED, light PA (LPA), moderate PA (MPA), and vigorous PA (VPA). Girls engaged in

16 significantly more SED and LPA than boys during recess and lunch break ($p < 0.05$), while boys engaged in

17 significantly higher levels of VPA during recess ($p < 0.001$) and MPA and VPA during lunch break ($p < 0.001$).

18 PA engagement was similar between sexes during other segments of the day. *Conclusion* PA patterns appear

19 more beneficial for health in boys during less structured school-based time periods and interventions may

20 therefore target opportunities for girls to be physically active during these times to overcome this observed sex

21 deficit.

22

23 **Keywords**

24 Children; adolescents; physical activity; sedentary behaviour; accelerometry

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26   **Introduction**

27   The prevalence of childhood obesity has reached epidemic proportions in the UK [39], as well as in other

28   European countries [46] and the US [30]. Despite significant investment in research and changes in policy

29   making, there have been no signs of decline in childhood obesity levels in recent years [30,39]. In children,

30   overweight and obesity may predispose to dyslipidaemia, hypertension, impaired glucose metabolism, and low

31   cardiorespiratory fitness (CRF) [2,7] and each of these risk factors may confer poor cardiometabolic health and

32   associated co-morbidities in later life [27,45].

33   The causes of overweight and obesity are varied and complex, but at population level, are consistent

34   with sustained positive energy balance that may be a result of sedentary behaviour and low levels of physical

35   activity (PA) [40]. Guidelines for health thus recommend that young people engage in at least 60 minutes per

36   day of moderate-to-vigorous PA (MVPA) and that time spent being sedentary (SED) should be minimised [13].

37   However, there is debate as to whether children are sufficiently active to benefit their health and prevalence

38   values for sufficiently active youth range between 1% and 100% when assessed using accelerometry [15,32,11]

39   and recent data suggest that only 32% of boys and 24% of girls in England aged 2-15 years typically meet the

40   government's recommended guidelines [12]. Although variations in reported PA levels may be due in part to

41   discrepancies in methods of accelerometry data analysis [15], these findings advocate the need for a greater

42   insight into young people's PA patterns to more effectively tailor PA promotion strategies in this population.

43   The school day offers several opportunistic time periods (e.g. school transport, morning recess, lunch

44   break, class time, and after school) for youth to be physically active through informal play, sport, and active

45   commuting. There is considerable evidence that demonstrates sex differences in PA levels, with boys typically

46   engaging in more habitual PA than girls [32,12]. However, little is known about the PA patterns of boys and

47   girls during segments of the school day, and, more specifically, their engagement in different subcomponents of

48   the PA intensity continuum i.e. SED, light PA (LPA), moderate PA (MPA), and vigorous PA (VPA). Given that

49   the magnitude of the association between PA and some health outcomes are intensity driven [13], it is of

50   paramount importance to gain an insight into which segments of the day may benefit from strategies to reduce

51   sedentary behaviour and increased engagement in MPA and VPA.

52   Accelerometers may permit greater accuracy and precision than self-report measures and pedometers

53   [16,1] and allow analysis and interpretation of PA patterns and intensity across various segments of the day.

54   Accelerometry-based studies to date investigating PA patterns typically report on total PA [34], combined

55   MVPA [19], or only selected PA subcomponents e.g. only SED and VPA [41]. In addition, these studies have

56   also focused on average weekday and weekend day PA [34], hourly patterns [41], or in- and out-of-school time

57   periods [19] as opposed to specific segments of the day. These investigations have suggested that both in- and

58   out-of-school hours are important times for youths to engage in PA. However, the patterns of children's

59   engagement in different PA intensities during specific segments of the school day remains unclear, nor is it

60   understood which segments of the day boys and girls differ in their PA intensity engagement. Furthermore, PA

61   levels may be influenced by cardiorespiratory fitness (CRF) [21] and adiposity [5] and many past studies have

62   failed to adjust for these important covariates when investigating the pattern and volume of boys and girls PA

63   levels during the school day [29,44]. Quantifying and adjusting for the potential effects of these variables would

64   strengthen our understanding of any observed sex differences in PA levels.

65   The primary aim of this study was therefore to utilise accelerometry to explore the volume and patterns

66   of 10-14 year-old boys' and girls' engagement in SED, LPA, MPA, and VPA during different segments of the

67   school day: a) school transport, b) morning recess, c) lunch break, d) class time, and e) after school. The

68   secondary aim of this study was to explore boys' and girls' compliance with recommendations for MVPA

69   during recess and lunch breaks.

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71

72   **Methodology**

73   **Sample**

74   The 135 participants (78 girls) included were part of the HAPPY (Health And Physical activity Promotion in

75   Youth) study. This school-based study explored the effects of three interventions on PA levels and health

76   outcomes in 10-14 year-old schoolchildren. Participants were recruited on a voluntary basis from 11 schools

77   across Bedfordshire, UK and their baseline data used for analyses in the present study. Participants were

78   excluded if they had any contraindications to taking part in physical exercise. The study was approved by the

79   University of Bedfordshire ethics review board. Written informed consent was obtained from participants'

80   parents and verbal assent from the participants before any testing procedures.

81

82   **Measurements**

83   Age was recorded as a decimal value for each participant using date of birth. Ethnicity was recorded as white or

84   non-white. A score for socioeconomic status (SES) was attributed to each participant using home postcode and

85   the 2007 Indices of Multiple Deprivation (IMD) [18,26]. Postcodes were converted into IMD scores using the

86 GeoConvert application [26]. These scores were categorised into tertiles with the lowest tertile indicating the
87 most deprived.

88 Stature was recorded to the nearest 0.5 cm using the portable Leicester Height Measure (Seca,
89 Birmingham). Body mass was recorded to the nearest 0.1 kg and body fat % (BF%) recorded to the nearest 0.1
90 % using the Tanita BC-418® Segmental Body Composition Analyzer (Tanita Corp., Tokyo). To determine
91 CRF, participants completed an age- and sex-specific all-out progressive cycle ergometer test to exhaustion
92 using a previously validated protocol [31]. Briefly, workloads increased every 3 min until the participant was no
93 longer able to continue. A maximal effort was deemed as a final heart rate $\geq$ 185 beats per min (bpm) and
94 subjective observation from the researcher that the child could not continue. Power output (watts) was
95 calculated as being equal to $W_1 + (W_2 \cdot t/180)$, where W_1 is work rate at fully completed stage, W_2 is the work
96 rate increment at final incomplete stage, and t is time in seconds at final incomplete stage. VO_{2max} was
97 calculated using previously described formula [31] and expressed relative to body mass (mL/kg/min).

98 RT3® triaxial accelerometers (Stayhealthy, Inc., Monrovia, CA.) were used to measure seven
99 consecutive days of habitual PA using minute-by-minute sampling. Total minutes and proportion of total time
100 (to account for variations in the length of daily wear time between participants) spent in each segment of the
101 school day was determined for SED (< 288 counts per min [cpm]), LPA (288-969 cpm), MPA (970-2332 cpm),
102 and VPA ($\geq$ 2333 cpm). PA intensity cut-off points were based on previously published literature in which the
103 RT3® triaxial accelerometer was validated against oxygen consumption ($r = 0.87$) in children [37]. Participants
104 were only included for data analysis if they had worn the accelerometer for a minimum of three school days [25]
105 and acquired a minimum daily wear time of nine hours [25]. Sustained 10 min periods of zero counts were
106 removed during the recoding process.

107 The segments of the school day analysed were a) school transport (the 30 min time period prior to
108 school starting time), b) morning recess, which ranged from 15-20 min in duration, c) lunch break, which ranged
109 from 45-65 min in duration, d) class time (typically five to six hours across the school day), and e) after school,
110 which included the time from the end of the last school lesson until 18:30.

111 The secondary aim of this study was to explore boys' and girls' compliance with recommendations for
112 MVPA during recess and lunch breaks. The recommendations applied were engagement in MVPA for at least
113 40% of recess and lunch breaks [35]. It is suggested that children should be active for 50% of physical education
114 lesson time [6]. However, when applying this guideline to recess time in previous research, few children met
115 this recommendation [42] and it may thus be an unrealistic target. In light of this, an alternative suggestion of

116   40% based on minimum activity recommendations that may be more achievable has been proposed [35] and

117   was thus applied in this study.

118

119   **Statistical analysis**

120   All analyses were carried out using SPSS version 18.0 (SPSS Inc., Chicago, IL.). Sex differences in descriptive

121   variables were determined by one-way ANOVA. ANCOVA was used to explore sex differences in accumulated

122   minutes and the proportion of time spent in each PA subcomponent during each segment of the school day.

123   Covariates entered into each of the ANCOVA models for school transport and after school segments were BF%,

124   CRF, ethnicity, and SES. Morning recess and lunch break models additionally included morning recess duration

125   and lunch break duration as covariates, respectively, while class time models included both morning recess and

126   lunch break duration as additional covariates. Prior to ANCOVA analysis, tests for homogeneity of regression

127   slopes were conducted and several significant interaction effects between sex (independent variable) and

128   covariates were found. Sub-group analyses were then conducted to explore where sex differences in the

129   dependent variable (PA intensity) varied according to levels of the covariate. Where interaction effects were

130   observed for BF% and CRF, these variables were split into tertiles (lowest tertile representing least fat and least

131   fit, respectively) for sub-group analyses, while for lunch break duration, this variable was split into fertiles with

132   the lowest fertile representing the shortest duration group. The proportion of boys and girls who met the

133   recommendations for PA engagement during recess and lunch break was determined i.e. those who spent 40%

134   of recess and lunch break time in MVPA [35]. X^2 tests were used to evaluate associations between sex and

135   achievement of the PA recommendations for recess and lunch break. The level of significance was set at $p <$

136   0.05.

137

138   **Results**

139   Table 1 shows the descriptive characteristics of the participants. One-way ANOVA revealed that BF% was

140   significantly higher in girls versus boys, while CRF was significantly higher in boys. The proportion of white

141   and non-white children was similar for both boys and girls.

142   Table 2 shows the percentage of total daily (i.e. school transport to after school hours time period) PA

143   intensity minutes accrued in each segment of the school day. The majority of SED time was accrued during

144   class time (63.9%), while after school hours also contributed substantially (25.8%). The majority of LPA was

145   also accrued during class time (46.3%) and after school hours (30.3). In addition to class time (37.1 and 31.2%

146 for MPA and VPA, respectively) and after school (27.9 and 30.3% for MPA and VPA, respectively), lunch

147 break also substantially contributed towards total daily minutes of MPA and VPA (18.1 and 22.3%,

148 respectively). School transport and morning recess time periods contributed towards SED, LPA, MPA and VPA

149 to a lesser extent compared with the other longer duration segments.

150   Comparisons were made between sexes for total minutes spent in each PA subcomponent during

151 segments of the school day (see Table 3). Girls engaged in significantly more LPA than boys during the school

152 transport time period, but there were no significant differences in any other PA subcomponent. During morning

153 recess and lunch break, girls spent significantly more minutes in SED and LPA compared to boys, while boys

154 engaged in significantly more minutes of VPA during morning recess and significantly more MPA and VPA

155 during lunch break. Girls also spent significantly more minutes in SED during class time than boys, but no other

156 significant differences were observed for any other PA subcomponents. Minutes spent in SED, LPA, MPA, and

157 VPA did not differ significantly between girls and boys after school.

158   In terms of the proportion of total time spent in each PA subcomponent during segments of the school

159 day (Table 2), girls spent a significantly greater proportion of time in LPA during school transport than boys.

160 Girls also spent a significantly greater proportion of time in SED and LPA during morning recess compared to

161 boys, while boys spent significantly more in VPA. The proportion of time in SED and LPA was also

162 significantly higher in girls than in boys during lunch break, whereas boys spent significantly more in MPA and

163 VPA during this segment of the day. There were no significant differences between boys and girls for the

164 proportion of time spent in any PA subcomponent during class time and after school hours.

165   Main effect sizes for sex (according to Cohen's effect sizes for ANCOVA [9]) were small (eta-squared

166 = 0.01-0.05) for minutes and proportions of time spent in SED, LPA, MPA, VPA and MVPA during the school

167 transport segment. Effect sizes ranged from small to large (eta-squared = $\geq$ 0,14) for minutes and proportions of

168 time spent in SED, LPA, MPA, VPA and MVPA during morning recess and ranged from medium (eta-squared

169 = 0.06-0.13) to large for lunch break, apart from LPA%, which was small. For class time and after school, effect

170 sizes for sex were small for all PA subcomponents.

171   However, as noted in Table 3, a number of significant interaction effects were evident, suggesting that

172 differences on the dependent variable among groups may vary as a function of a covariate and this particular

173 data where the homogeneity of regression slopes assumption (i.e. equal sex effects across different levels of

174 covariates) is violated should be interpreted with caution. In light of this, where significant interaction effects

175 were observed, further sub-group analyses were conducted to explore sex differences in PA according to

176   different levels of covariates. It was revealed that mean adjusted differences for VPA min (minutes in VPA) and

177   VPA% (proportion of time in VPA) during school transport between boys and girls in the highest BF% tertile

178   were significant; mean (SE) = 5.8 (1.2) and 1.7 (0.6) VPA minutes and 19.3 (4.2) and 5.7 (2.0) VPA% for boys

179   and girls, respectively ($p < 0.05$); whereas no significant sex differences were observed in the lowest and middle

180   tertiles. There was also a significant sex difference for VPA% during school transport in white participants (12.6

181   (1.8) and 5.9 (1.3) for boys and girls, respectively, $p < 0.05$), but not in non-white participants. A significant

182   interaction effect between sex and CRF for after school VPA min was also evident, with girls in the highest

183   CRF tertile accumulating significantly more VPA minutes than boys (13.6 (1.9) and 4.9 (1.9) minutes,

184   respectively, $p < 0.05$), with no significant sex differences being observed in the middle and lowest tertiles.

185   Significant interactions between sex and SES were also observed. Girls in the lowest SES tertile (most

186   deprived) spent a significantly higher proportion of time in SED during school transport compared to boys

187   (41.5% (3.7%) and 24.8% (4.4%) for girls and boys, respectively, $p < 0.05$), with no significant sex differences

188   in the middle and highest tertiles. Furthermore, boys in the lowest SES tertile spent a significantly higher

189   proportion of time in MPA during school transport compared to girls (35.9% (3.8%) and 21.3% (3.2%) for boys

190   and girls, respectively, $p < 0.05$). There was also a significant interaction between sex and lunch break duration

191   for the proportion of time children engaged in VPA during this time period, with boys in the highest lunch break

192   duration fertile spending significantly higher proportions of time in VPA than girls (19.5% (2.0%) and 6.0%

193   (1.4%) for boys and girls, respectively, $p < 0.05$), whereas no significant sex difference was observed in the

194   lowest fertile.

195   The secondary aim of this study was to explore boys' and girls' compliance with recommendations for

196   MVPA during recess and lunch breaks. As shown in Figure 1, significantly more boys met the guideline for

197   recess and lunch break PA engagement i.e. taking part in MVPA for at least 40% of the time. 59.6% of boys met

198   the suggested PA guideline for recess compared with 28.2% of girls. During lunch break, 64.9% of boys

199   achieved the recommended level of MVPA engagement compared to only 10.3% of girls.

200   **Table I** Characteristics of the study population by sex. Mean (SD), $n = 135$

	Boys ($n = 57$)	Girls ($n = 78$)
Age (yr)	11.8 (1.4)	11.6 (1.4)
Ethnicity (% non-white)	21.1	21.8
Height (cm)	150.1 (12.0)	150.2 (9.6)
Weight (kg)	39.5 (11.5)	41.1 (11.9)
Body Fat %	16.8 (4.6)	22.7 (5.7)*
CRF (mL/kg/min)	46.7 (9.0)	39.0 (9.3)*

201   CRF, cardiorespiratory fitness. * $p < 0.05$ between sexes.

202

203 **Table II** Percentage of daily physical activity minutes accrued in each segment of the day. Mean (SD)

	Sedentary (%)	Light PA (%)	Moderate PA (%)	Vigorous PA (%)	MVPA (%)
School transport	2.6 (1.5)	7.4 (3.0)	10.4 (5.8)	8.8 (10.5)	10.0 (5.9)
Morning recess	1.8 (1.3)	4.1 (2.1)	6.4 (3.5)	7.4 (8.4)	6.8 (3.9)
Lunch break	6.0 (2.0)	11.9 (3.7)	18.1 (6.8)	22.3 (16.3)	19.5 (8.2)
Class time	63.9 (7.0)	46.3 (7.6)	37.1 (10.3)	31.2 (19.2)	35.3 (10.6)
After school	25.8 (6.6)	30.3 (7.4)	27.9 (10.3)	30.3 (21.8)	28.4 (11.5)

204 PA, physical activity; MVPA, moderate-to-vigorous physical activity

205 **Table III** Segmented school day physical activity levels by sex. Mean (SD), $n = 135$

	School Transport		Morning Recess		Lunch Break		Class time		After School	
	Boys ($n = 57$)	Girls ($n = 78$)	Boys ($n = 57$)	Girls ($n = 78$)	Boys ($n = 57$)	Girls ($n = 78$)	Boys ($n = 57$)	Girls ($n = 78$)	Boys ($n = 57$)	Girls ($n = 78$)
SED (min)	8.8 (5.7)	10.3 (5.6)	5.4 (4.5)	7.2 (5.1)[a]	16.4 (6.8)	25.5 (7.2)[c]	219.9 (27.2)	234.7 (29.0)[a]	92.9 (31.8)	95.0 (30.8)
SED (%)	29.5 (19.7)	34.2 (18.9)[d]	28.1 (21.7)	38.2 (21.3)	29.7 (12.6)	44.6 (12.1)[c]	69.4 (7.6)	71.2 (7.7)	56.3 (12.3)	55.9 (12.4)
LPA (min)	9.2 (3.5)	10.3 (4.3)[a]	4.8 (2.7)	5.7 (2.4)[a]	13.8 (5.7)	16.8 (4.3)[b]	61.0 (16.0)	61.4 (17.1)	36.9 (13.3)	42.8 (13.9)
LPA (%)	31.6 (12.9)	34.9 (14.2)[a]	25.0 (12.8)	31.5 (11.5)[a]	25.1 (11.5)	29.5 (8.2)[b]	19.4 (4.7)	18.6 (5.0)	23.9 (6.7)	26.2 (7.2)
MPA (min)	9.3 (5.3)	7.4 (4.3)	5.1 (2.3)	4.3 (2.5)	15.6 (5.3)	11.9 (4.7)[c]	27.4 (9.5)	28.0 (9.6)	21.3 (10.5)	22.0 (11.6)
MPA (%)	30.8 (18.0)	24.9 (14.4)[d]	28.3 (13.3)	24.7 (13.9)	28.0 (9.2)	20.6 (7.8)[c]	8.7 (2.8)	8.5 (2.7)	14.9 (7.0)	13.6 (6.6)
VPA (min)	2.7 (3.0)	2.0 (2.9)[d]	3.3 (3.2)	1.0 (1.4)[c]	10.0 (8.3)	3.1 (3.3)[c]	7.8 (5.9)	5.8 (4.3)	6.6 (5.8)	7.2 (8.0)[d]
VPA (%)	8.2 (0.1)	6.1 (0.1)[d]	18.7 (17.5)	5.8 (8.3)[c]	17.4 (14.1)	5.4 (5.7)[c, d]	2.5 (1.9)	1.7 (1.4)	4.9 (4.2)	4.4 (4.9)
MVPA (min)	12.0 (7.2)	9.4 (6.1)	8.5 (4.3)	5.3 (3.4)[c]	25.6 (10.8)	15.0 (6.8)[c]	35.2 14.0)	33.8 (12.2)	27.8 (14.3)	29.2 (16.4)
MVPA (%)	39.00 (23.9)	31.0 (20.5)	47.0 (24.9)	30.5 (1.95)[c]	45.3 (17.5)	26.1 (11.3)[c]	11.2 (4.2)	10.2 (3.5)	19.8 (9.9)	18.0 (9.4)

206 SED, sedentary; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity. [a] $p < 0.05$; [b] $p < 0.01$; [c] $p < 0.001$ between sexes; [d] significant interaction effect

207 between sex and covariate(s)

208
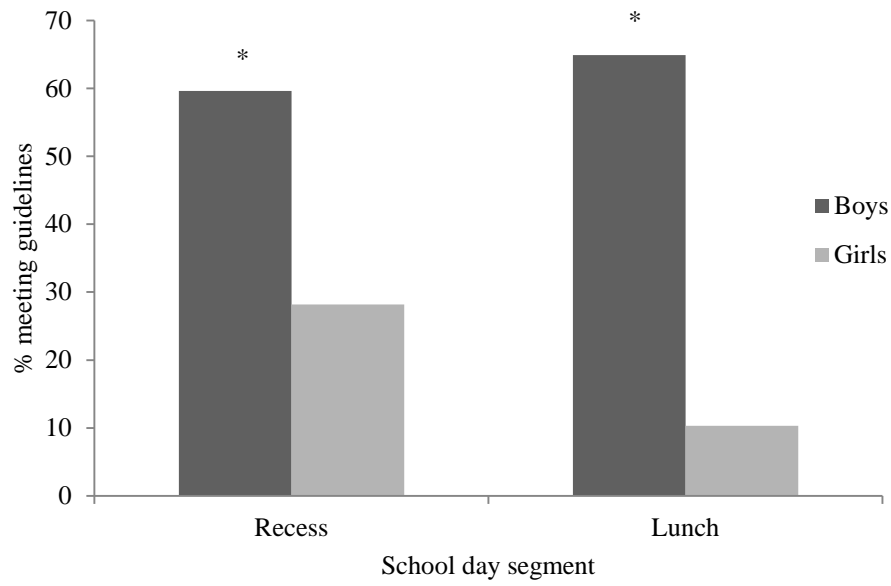
Fig. 1 Percentage of children meeting physical activity recommendations during school recess. Recommendations are 1) 40% of recess time in MVPA [35] and 2) 40% of lunch break in MVPA [35]. * $p <$ 0.001 between sexes.

212 **Discussion**

213 The primary aim of this study was to investigate the volume and patterns of boys' and girls' engagement in PA

214 intensities and sedentary behaviours during different segments of the school day. The results of this study extend

215 the current literature by providing a detailed analysis of sex differences in SED, LPA, MPA, and VPA during

216 specific segments of the day. Current PA guidelines recommend young people engage in at least 60 minutes per

217 day of MVPA [13]. The results of this study suggest that segments both during and out of school hours are

218 important sources for MPA and VPA engagement in boys and girls. In particular, morning recess, lunch break,

219 and school transport appear to be key segments of the school day where both sexes engage in MPA and VPA

220 and spend less time in SED. However, important sex differences in PA engagement during recess and lunch

221 break were observed with boys engaging in greater levels of MPA and VPA than girls.

222 The majority of daily SED and LPA minutes were accrued during class time and after school, while a

223 higher proportion of time was also spent in SED during these segments of the day compared with school

224 transport, morning recess and lunch break. However, a higher proportion of time was spent in LPA during

225 school transport and the lowest during class time compared with the other time periods for both boys and girls.

226 Class time contributed the highest amount of daily MPA minutes, followed by after school and lunch break,

227 respectively. However, class time and after school contributed similar total minutes of daily VPA, while a

228 relatively high proportion of VPA minutes were also accrued during lunch break.

229 Given the relatively shorter durations of school transport (30 min) and morning recess (15 to 20 min),

230 these segments of the day expectedly contributed to daily minutes of SED, LPA, MPA and VPA to a lesser

231 extent compared with the other longer duration time periods. However, the proportion of time spent in MPA was

232 substantially higher during school transport, morning recess and lunch break in comparison to class time and

233 after school for both boys and girls. For VPA, boys spent substantially higher proportions of time in this PA

234 intensity during morning recess and lunch break compared to other segments of the day, while girls spent higher

235 proportions of time in VPA during school transport, morning recess, lunch break and after school compared

236 with class time. As most minutes of SED are accrued during class time and after school with both sexes also

237 spending the highest proportion of time in SED during these segments of the day, strategies to reduce sedentary

238 time during these time periods, such as reducing TV viewing time [10], may be appropriate to reduce health

239 risk. Additionally, despite its relatively short duration (compared to class time and after school), lunch break

240 makes a substantial and promising contribution to total daily minutes of MVPA and schools should thus be

241 encouraged to maintain or extend the duration of this time period.

242   In the present study, 10-14 year-old boys spent significantly more minutes and a greater proportion of

243   time in VPA compared to girls during morning recess and accumulated significantly fewer minutes and a lower

244   proportion of time in SED and LPA. Although in a slightly younger age group (5-10 year-olds), previous

245   research supports the finding of greater VPA engagement in boys compared to girls during morning recess [36].

246   However, the cohort of boys in the current research engaged in substantially higher levels of VPA compared to

247   those in Ridger et al's [36] study (19.1 vs. 4.5-7.0%, respectively), whereas girls' engagement in VPA was

248   similar between studies; 5.5% in the current study vs. 2.9-6.5% in Ridger et al's [36]. The disparity observed in

249   boys may be due to differences in accelerometry device and there remains controversy regarding which set of

250   cut-points for PA intensity thresholds is most representative of 'moderate' and 'vigorous' levels of physical

251   exertion in youths [33]. It is possible that the amount of time spent in each PA intensity may vary with different

252   cut-points.

253   A pedometer-based study in third- to fifth-grade students reported that boys were physically active for

254   78% of recess time, which was significantly higher than girls (63%) [4]. Nettleford et al. [29] found that 8-11

255   year-old boys and girls spent 27.9% and 19.6% ($p < 0.001$) of recess in MVPA, respectively, while boys and

256   girls in the current study engaged in MPA for 27.8% and 25.1% ($p > 0.05$) and in VPA for 19.1% and 5.5% ($p <$

257   0.001) of recess, respectively. The main reason for differences in PA levels between accelerometer and

258   pedometer-based studies is due to the fact that pedometry data represents total volume of PA accumulated,

259   whereas accelerometers permit representation of engagement in specific PA intensities. Since the magnitude of

260   the association between PA and some health outcomes are intensity driven [13] and given that current PA

261   guidelines pertain specifically to time spent in MVPA [13], the latter method appears to be preferable when

262   analysing PA patterns and targeting interventions in youth.

263   Regarding sex differences in PA during lunch break, boys engaged in significantly higher amounts of

264   MPA and VPA compared to girls and significantly less SED and LPA. Since health benefits of PA primarily

265   accrue at or above moderate intensity PA [13], the higher levels of MPA and VPA exhibited by boys during this

266   segment of the school day are more likely to result in enhanced CRF [21,3] and cardiometabolic health [14].

267   Similar to these findings, Tudor-Locke et al. [44] reported that in sixth-grade students, boys accumulated more

268   steps than girls during lunch break, while Nettleford et al. [29] reported that boys spent more time in

269   accelerometry-determined MVPA (34.7 vs. 27.9) and less time in SED (45.5 vs. 51.6%) compared to girls.

270   However, the current study is the first to report on children's engagement in SED, LPA, MPA, and VPA during

271   lunch break, which is important given that current PA guidelines encourage participation in both MVPA and

272   VPA, as well as minimising sedentary time [13].

273   During class time, girls accumulated significantly more minutes of SED compared to boys, although no

274   significant differences were noted for any of the PA variables. In 8-11 year-olds, it was reported that girls

275   accumulated more minutes (209.7 vs. 200.3 min) of SED than boys during regular class time (i.e. excluding PE),

276   although unlike the present study, girls also spent a significantly higher proportion of time in SED than boys

277   (74.2 vs. 71.2%, respectively) [29]. The school setting appears to promote prolonged periods of sitting and it is

278   hence unsurprising to observe high levels of SED during class time [22]. Nettleford et al. [29] reported that girls

279   accumulated fewer minutes and spent a smaller proportion of time in MVPA than boys during regular class time

280   (33.8 vs. 39.9 min and 12.0 vs. 14.1 % in girls and boys, respectively), although there was no difference in LPA.

281   During PE, however, no significant differences were observed between girls' and boys' engagement in SED,

282   LPA, and MVPA [29]. Unfortunately, PA patterns could not be determined separately for regular and PE class

283   time in the current study as it was unknown when PE classes took place. A previous investigation, however,

284   reported no sex differences in accumulated number of steps during PE in sixth-grade children [44], although

285   other studies using pedometry and accelerometry have observed higher PA levels in boys [28,24]. It has been

286   suggested that boys' PA may be greater during PE due to sex differences in lesson content, such as boys taking

287   part in team invasion games whereas girls lessons may focus more on PE curricula movement based activities

288   that expel less energy [17].

289   PA patterns for school transport and after school were similar between sexes; the only significant

290   difference observed being girls' higher accumulated minutes and proportion of time in LPA during school

291   transport. Boys did engage in higher levels of MPA and less SED, but these differences were non-significant (p

292   > 0.05). One previous pedometry study also reported similar PA engagement during the school transport time

293   period for sixth-grade boys and girls, although boys accumulated more steps than girls after school [44]. In

294   third- to fifth-grade children, higher levels of PA were observed in boys outside of school hours compared to

295   girls using pedometry [4]. However, because this study failed to discriminate between school transport and after

296   school hours, it is unknown whether sex differences existed for these specific segments of the school day.

297   Nonetheless, using self-report, 12-18 year-old boys were 1.32 (95% CI 1.15-1.50) and 1.38 (95% CI 1.20-1.59)

298   times more likely to be 'more active' during school commuting and after school, respectively, compared to girls

299   [23]. However, it is difficult to compare these studies to the current investigation due to differences in the

300 assessment of PA and the fact that pedometry and self-report measures limit the interpretation of PA intensity

301 and patterns [1].

302 The current study also identifies a number of groups which have different PA engagement between

303 boys and girls. There were a number of significant interaction effects observed between sex and covariates for

304 PA engagement; the majority being evident for PA during the school transport time period. Boys in the highest

305 BF% tertile engaged in significantly more VPA than girls during school transport. White boys also engaged in a

306 higher proportion of VPA during school transport than white girls. Previous research in youths has shown that

307 PA is lowest for female and ethnic minorities [20] and children with high levels of body fat [5]. Furthermore,

308 boys in the lowest SES tertile spent a significantly lower proportion of time in SED and significantly higher

309 proportion of time in MPA during school transport compared to girls. No previous studies have reported sex by

310 SES differences in PA intensity engagement and future research should continue to address this issue.

311 For the after school segment, a significant interaction effect was observed between sex and CRF for

312 VPA min, with girls in the highest CRF tertile accumulating significantly more VPA minutes than boys. The

313 last significant interaction effect observed was between sex and lunch break duration for VPA%. Previous

314 research demonstrates that boys are more active than girls during lunch break [29]. However, the present study

315 revealed that boys in the highest lunch break fertile spent a significantly higher proportion of time in VPA than

316 girls. Interventions to promote equal PA opportunities for boys and girls during school transport might thus

317 target girls with high levels of BF%, those of white ethnic origin, and those who are most deprived.

318 Interventions might also target increasing PA in girls at schools that have longer lunch break durations.

319 Regarding CRF, VPA engagement was significantly lower ($p < 0.05$) in the middle (5.7 (1.3) min) and least fit

320 girls (4.9 (1.5) min) compared to the highest fit girls (13.7 (1.9) min), whereas no significant differences

321 between tertiles were observed for boys and it may thus be appropriate for interventions to target PA promotion

322 in girls with lower levels of CRF.

323 The secondary aim of this study was to explore girls' and boys' achievement of suggested guidelines

324 for PA engagement during recess and lunch break [35]. 59.6% of boys engaged in MVPA for 40% of recess

325 time compared with 28.2% of girls, while during lunch break, 64.9% of boys achieved the recommended time in

326 MVPA compared to just 10.3% of girls. Nettleford et al [29] also found that more 8-11 year-old boys achieved

327 the recommended level of PA during recess and lunch break, although the proportion of boys sufficiently active

328 was less than that of the current study (34.1 vs. 59.6% for recess and 37.4% vs. 64.9% for lunch break,

329 respectively). However, although less girls achieved the recommended level of PA during recess in Nettleford et

330 al's study [29] compared to the present findings (15.7 vs. 28.2%, respectively), less girls in the current study

331 were sufficiently active during lunch break (16.7 vs. 10.3%, respectively). In slightly younger children (mean

332 age 8 ± 1.4 years), 14.9% of boys and 4.3% of girls engaged in at least moderate intensity PA for 40% of recess

333 time [35], which is lower than that of the current study.

334   This disparity observed between studies regarding the proportion of boys and girls who are sufficiently

335 active during recess and lunch break may be in part due to differences in accelerometry device and the cut-

336 points employed to define PA intensity [33]. Furthermore, it is possible that differences in school policy and

337 length of recess and lunch break may influence children's PA engagement during these segments of the day. In

338 the current study, recess was 15-20 min and lunch 45-65 min in duration and it is unknown how school policy or

339 seasonal variations influenced PA during these times e.g. whether and for how long children had to sit and eat

340 before playing outside. However, although disparities in the proportion of children sufficiently active during

341 recess and lunch breaks may be observed between studies, the finding that more boys are sufficiently active than

342 girls is consistent [35,29]. It may therefore be particularly important to focus intervention strategies towards

343 increasing girls' participation in MVPA during these segments of the school day.

344   Limitations of this study include the absence of a physical maturity measure. Previous research

345 suggests that sex differences in PA levels may be eliminated after controlling for maturation [43] and it is

346 unknown whether this hypothesis is applicable to the current cohort. However, unlike previous research

347 [29,4,44,35], this study accounted for BF% and CRF when comparing boys' and girls' segmented PA levels.

348 Given that there are sex differences in body fat [38,3] and CRF [38] and that both variables may influence PA

349 engagement [21,5], we can be confident that these factors were not accountable for the sex differences observed.

350 Next, although accelerometry is now considered the gold-standard measure of PA levels, this method still has

351 limitations. In addition to variation in intensity cut-points discussed above, most accelerometers cannot be worn

352 in water and devices also fail to accurately reflect energy expenditure associated with cycling, upper body

353 movements, and walking up-hill. Furthermore, the definition of school transport has potential limitations in that

354 much PA prior to school may be non-commuting PA. It is possible that some inactive commuters (i.e. who

355 travel by car) may have arrived at school relatively early and accumulated PA before school started, which

356 would thus misrepresent the amount of PA they accumulate during their commute. The study is also limited due

357 to the inability to explore the independent contributions of PE and normal class time to total daily PA or indeed

358 sex differences in PA intensities during these specific time periods. Lastly, the sample size was relatively small

359 and included only schools in Bedfordshire, UK. Although socioeconomic status of the recruitment areas was

360 similar to other regions of the UK according to local area statistics [8], the ability to generalise the findings may

361 be limited due to lower overweight and obesity levels in comparison to national averages [39] as well as

362 variations in ethnic representation between schools.

363   In conclusion, this study has added important information on the patterns of boys' and girls'

364 engagement in different PA intensities during segments of the school day, with boys utilising more opportunities

365 to engage in health-promoting MVPA and minimising their time spent sedentary. This study showed that girls

366 are substantially less active than boys during recess and lunch breaks, although a relatively large proportion of

367 both sexes are not achieving PA recommendations during these time periods. Strategies to increase engagement

368 in MVPA and promote equal opportunities for PA in girls and boys during these segments are warranted.

369

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373 **Conflict of interest**

374 The authors declare that they have no conflict of interest.

375

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