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Coláiste na hOllscoile Corcaigh

1 **Title Page**

2

3 **Title:** Physical activity, sedentary behaviour and the risk of overweight and obesity in school aged

4 children

5 **Preferred running head:** Objective physical activity and childhood obesity

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9

10   **Abstract**

11   **Purpose:** Globally, public health policies are targeting modifiable lifestyle behaviours. We explore the

12   independent association of moderate-to-vigorous physical activity (MVPA) and sedentary behaviour

13   on the risk of childhood overweight/obesity.

14

15   **Method:** A cross-sectional survey of children aged 8-11 years (N=826). Objective body mass index was

16   used to classify children as normal weight or overweight/obese. Children wore wrist-worn Geneactiv

17   accelerometers for 7-days and thresholds were applied to categorise MVPA and sedentary time.

18   Screen time (ST) was parent reported. Poisson regression examined the independent association of

19   (1) MVPA, (2) objective sedentary time and (3) ST on the risk of overweight/obesity.

20

21   **Results:** Overall, 23.7% (95% CI, 20.8-26.6%) of children were overweight/obese. On average, children

22   spent 10.8% of waking time at MVPA and 61.3% sedentary. One-fifth (22.1%, 95% CI, 19.3-25.0%) of

23   children achieved MVPA recommendations (≥60 minutes each day) and 17.5% (95% CI, 14.9-20.1%)

24   met ST recommendations (<2 hours per day). Time spent at MVPA was inversely associated with the

25   risk of overweight/obese independent of total sedentary time. Total time spent sedentary was not

26   associated with overweight/obese independent of MVPA. ST was associated with an increased risk of

27   overweight/obese independent of physical activity.

28

29   **Conclusion**: Few schoolchildren met physical activity and screen time recommendations suggesting

30   population based measures are needed.

31 **Background**

32 The World Health Organisation (WHO) has recommended that children achieve at least 60 minutes of

33 moderate-to-vigorous physical activity (MVPA) daily (World Health Organization, 2010). However,

34 large proportions of children fail to meet these guidelines. Recent estimates from a European study

35 from five countries reported that only 4.6% of girls and 16.8% of boys aged 10-12 years met MVPA

36 guidelines (Verloigne et al., 2012). Regular physical activity is beneficial for cardiovascular health, bone

37 health, mental health and weight status (Poitras et al., 2016). Studies assessing the association

38 between MVPA and childhood obesity have been relatively consistent with less active children at an

39 increased risk of obesity when compared to more active children (Jiménez-Pavón, Kelly, & Reilly, 2010;

40 Wittmeier, Mollard, & Kriellaars, 2008).

41

42 Sedentary behaviour can be defined whereby very little energy is being expended (≤1.5 metabolic

43 equivalent units [METS]) during waking time, including sitting and lying down (Mark S Tremblay et al.,

44 2011). Children have become increasingly sedentary in recent decades (Bucksch et al., 2016) and the

45 association between sedentary behaviour and unfavourable health outcomes including obesity have

46 received increased attention (Carson et al., 2016). Screen time (ST) is a distinct sub-domain of

47 sedentary behaviour (Sigman, 2012). Current recommendations suggest that children should limit

48 recreational ST to no more than two hours per day (Mark S Tremblay et al., 2016). However, more

49 than half of all children exceed ST recommendations (Fakhouri, Hughes, Brody, Kit, & Ogden, 2013;

50 LeBlanc et al., 2015).

51

52 An emerging evidence base suggests that physical activity and sedentary behaviour are separate

53 constructs independently impacting on obesity risk, rather than sedentary behaviour simply

54 representing low MVPA (Carson & Janssen, 2011; Pearson, Braithwaite, Biddle, Sluijs, & Atkin, 2014;

55   Salmon, Tremblay, Marshall, & Hume, 2011; Mark Stephen Tremblay, Colley, Saunders, Healy, &

56   Owen, 2010). Children can meet MVPA guidelines but can also spend a high proportion of time

57   sedentary and visa-versa (Eisenmann, Bartee, Smith, Welk, & Fu, 2008; Herman, Sabiston, Mathieu,

58   Tremblay, & Paradis, 2014; Laurson et al., 2008). A recent systematic review suggested that further

59   research is needed to clarify the interplay of physical activity and sedentary behaviour due to

60   conflicting findings in the current literature (Pearson et al., 2014). Understanding the relationship

61   between physical activity and sedentary behaviour may help inform the design of polices and

62   interventions to tackle poor lifestyle behaviours and obesity in children.

63

64   Few studies have assessed the independent association of physical activity and sedentary time on

65   adiposity in schoolchildren using objective measurements (Ekelund, Hildebrand, & Collings, 2014),

66   with the majority of evidence from the UK and USA (Ekelund et al., 2014). To date, studies have

67   consistently found that physical activity is associated with obesity indicators independent of sedentary

68   time (Ekelund et al., 2014; Katzmarzyk et al., 2015). However, the association between objective

69   sedentary time and obesity markers independent of physical activity is less clear (Cliff et al., 2016;

70   Ekelund et al., 2014). Generally, the association between objective sedentary time and obesity is

71   attenuated after adjustment for MVPA (Chaput et al., 2012; Ekelund et al., 2012; J. Mitchell, Pate,

72   Beets, & Nader, 2013; J. A. Mitchell et al., 2009; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009).

73   Other studies have assessed associations between subjectively measured sedentary behaviour and

74   obesity independent of objective physical activity. Findings from these studies are mixed with some

75   studies reporting positive associations (Coombs & Stamatakis, 2015; Ekelund et al., 2006) and others

76   reporting no association (Colley et al., 2012; Ortega, Ruiz, & Sjöström, 2007).

77

78 The Cork Children's Lifestyle (CCLaS) Study is the first population based sample of schoolchildren in

79 Ireland to collect objective physical activity data. We hypothesised that schoolchildren with

80 overweight/obesity would be less active and more sedentary than those who are normal weight. This

81 study describes objectively measured physical activity and sedentary time throughout the week, by

82 gender and weight status. Second, we describe the characteristics of children who meet MVPA and ST

83 recommendations (neither, one or both). Third, we explore the independent association of MVPA and

84 sedentary behaviour (objective and questionnaire based data) on the risk of childhood

85 overweight/obesity whilst considering demographic characteristics and other lifestyle factors (diet

86 and parent reported sleep time).

87

88 **Methods**

89 **Study design**

90 Details of the CCLaS Study have been described elsewhere (Keane, Kearney, Perry, Browne, &

91 Harrington, 2014). Briefly, the study aimed to recruit 1,000 schoolchildren to estimate the prevalence

92 of overweight/obesity in Irish children with a precision of ±2.7% assuming a 26% prevalence rate

93 within the study sample. Information on primary schools in Cork City (an urban area) and

94 Mitchelstown (a rural area) was obtained from the Department of Education and Skills website.

95 Children in 3rd and 4th classes (years 5 and 6 of enrollment into primary school) were the target

96 population. Schools were recruited from Cork City using probability proportionate-to-size and

97 purposive sampling. All schools in one rural area in Cork County were invited to participate. Data were

98 collected in schools during school term times between April 2012 and June 2013. Overall, 1,075 8-11

99 year old children living in Cork, Ireland took part in the survey. At the school level, a response rate of

100 65.5% (N=27) was achieved, while 59% (N=1,075) of invited children participated in the study. Data

101 were collected using physical measurements, child and parent questionnaires, 3 day food diaries and

102 accelerometers. Ethical clearance was granted from the Clinical Research Ethics committee of the Cork

103 Teaching Hospitals, Cork, Ireland. Only children whose parents/guardians provided informed consent

104 participated in the study (Keane et al., 2014).

105

106 **Anthropometric measurements and obesity definition**

107 Trained researchers measured child height and weight using standard methods (Keane et al., 2014).

108 Height was measured to the nearest millimetre using a Leicester portable height stick and weight was

109 measured to the nearest 0.1 kilogram using a Tanita WB100MA mechanical scale. Measurements were

110 taken without shoes and in light clothing. Age and gender specific International Obesity Taskforce

111 definitions for body mass index (BMI) were used to categorise children as (1) normal weight or (2)

112 overweight/obese (Cole, Bellizzi, Flegal, & Dietz, 2000).

113

114 **Physical activity and sedentary variables**

115 <u>Accelerometers</u>

116 Free living physical activity was measured over seven consecutive days using a wrist worn validated

117 tri-axial Geneactiv accelerometer (Esliger et al., 2011; Phillips, Parfitt, & Rowlands, 2012). The

118 accelerometers were set to record at 100Hz for seven days using the 'on button press' setting of

119 Geneactiv software version 2.2. The accelerometers were placed on the non-dominant hand of each

120 participating child. Children were asked to wear the accelerometers 24 hours a day each day. The

121 children were advised that the accelerometers were waterproof and were only to be removed if

122 necessary.

123

124 The accelerometer data were downloaded using Geneactiv software version 2.2 and saved on hard

125 drives. The day and month the accelerometer was worn was extracted from the accelerometers during

126 processing. Days of the week were categorised as total week (Sunday-Saturday), week days (Monday-

127 Friday) or weekend days (Saturday-Sunday). Accelerometer wear month was categorised to reflect

128 the school year as January-March, April-June or October-December.

129

130 Parent questionnaire data were used to identify the most frequent waking time and bed time on week

131 and weekend days. These data were then used to estimate the number of waking hours each day. The

132 mean waking time was 14 hours per day. To be included in the analysis, children needed to have

133 recorded ≥600 minutes of waking time data for each of the seven days. For children included in the

134 analysis who had missing data, data were scaled to full waking time. Non-wear time was determined

135 using an algorithm by van Hees et al, 2011 (van Hees et al., 2011).

136

137 The raw data files (*.bin) were first read into minute by minute data files (*.csv) using R software and

138 then summarised using SAS 9.3 (Statistical Analysis System Inc., 2002). Minutes per day spent

139 sedentary and at light, moderate and vigorous physical activity were categorised using classification

140 thresholds defined by Phillips et al., 2012 (Phillips et al., 2012). As our data were collected at 100Hz,

141 the classification thresholds were adjusted from 80Hz to 100Hz (Phillips et al., 2012). Sedentary time

142 minutes were divided by 60 and presented as hours per day. Children who achieved ≥60 minutes of

143 MVPA on all seven days were categorised as meeting MVPA guidelines (World Health Organization,

144 2010).

145

146 <u>Parent reported screen time</u>

147 Two parent reported responses to questions were used to define ST. The first question asked how

148 many hours per weekday the study child spends watching television, videos or DVDs and the second

149 asked how many hours per weekday the study child spends using computer and non-active game

150 consoles. Both questions had 6 level responses; none, less than an hour, 1 hour to less than 3 hours,

151 3 hours to less than 5 hours, 5 hours to less than 7 hours, or 7 hours or more. The responses were

152 combined and those who engaged in <1 hour in both behaviours were categorised as <2 hours per day

153 and the remainder of children were categorised as >2 hours per day (Mark S Tremblay et al., 2016).

154

155 <u>Combined index for meeting public health recommendations</u>

156 Children were categorised into four groups based on MVPA and ST recommendations as (1) met both,

157 (2) met MVPA only, (3) met ST only or (4) met neither recommendation. This variable was

158 dichotomised as met both recommendations versus met neither/one recommendation for the

159 regression analysis (Table 4) due to the small numbers of children with overweight/obesity who met

160 both recommendations.

161

162 **Covariates**

163 Gender was recorded as girl or boy by trained researchers during physical measurements. Child age

164 was calculated using date of physical measurement and date of birth (parent reported). Parent

165 reported highest level of maternal education is used as a proxy measure of socio-economic status. The

166 variable was coded as lower secondary education or less, higher secondary education, post-secondary

167 education, third level education or missing. A missing maternal education category (N=77) was created

168 to retain the maximum number of children in the analysis.

169

170 Consecutive three day estimated food diaries were completed by the children and assessed for

171 completeness with the children by trained research assistants (Keane et al., 2014). The food diary

172 data were entered into WISP version 4 (Tinuviel Software, Anglesey, UK). Average daily energy (kcal)

173 intake, average daily fruit and vegetable (g/day) intake, and average daily sugar sweetened beverage

174 (SSB; ml/day) intake were estimated. An energy intake to estimated basal metabolic rate (BMR) ratio

175 was calculated, to classify under reporters (energy intake). BMR was calculated using equations by

176 Schofield, 1985 (Schofield, 1984). Cut-off values for energy intake to BMR were defined using an

177 equation proposed by Goldberg as either (1) under reporters or (2) plausible reporters (Black, 2000;

178 Goldberg et al., 1991).

179

180 Sleep time was parent reported. Parents were asked to report when the child usually wakes up and

181 goes to bed on week and weekend days separately. Average sleep time per night was calculated and

182 sleep time was categorised as either adequate (>10 hours for 5-10 year olds, >9 hours for 10+ year

183 olds) or not adequate (≤10 hours for 5-10 year olds, ≤9 hours for 10+ year olds) (Chen, Beydoun, &

184 Wang, 2008).

185

186 **Statistical analysis**

187 Prevalence estimates with 95% confidence intervals were calculated. Continuous variables were

188 assessed for Normality using histograms. Normally distributed data are presented as means and

189 standard deviations and non-Normally distributed data are presented as medians and quartiles.

190 Differences in time spent sedentary and at each physical activity intensity between children who were

191 normal weight and those affected by overweight/obesity were tested using gender and age adjusted

192 ANCOVA while gender differences were tested using age adjusted ANCOVA.

193

194 Poisson regression was used to examine the risk of overweight/obesity by (1) average daily quartile of

195 sedentary time, (2) average daily quartile of MVPA time, (3) meeting MVPA recommendations, (4)

196 meeting ST recommendations and (5) meeting both recommendations. Models 1 were adjusted for

197 gender, child age, maternal education and accelerometer wear month. Models 2 were further

198   adjusted for average daily kcal intake, average daily fruit and vegetable intake, average daily SSB

199   intake and parent reported sleep time. To assess the independent association of sedentary time and

200   MVPA on childhood overweight/obesity, the quartiles of MVPA time and quartiles of sedentary time

201   variables were adjusted for one another whilst including all other covariates. The MVPA and ST

202   recommendation variables were also adjusted for one another. Tests for trend were obtained by

203   including sedentary and MVPA quartiles values as continuous variables. Possible multicollinearity

204   between MVPA and sedentary time was assessed using correlation coefficients and variance inflation

205   factor (VIF). All regression analysis accounted for the clustering of children within schools. Regression

206   analysis excluding children who under reported their average daily kcals intake was also undertaken.

207   Statistical analysis was conducted in Stata 12 IC (StataCorp LP, USA).

208

209

210   **Results**

211   Of the 1,075 children who participated in the study, 1,029 had accelerometer data available. The case

212   base for the current paper is the 826 children who provided valid physical activity (≥600 minutes of

213   waking time data recorded for each of the seven days) and BMI data. The median accelerometer wear

214   time for the 826 children was 99.2% (IQR 98.5-99.7%) and missing wear time data were scaled to full

215   wear time for each child. Table 1 describes the characteristics of the participating children by gender.

216   Overall, 56.3% of the participating children were boys and mean age was 9.9 years (SD 0.7). Median

217   daily fruit and vegetable intake in girls and boys was 112.0g and 95.3g, respectively. Median daily SSB

218   intake was 166.7ml in girls and 194.7ml in boys. Overall, 94.6% of girls and 89.6% of boys had adequate

219   parent reported sleep time. One hundred and ninety six children (23.7%, 95% CI, 20.8-26.6%) were

220   affected by overweight/obesity.

221

222   Figure 1 presents the proportion of children achieving WHO recommended MVPA levels, by gender

223   and weight status. In total, 22.1% (95% CI, 19.2-24.9%) of children achieved the recommended

224   physical activity levels on each of the seven days. A higher proportion of boys met the

225   recommendations than girls (26.6% vs. 16.3%, p<0.001). A higher proportion of normal weight

226   children met the MVPA recommendations than children with overweight/obesity (26.0% vs. 9.7%,

227   p<0.001).

228

229   Table 2 presents mean time spent engaging in each physical activity intensity and mean time spent

230   sedentary over the total week, on weekdays and on weekend days in the total sample and by weight

231   status. Over the total week, children spent on average 27.9% (234.6 minutes) of their time at light

232   physical activity, 10.8% (90.6 minutes) of their time at MVPA and 61.3% (8.6 hours) of their time

233   sedentary (not including sleeping time). Boys spent more time engaged in MVPA than girls on

234   weekdays (p<0.001), weekend days (p=0.002) and over the total week (p<0.001) and also spent slightly

235   more time sedentary than girls over the total week (8.6 v 8.5 hours, p=0.06).

236

237   Time spent at light physical activity did not differ between the normal weight children and children

238   with overweight/obesity. Normal weight children spent an average of 20 minutes longer per day

239   engaging in MVPA than children with overweight/obesity over the total week (95.4 v 75.1 minutes,

240   p<0.001). Normal weight children spent less time sedentary than children with overweight/obesity on

241   weekdays (8.6 v 8.9 hours, p=0.008), weekend days (8.2 v 8.6 hours, p=0.001) and over the total week

242   (8.5 v 8.8 hours, p=0.001) (Table 2).

243

244   Table 3 presents the proportion and characteristics of children who met neither, one or both

245   recommendations (physical activity and ST) over a total week. Overall, 5.2% of children met both

246 recommendations, 17.0% met MVPA recommendations only, 12.3% met ST recommendations only,

247 and 65.5% met neither recommendation. More children with overweight/obesity met neither

248 recommendation than normal weight children (81.4% v 60.6%, p<0.001). Children who achieved

249 neither recommendation spent less time at MVPA, more time sedentary, had a lower median fruit and

250 vegetable intake, a higher median SSB intake and fewer achieved sleep time guidelines than those

251 who met both recommendations.

252

253 Table 4 presents the independent association of MVPA and total sedentary time on the risk of

254 childhood overweight/obesity over the total week. Children in the lowest MVPA quartile compared to

255 the highest quartile were at a 4.29 (95% CI, 2.34-7.88, p-trend<0.001) times increased risk of

256 overweight/obesity compared to children who were normal weight, independent of sedentary time.

257 There was a graded association between total time spent sedentary and obesity risk whilst controlling

258 for demographic and lifestyle factors (diet and sleep) though this association did not persist following

259 adjustment for MVPA. Independent of MVPA, the risk of overweight/obesity in children in the most

260 sedentary quartile was 0.74 (95% CI, 0.41-1.34, p-trend=0.5) when compared to the least sedentary

261 quartile. Children who did not achieve MVPA recommendations were at a 2.45 (95% CI, 1.59-3.77)

262 times increased risk of overweight/obesity compared to those who met MVPA recommendations.

263 Children who had greater than two hours of ST per day were at a 1.90 (95% CI, 1.21-3.02) times

264 increased risk of overweight/obesity compared with those who had less than 2 hours of ST per day.

265 Similar findings were observed when the analysis was conducted on the 560 children considered as

266 plausible energy intake reporters (data not shown).

267

268 **Discussion**

269 **Main findings**

270   This study examined the independent association of MVPA and sedentary behaviour (objective and

271   questionnaire based data) on the risk of childhood overweight/obesity. There are three key findings.

272   First, children spent 10.8% of their waking time at MVPA and 61.3% sedentary, with those who were

273   overweight/obese less active than children who were normal weight. Second, few children met

274   physical activity (22.1%) or ST recommendations (17.5%), with only 5.2% of children meeting both

275   recommendations. Furthermore, a higher proportion of children with overweight/obesity met neither

276   recommendation than those with a normal weight (81.4% v 60.6%). Third, MVPA was associated with

277   an increased risk of childhood overweight/obesity independent of sedentary time. In contrast, total

278   sedentary time was not associated with childhood overweight/obesity independent of MVPA.

279   However, children who did not meet ST recommendations were at an increased risk of

280   overweight/obesity, independent of physical activity.

281

282   On individual days of the week, up to three quarters of children met MVPA guidelines though only

283   22% of children met WHO recommendations of 60 minutes of MVPA each day suggesting that children

284   are not consistently active over a full week. Children with a normal weight were also more active and

285   spent less time sedentary than those with overweight/obesity on week and weekend days. Over the

286   full week, normal weight children spent approximately 20 additional minutes per day engaging in

287   MVPA when compared to children with overweight/obesity. Though the findings of this study may not

288   be generalisable to children of all ages, increasing MVPA levels in children with overweight/obesity to

289   reach levels in normal weight children may be an achievable goal for policy makers.

290

291   Having used a wrist worn accelerometer, our study adds to the current evidence base as many cross

292   sectional associations to date are from studies using hip worn monitors (Ekelund et al., 2014). Our

293   findings suggest that lack of physical activity and high ST are both predominant risk factors for

294   childhood overweight/obesity, independent of one another and other factors including dietary intake

295   and parent reported sleep time. Furthermore, a dose response relationship was evident for increasing

296   levels of MVPA and the risk of overweight/obesity. The association between total sedentary time and

297   overweight/obesity was attenuated once MVPA was accounted for in the model. However, there is

298   lack of consensus on the appropriateness of including two accelerometer derived activity behaviours

299   in one model. Some studies have reported similar findings where sedentary time was either weakly or

300   not associated with overweight/obesity independent of MVPA (Ekelund et al., 2014). However, we

301   found that meeting ST recommendations was associated with overweight/obesity independent of

302   physical activity, which contributes to the current evidence base. Our finding suggests that how

303   sedentary time is spent (e.g. ST) may be more important than total time spent sedentary. However,

304   as this study only collected data on weekday ST, this may have influenced the prevalence estimates

305   and the subsequent associations with weight status. Some research suggests that diet may help

306   explain the association between time at screen based activities and obesity (Prentice-Dunn & Prentice-

307   Dunn, 2012). Further research is warranted to assess the potential mediating role of diet on the

308   association between ST and obesity.

309

310   Due to the low number of children with overweight/obesity meeting both recommendations in this

311   study, we were unable to assess any additive effect of meeting both recommendations on the risk of

312   childhood overweight/obesity. However, children who achieved neither recommendation (physical

313   activity or ST) were less active, more sedentary, had a poorer dietary intake and fewer achieved

314   adequate sleep compared to those who met both recommendations. This suggests that targeting

315   multiple lifestyle behaviours with a focus on increasing physical activity and reducing ST behaviour

316   may be important to tackle childhood overweight/obesity. However, this area of research would

317   benefit from further study, particularly with a longitudinal approach.

318

319 **Strengths and limitations**

320 To our knowledge, this is the first population based study to report levels of objectively measured

321 physical activity in Irish children. This is one of few population based studies which included objectively

322 measured height, weight, sedentary time and physical activity along with 3 day food diaries. Parent

323 reported data were also collected which allowed a variable to reflect ST recommendations to be

324 constructed.

325

326 This study also has a number of limitations. As the study is cross-sectional, the direction of the

327 relationships between activity, ST and BMI cannot be proven, and may be reciprocal throughout

328 childhood. Decisions made during data processing of accelerometers can have a methodological

329 influence on whether children are found to comply with recommendations (Cain, Sallis, Conway, Van

330 Dyck, & Calhoon, 2013). Data processing decisions can also influence whether time is categorised as

331 either sedentary or non-wear time. Further, the classification thresholds for the non-dominant wrist

332 may overestimate sedentary time (van Loo et al., 2016). The parental questionnaire did not collect

333 data on all electronic devices that can be used for ST purposes. Furthermore, information on sedentary

334 multi-tasking was not collected as part of the study. Though the ST variables in the study were based

335 on parent reported weekday ST patterns, it is arguably appropriate for ranking individuals. However,

336 children typically have more ST on weekends than weekdays (Bucksch et al., 2016). Finally, the validity

337 and reliability of the food diary needs to be tested though we assessed for measurement error in

338 energy intake reporting in this study.

339

340 **Conclusions**

341 Less than one quarter of schoolchildren met international physical activity (22.1%) recommendations

342 and less than one-fifth (17.5%) met ST recommendations. Overall, two-thirds (65.5%) of children met

343 neither recommendation. Low MVPA was associated with an increased risk of childhood

344   overweight/obesity independent of sedentary time. Further, meeting ST recommendations (but not

345   objective sedentary time) was associated with childhood overweight/obesity independent of physical

346   activity. As physical inactivity and sedentary behaviour are common modifiable behaviours in children,

347   effective population based strategies are urgently needed. Improving compliance to health

348   recommendations and targeting the mean difference of 20 minutes per day spent at MVPA between

349   children who are normal weight and those with overweight/obesity are achievable goals for policy

350   makers.

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477 **Table 1. Characteristics of the girls and boys participating in the Cork Children's Lifestyle (CCLaS)**

478 **Study**

	Girls	Boys
	N=362	**N=464**
	Mean ± SD/ Median (IQR)	**Mean ± SD/ Median (IQR)**
Age (continuous)	9.9 ±0.7	9.9 ±0.6
Height (cm)	139.7 ±7.3	139.9 ±6.9
Weight (kg)	34.4 (29.9, 40.8)	34.8 (30.0,39.5)
BMI (kg/m^2)	17.7 (16.1,20.0)	17.4 (16.1,19.5)
Average daily energy intake (kcals)	1434.0 (1151.3, 1735.0)	1588.3 (1301.7, 1924.0)
Average daily sugar sweetened beverage intake (ml)	166.7 (50.0, 329.3)	194.7 (55.7, 403.3)
Average daily fruit and vegetable intake (g)	112.0 (48.3, 209.3)	95.3 (37.0, 181.5)
Time spent sedentary**		
Total week (mins/day)	509.8 ±65.7	518.8 ±67.1
(hours/day)	8.5 ±1.1	8.6 ±1.1
Week days (mins/day)	517.8 ±66.1	524.1 ±68.4
(hours/day)	8.6 ±1.1	8.7 ±1.1
Weekend days (mins/day)	489.8 ±87.2	505.7 ±93.4
(hours/day)	8.2 ±1.5	8.4 ±1.6
Time spent at MVPA**		
Total week (mins/day)	78.7 ±31.3	99.9 ±36.7
Week days (mins/day)	80.4 ±30.1	101.4 ±37.1
Weekend days(mins/day)	74.3 ±45.2	96.1 ±54.3

ST recommendations (<2 hours per day)	N (%)	N (%)
Met recommendations	72 (20.6)	68 (15.1)
Didn't meet recommendations	277(79.4)	383 (84.9)
MVPA recommendations (≥60 mins each day)		
Met recommendations	59 (16.3)	124 (26.7)
Didn't meet recommendations	303 (83.7)	340 (73.3)
Average daily MVPA ≥60 mins		
Yes	246 (68.0)	398 (85.8)
No	116 (32.0)	66 (14.2)
Parent reported sleep time		
Adequate	334 (94.6)	407 (89.6)
Not adequate	19 (5.4)	47 (10.4)
Weight status*		
Normal weight	270 (74.6)	360 (77.6)
Overweight	68 (18.8)	85 (18.3)
Obese	24 (6.6)	19 (4.1)

479 **Footnotes:** MVPA= moderate to vigorous physical activity, ST= screen time. Values are either

480 presented as means and SD, medians and IQR or N and %. Data on ST was missing for 26 children.

481 *Weight status calculated from BMI and categorised using IOTF definitions, **Based on an average of

482 14 hours of waking time over total day, an average of 14.2 hours of waking time on week days and an

483 average of 13.4 hours of waking time on weekend days.

484

Table 2. Mean time spent sedentary and at each physical activity intensity in school aged children, by weight status

	Total sample (mean, 95% CI)	Normal weight (mean, 95% CI)	Overweight/obese (mean, 95%CI)	P-value
	N=826	**630 (76.3%)**	**196 (23.7%)**	
Total week**				
Sedentary (mins/day)	514.9 (510.3-519.4)	510.7 (505.5-515.8)	528.4 (519.0-537.8)	<0.001
(hours/day)	8.6 (8.5-8.7)	8.5 (8.4-8.6)	8.8 (8.7-9.0)	
Light PA (mins/day)	234.6 (231.2-237.9)	234.0 (230.2-237.8)	236.5 (229.5-243.6)	0.92
Moderate PA (mins/day)	79.8 (77.8-81.8)	83.4 (81.1-85.8)	68.1 (64.4-71.8)	<0.001
Vigorous PA (mins/day)*	9.5 (5.1-16.3)	11.1 (6.0-17.7)	6.0 (3.9-10.7)	<0.001
MVPA (mins/day)	90.6 (88.2-93.1)	95.4 (92.6-98.3)	75.1 (70.8-79.4)	<0.001
Total weekdays**				
Sedentary (mins/day)	521.3 (516.7-525.9)	517.9 (512.6-523.1)	532.4 (522.9-542.0)	0.003
(hours/day)	8.7 (8.6-8.8)	8.6 (8.5-8.7)	8.9 (8.7-9.0)	
Light PA (mins/day)	238.5 (235.1-241.9)	237.4 (233.6-241.3)	241.9 (234.5-249.3)	0.53
Moderate PA (mins/day)	80.9 (78.9-82.9)	84.2 (81.9-86.5)	70.2 (66.5-73.8)	<0.001
Vigorous PA (mins/day)*	9.8 (5.0-17.0)	11.0 (6.0-18.4)	5.8 (3.4-11.0)	<0.001

MVPA (mins/day)	92.2 (89.8-94.7)	96.8 (93.9-99.6)	77.6 (73.4-81.9)	<0.001
Total weekend days**				
Sedentary (mins/day)	498.7 (492.5-504.9)	492.7 (485.6-499.7)	518.2 (505.4-531.1)	<0.001
(hours/day)	8.3 (8.2-8.4)	8.2 (8.1-8.3)	8.6 (8.4-8.9)	
Light PA (mins/day)	224.8 (220.5-229.1)	225.3 (220.4-230.2)	223.0 (214.3-231.8)	0.34
Moderate PA (mins/day)	77.0 (74.1-80.0)	81.5 (78.0-84.9)	62.8 (57.2-68.3)	<0.001
Vigorous PA (mins/day)*	6.4 (2.0-14.6)	7.1 (2.5-16.5)	4.5 (1.0-8.6)	<0.001
MVPA (mins/day)	86.5 (83.0-90.0)	92.0 (87.9-96.1)	68.8 (62.5-75.1)	<0.001

Footnotes: PA = physical activity, MVPA= moderate to vigorous physical activity. All values except vigorous PA are means and 95% CI. Weight status comparisons for means were made using age and gender adjusted ANCOVA. *Medians and IQR. Weight status comparisons for medians were made using Wilcoxon's rank sum test. **Based on an average of 14 hours of waking time over total day, an average of 14.2 hours of waking time on week days and an average of 13.4 hours of waking time on weekend days.

Table 3. Proportion and lifestyle characteristics of children who meet moderate to vigorous physical activity and screen time recommendations over a total week

	N (%)	Sedentary hours/day Mean (SD)	MVPA minutes/day Mean (SD)	Average daily fruit and vegetable intake (g) Median (IQR)	Average daily sugar sweetened beverage intake (ml) Median (IQR)	Sleep time not adequate %
Met physical activity and screen time recommendations						
Met both	42 (5.3)	7.5 (0.7)	130.7 (26.1)	192.0 (91.7, 301.7)	83.3 (0, 202.7)	4.8
Met MVPA only	136 (17.0)	7.7 (0.9)	128.9 (25.2)	112.8 (50.5, 234.5)	182.6 (53.7, 370.3)	11.0
Met ST only	98 (12.3)	8.6 (1.1)	81.1 (33.4)	126.0 (70.7, 252.3)	150.0 (17.7, 353.3)	5.1
Met neither	524 (65.5)	8.9 (1.0)	79.0 (30.1)	91.7 (33.0, 166.7)	200.0 (59.3, 378.0)	8.2

Footnote: MVPA= moderate to vigorous physical activity, ST=screen time.

1 **Table 4. Independent associations between sedentary time, moderate to vigorous physical activity**

2 **and the risk of childhood overweight/obesity over the total week**

		Model 1[1]	Model 2[2]	Model 3
		Adjusted for demographic factors	Adjusted for demographics and lifestyle factors	Fully adjusted
		RR (95% CI)	RR (95% CI)	
Objective sedentary time	Quartile 1 (least sedentary)	1	1	1 [3]
	Quartile 2	0.89 (0.61-1.30)	0.89 (0.59-1.33)	0.69 (0.45-1.05)
	Quartile 3	1.54 (1.07-2.21)	1.47 (0.98-2.18)	0.86 (0.51-1.45)
	Quartile 4 (most sedentary)	1.72 (1.18-2.50)	1.63 (1.09-2.45)	0.74 (0.41-1.34)
		p-trend<0.001	p-trend=0.002	p-trend=0.5
Objective MVPA time	Quartile 4 (most MVPA)	1	1	1 [4]
	Quartile 3	1.96 (1.25-3.07)	1.92 (1.25-2.95)	2.06 (1.25-3.38)

	Quartile 2	2.73 (1.92-3.87)	2.47 (1.81-3.36)	2.73 (1.71-4.35)
	Quartile 1 (least MVPA)	3.99 (2.53-6.29)	3.71 (2.43-5.67)	4.29 (2.34-7.88)
		p-trend<0.001	p-trend<0.001	p-trend<0.001
Met MVPA recommendations	Yes (≥60 mins each day)	1	1	1 [5]
	No (<60 mins each day)	2.63 (1.72-4.00)	2.42 (1.61-3.64)	2.45 (1.59-3.77)
Met ST recommendations	Yes (< 2 per hours)	1	1	1 [6]
	No (> 2 per hours)	1.96 (1.22-3.16)	1.90 (1.21-2.96)	1.90 (1.21-3.02)
Met both recommendations	Met both	1	1	
	Met one/ neither	2.13 (1.47-3.07)	2.12 (1.47-3.07)	-

3 **Footnotes:** [1]Model 1 adjusted for gender, child age, highest level of maternal education, and

4 accelerometer wear month. [2]Model 2 adjusted for gender, child age, highest level of maternal

5 education, accelerometer wear month, average daily kcal intake, average daily fruit and vegetable

6 intake, average daily SSB intake and parent reported sleep time. [3]Partially adjusted model plus quartile

7 of MVPA time. [4] Partially adjusted model plus quartile of sedentary time. [5] Partially adjusted model

8   plus whether participants met ST recommendations. [6] Partially adjusted model plus whether

9   participants met MVPA recommendations.

Figure 1. Proportion of children achieving recommended level of moderate to vigorous physical activity by (1) gender and (2) weight status