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1 **Title Page**

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Abstract

Purpose: Globally, public health policies are targeting modifiable lifestyle behaviours. We explore the independent association of moderate-to-vigorous physical activity (MVPA) and sedentary behaviour on the risk of childhood overweight/obesity.

Method: A cross-sectional survey of children aged 8-11 years (N=826). Objective body mass index was used to classify children as normal weight or overweight/obese. Children wore wrist-worn Geneactiv accelerometers for 7-days and thresholds were applied to categorise MVPA and sedentary time. Screen time (ST) was parent reported. Poisson regression examined the independent association of (1) MVPA, (2) objective sedentary time and (3) ST on the risk of overweight/obesity.

Results: Overall, 23.7% (95% CI, 20.8-26.6%) of children were overweight/obese. On average, children spent 10.8% of waking time at MVPA and 61.3% sedentary. One-fifth (22.1%, 95% CI, 19.3-25.0%) of children achieved MVPA recommendations (≥ 60 minutes each day) and 17.5% (95% CI, 14.9-20.1%) met ST recommendations (< 2 hours per day). Time spent at MVPA was inversely associated with the risk of overweight/obese independent of total sedentary time. Total time spent sedentary was not associated with overweight/obese independent of MVPA. ST was associated with an increased risk of overweight/obese independent of physical activity.

Conclusion: Few schoolchildren met physical activity and screen time recommendations suggesting population based measures are needed.

Background

The World Health Organisation (WHO) has recommended that children achieve at least 60 minutes of moderate-to-vigorous physical activity (MVPA) daily (World Health Organization, 2010). However, large proportions of children fail to meet these guidelines. Recent estimates from a European study from five countries reported that only 4.6% of girls and 16.8% of boys aged 10-12 years met MVPA guidelines (Verloigne et al., 2012). Regular physical activity is beneficial for cardiovascular health, bone health, mental health and weight status (Poitras et al., 2016). Studies assessing the association between MVPA and childhood obesity have been relatively consistent with less active children at an increased risk of obesity when compared to more active children (Jiménez-Pavón, Kelly, & Reilly, 2010; Wittmeier, Mollard, & Kriellaars, 2008).

Sedentary behaviour can be defined whereby very little energy is being expended (≤ 1.5 metabolic equivalent units [METs]) during waking time, including sitting and lying down (Mark S Tremblay et al., 2011). Children have become increasingly sedentary in recent decades (Bucksch et al., 2016) and the association between sedentary behaviour and unfavourable health outcomes including obesity have received increased attention (Carson et al., 2016). Screen time (ST) is a distinct sub-domain of sedentary behaviour (Sigman, 2012). Current recommendations suggest that children should limit recreational ST to no more than two hours per day (Mark S Tremblay et al., 2016). However, more than half of all children exceed ST recommendations (Fakhouri, Hughes, Brody, Kit, & Ogden, 2013; LeBlanc et al., 2015).

An emerging evidence base suggests that physical activity and sedentary behaviour are separate constructs independently impacting on obesity risk, rather than sedentary behaviour simply representing low MVPA (Carson & Janssen, 2011; Pearson, Braithwaite, Biddle, Sluijs, & Atkin, 2014;

Salmon, Tremblay, Marshall, & Hume, 2011; Mark Stephen Tremblay, Colley, Saunders, Healy, & Owen, 2010). Children can meet MVPA guidelines but can also spend a high proportion of time sedentary and visa-versa (Eisenmann, Barteel, Smith, Welk, & Fu, 2008; Herman, Sabiston, Mathieu, Tremblay, & Paradis, 2014; Laurson et al., 2008). A recent systematic review suggested that further research is needed to clarify the interplay of physical activity and sedentary behaviour due to conflicting findings in the current literature (Pearson et al., 2014). Understanding the relationship between physical activity and sedentary behaviour may help inform the design of policies and interventions to tackle poor lifestyle behaviours and obesity in children.

Few studies have assessed the independent association of physical activity and sedentary time on adiposity in schoolchildren using objective measurements (Ekelund, Hildebrand, & Collings, 2014), with the majority of evidence from the UK and USA (Ekelund et al., 2014). To date, studies have consistently found that physical activity is associated with obesity indicators independent of sedentary time (Ekelund et al., 2014; Katzmarzyk et al., 2015). However, the association between objective sedentary time and obesity markers independent of physical activity is less clear (Cliff et al., 2016; Ekelund et al., 2014). Generally, the association between objective sedentary time and obesity is attenuated after adjustment for MVPA (Chaput et al., 2012; Ekelund et al., 2012; J. Mitchell, Pate, Beets, & Nader, 2013; J. A. Mitchell et al., 2009; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009). Other studies have assessed associations between subjectively measured sedentary behaviour and obesity independent of objective physical activity. Findings from these studies are mixed with some studies reporting positive associations (Coombs & Stamatakis, 2015; Ekelund et al., 2006) and others reporting no association (Colley et al., 2012; Ortega, Ruiz, & Sjöström, 2007).

The Cork Children's Lifestyle (CCLaS) Study is the first population based sample of schoolchildren in Ireland to collect objective physical activity data. We hypothesised that schoolchildren with overweight/obesity would be less active and more sedentary than those who are normal weight. This study describes objectively measured physical activity and sedentary time throughout the week, by gender and weight status. Second, we describe the characteristics of children who meet MVPA and ST recommendations (neither, one or both). Third, we explore the independent association of MVPA and sedentary behaviour (objective and questionnaire based data) on the risk of childhood overweight/obesity whilst considering demographic characteristics and other lifestyle factors (diet and parent reported sleep time).

Methods

Study design

Details of the CCLaS Study have been described elsewhere (Keane, Kearney, Perry, Browne, & Harrington, 2014). Briefly, the study aimed to recruit 1,000 schoolchildren to estimate the prevalence of overweight/obesity in Irish children with a precision of $\pm 2.7\%$ assuming a 26% prevalence rate within the study sample. Information on primary schools in Cork City (an urban area) and Mitchelstown (a rural area) was obtained from the Department of Education and Skills website. Children in 3rd and 4th classes (years 5 and 6 of enrollment into primary school) were the target population. Schools were recruited from Cork City using probability proportionate-to-size and purposive sampling. All schools in one rural area in Cork County were invited to participate. Data were collected in schools during school term times between April 2012 and June 2013. Overall, 1,075 8-11 year old children living in Cork, Ireland took part in the survey. At the school level, a response rate of 65.5% (N=27) was achieved, while 59% (N=1,075) of invited children participated in the study. Data were collected using physical measurements, child and parent questionnaires, 3 day food diaries and accelerometers. Ethical clearance was granted from the Clinical Research Ethics committee of the Cork

Teaching Hospitals, Cork, Ireland. Only children whose parents/guardians provided informed consent participated in the study (Keane et al., 2014).

Anthropometric measurements and obesity definition

Trained researchers measured child height and weight using standard methods (Keane et al., 2014). Height was measured to the nearest millimetre using a Leicester portable height stick and weight was measured to the nearest 0.1 kilogram using a Tanita WB100MA mechanical scale. Measurements were taken without shoes and in light clothing. Age and gender specific International Obesity Taskforce definitions for body mass index (BMI) were used to categorise children as (1) normal weight or (2) overweight/obese (Cole, Bellizzi, Flegal, & Dietz, 2000).

Physical activity and sedentary variables

Accelerometers

Free living physical activity was measured over seven consecutive days using a wrist worn validated tri-axial Geneactiv accelerometer (Esliger et al., 2011; Phillips, Parfitt, & Rowlands, 2012). The accelerometers were set to record at 100Hz for seven days using the 'on button press' setting of Geneactiv software version 2.2. The accelerometers were placed on the non-dominant hand of each participating child. Children were asked to wear the accelerometers 24 hours a day each day. The children were advised that the accelerometers were waterproof and were only to be removed if necessary.

The accelerometer data were downloaded using Geneactiv software version 2.2 and saved on hard drives. The day and month the accelerometer was worn was extracted from the accelerometers during processing. Days of the week were categorised as total week (Sunday-Saturday), week days (Monday-

Friday) or weekend days (Saturday-Sunday). Accelerometer wear month was categorised to reflect the school year as January-March, April-June or October-December.

Parent questionnaire data were used to identify the most frequent waking time and bed time on week and weekend days. These data were then used to estimate the number of waking hours each day. The mean waking time was 14 hours per day. To be included in the analysis, children needed to have recorded ≥ 600 minutes of waking time data for each of the seven days. For children included in the analysis who had missing data, data were scaled to full waking time. Non-wear time was determined using an algorithm by van Hees et al, 2011 (van Hees et al., 2011).

The raw data files (*.bin) were first read into minute by minute data files (*.csv) using R software and then summarised using SAS 9.3 (Statistical Analysis System Inc., 2002). Minutes per day spent sedentary and at light, moderate and vigorous physical activity were categorised using classification thresholds defined by Phillips et al., 2012 (Phillips et al., 2012). As our data were collected at 100Hz, the classification thresholds were adjusted from 80Hz to 100Hz (Phillips et al., 2012). Sedentary time minutes were divided by 60 and presented as hours per day. Children who achieved ≥ 60 minutes of MVPA on all seven days were categorised as meeting MVPA guidelines (World Health Organization, 2010).

Parent reported screen time

Two parent reported responses to questions were used to define ST. The first question asked how many hours per weekday the study child spends watching television, videos or DVDs and the second asked how many hours per weekday the study child spends using computer and non-active game consoles. Both questions had 6 level responses; none, less than an hour, 1 hour to less than 3 hours,

3 hours to less than 5 hours, 5 hours to less than 7 hours, or 7 hours or more. The responses were combined and those who engaged in <1 hour in both behaviours were categorised as <2 hours per day and the remainder of children were categorised as >2 hours per day (Mark S Tremblay et al., 2016).

Combined index for meeting public health recommendations

Children were categorised into four groups based on MVPA and ST recommendations as (1) met both, (2) met MVPA only, (3) met ST only or (4) met neither recommendation. This variable was dichotomised as met both recommendations versus met neither/one recommendation for the regression analysis (Table 4) due to the small numbers of children with overweight/obesity who met both recommendations.

Covariates

Gender was recorded as girl or boy by trained researchers during physical measurements. Child age was calculated using date of physical measurement and date of birth (parent reported). Parent reported highest level of maternal education is used as a proxy measure of socio-economic status. The variable was coded as lower secondary education or less, higher secondary education, post-secondary education, third level education or missing. A missing maternal education category (N=77) was created to retain the maximum number of children in the analysis.

Consecutive three day estimated food diaries were completed by the children and assessed for completeness with the children by trained research assistants (Keane et al., 2014). The food diary data were entered into WISP version 4 (Tinuviel Software, Anglesey, UK). Average daily energy (kcal) intake, average daily fruit and vegetable (g/day) intake, and average daily sugar sweetened beverage

(SSB; ml/day) intake were estimated. An energy intake to estimated basal metabolic rate (BMR) ratio was calculated, to classify under reporters (energy intake). BMR was calculated using equations by Schofield, 1985 (Schofield, 1984). Cut-off values for energy intake to BMR were defined using an equation proposed by Goldberg as either (1) under reporters or (2) plausible reporters (Black, 2000; Goldberg et al., 1991).

Sleep time was parent reported. Parents were asked to report when the child usually wakes up and goes to bed on week and weekend days separately. Average sleep time per night was calculated and sleep time was categorised as either adequate (>10 hours for 5-10 year olds, >9 hours for 10+ year olds) or not adequate ($\leq$ 10 hours for 5-10 year olds, $\leq$ 9 hours for 10+ year olds) (Chen, Beydoun, & Wang, 2008).

Statistical analysis

Prevalence estimates with 95% confidence intervals were calculated. Continuous variables were assessed for Normality using histograms. Normally distributed data are presented as means and standard deviations and non-Normally distributed data are presented as medians and quartiles. Differences in time spent sedentary and at each physical activity intensity between children who were normal weight and those affected by overweight/obesity were tested using gender and age adjusted ANCOVA while gender differences were tested using age adjusted ANCOVA.

Poisson regression was used to examine the risk of overweight/obesity by (1) average daily quartile of sedentary time, (2) average daily quartile of MVPA time, (3) meeting MVPA recommendations, (4) meeting ST recommendations and (5) meeting both recommendations. Models 1 were adjusted for gender, child age, maternal education and accelerometer wear month. Models 2 were further

adjusted for average daily kcal intake, average daily fruit and vegetable intake, average daily SSB intake and parent reported sleep time. To assess the independent association of sedentary time and MVPA on childhood overweight/obesity, the quartiles of MVPA time and quartiles of sedentary time variables were adjusted for one another whilst including all other covariates. The MVPA and ST recommendation variables were also adjusted for one another. Tests for trend were obtained by including sedentary and MVPA quartiles values as continuous variables. Possible multicollinearity between MVPA and sedentary time was assessed using correlation coefficients and variance inflation factor (VIF). All regression analysis accounted for the clustering of children within schools. Regression analysis excluding children who under reported their average daily kcals intake was also undertaken. Statistical analysis was conducted in Stata 12 IC (StataCorp LP, USA).

Results

Of the 1,075 children who participated in the study, 1,029 had accelerometer data available. The case base for the current paper is the 826 children who provided valid physical activity (≥ 600 minutes of waking time data recorded for each of the seven days) and BMI data. The median accelerometer wear time for the 826 children was 99.2% (IQR 98.5-99.7%) and missing wear time data were scaled to full wear time for each child. Table 1 describes the characteristics of the participating children by gender. Overall, 56.3% of the participating children were boys and mean age was 9.9 years (SD 0.7). Median daily fruit and vegetable intake in girls and boys was 112.0g and 95.3g, respectively. Median daily SSB intake was 166.7ml in girls and 194.7ml in boys. Overall, 94.6% of girls and 89.6% of boys had adequate parent reported sleep time. One hundred and ninety six children (23.7%, 95% CI, 20.8-26.6%) were affected by overweight/obesity.

Figure 1 presents the proportion of children achieving WHO recommended MVPA levels, by gender and weight status. In total, 22.1% (95% CI, 19.2-24.9%) of children achieved the recommended physical activity levels on each of the seven days. A higher proportion of boys met the recommendations than girls (26.6% vs. 16.3%, $p<0.001$). A higher proportion of normal weight children met the MVPA recommendations than children with overweight/obesity (26.0% vs. 9.7%, $p<0.001$).

Table 2 presents mean time spent engaging in each physical activity intensity and mean time spent sedentary over the total week, on weekdays and on weekend days in the total sample and by weight status. Over the total week, children spent on average 27.9% (234.6 minutes) of their time at light physical activity, 10.8% (90.6 minutes) of their time at MVPA and 61.3% (8.6 hours) of their time sedentary (not including sleeping time). Boys spent more time engaged in MVPA than girls on weekdays ($p<0.001$), weekend days ($p=0.002$) and over the total week ($p<0.001$) and also spent slightly more time sedentary than girls over the total week (8.6 v 8.5 hours, $p=0.06$).

Time spent at light physical activity did not differ between the normal weight children and children with overweight/obesity. Normal weight children spent an average of 20 minutes longer per day engaging in MVPA than children with overweight/obesity over the total week (95.4 v 75.1 minutes, $p<0.001$). Normal weight children spent less time sedentary than children with overweight/obesity on 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 (8.5 v 8.8 hours, $p=0.001$) (Table 2).

Table 3 presents the proportion and characteristics of children who met neither, one or both recommendations (physical activity and ST) over a total week. Overall, 5.2% of children met both

recommendations, 17.0% met MVPA recommendations only, 12.3% met ST recommendations only, and 65.5% met neither recommendation. More children with overweight/obesity met neither recommendation than normal weight children (81.4% v 60.6%, $p<0.001$). Children who achieved neither recommendation spent less time at MVPA, more time sedentary, had a lower median fruit and vegetable intake, a higher median SSB intake and fewer achieved sleep time guidelines than those who met both recommendations.

Table 4 presents the independent association of MVPA and total sedentary time on the risk of childhood overweight/obesity over the total week. Children in the lowest MVPA quartile compared to the highest quartile were at a 4.29 (95% CI, 2.34-7.88, $p\text{-trend}<0.001$) times increased risk of overweight/obesity compared to children who were normal weight, independent of sedentary time. There was a graded association between total time spent sedentary and obesity risk whilst controlling for demographic and lifestyle factors (diet and sleep) though this association did not persist following adjustment for MVPA. Independent of MVPA, the risk of overweight/obesity in children in the most sedentary quartile was 0.74 (95% CI, 0.41-1.34, $p\text{-trend}=0.5$) when compared to the least sedentary quartile. Children who did not achieve MVPA recommendations were at a 2.45 (95% CI, 1.59-3.77) times increased risk of overweight/obesity compared to those who met MVPA recommendations. Children who had greater than two hours of ST per day were at a 1.90 (95% CI, 1.21-3.02) times increased risk of overweight/obesity compared with those who had less than 2 hours of ST per day. Similar findings were observed when the analysis was conducted on the 560 children considered as plausible energy intake reporters (data not shown).

Discussion

Main findings

This study examined the independent association of MVPA and sedentary behaviour (objective and questionnaire based data) on the risk of childhood overweight/obesity. There are three key findings. First, children spent 10.8% of their waking time at MVPA and 61.3% sedentary, with those who were overweight/obese less active than children who were normal weight. Second, few children met physical activity (22.1%) or ST recommendations (17.5%), with only 5.2% of children meeting both recommendations. Furthermore, a higher proportion of children with overweight/obesity met neither recommendation than those with a normal weight (81.4% v 60.6%). Third, MVPA was associated with an increased risk of childhood overweight/obesity independent of sedentary time. In contrast, total sedentary time was not associated with childhood overweight/obesity independent of MVPA. However, children who did not meet ST recommendations were at an increased risk of overweight/obesity, independent of physical activity.

On individual days of the week, up to three quarters of children met MVPA guidelines though only 22% of children met WHO recommendations of 60 minutes of MVPA each day suggesting that children are not consistently active over a full week. Children with a normal weight were also more active and spent less time sedentary than those with overweight/obesity on week and weekend days. Over the full week, normal weight children spent approximately 20 additional minutes per day engaging in MVPA when compared to children with overweight/obesity. Though the findings of this study may not be generalisable to children of all ages, increasing MVPA levels in children with overweight/obesity to reach levels in normal weight children may be an achievable goal for policy makers.

Having used a wrist worn accelerometer, our study adds to the current evidence base as many cross sectional associations to date are from studies using hip worn monitors (Ekelund et al., 2014). Our findings suggest that lack of physical activity and high ST are both predominant risk factors for

childhood overweight/obesity, independent of one another and other factors including dietary intake and parent reported sleep time. Furthermore, a dose response relationship was evident for increasing levels of MVPA and the risk of overweight/obesity. The association between total sedentary time and overweight/obesity was attenuated once MVPA was accounted for in the model. However, there is lack of consensus on the appropriateness of including two accelerometer derived activity behaviours in one model. Some studies have reported similar findings where sedentary time was either weakly or not associated with overweight/obesity independent of MVPA (Ekelund et al., 2014). However, we found that meeting ST recommendations was associated with overweight/obesity independent of physical activity, which contributes to the current evidence base. Our finding suggests that how sedentary time is spent (e.g. ST) may be more important than total time spent sedentary. However, as this study only collected data on weekday ST, this may have influenced the prevalence estimates and the subsequent associations with weight status. Some research suggests that diet may help explain the association between time at screen based activities and obesity (Prentice-Dunn & Prentice-Dunn, 2012). Further research is warranted to assess the potential mediating role of diet on the association between ST and obesity.

Due to the low number of children with overweight/obesity meeting both recommendations in this study, we were unable to assess any additive effect of meeting both recommendations on the risk of childhood overweight/obesity. However, children who achieved neither recommendation (physical activity or ST) were less active, more sedentary, had a poorer dietary intake and fewer achieved adequate sleep compared to those who met both recommendations. This suggests that targeting multiple lifestyle behaviours with a focus on increasing physical activity and reducing ST behaviour may be important to tackle childhood overweight/obesity. However, this area of research would benefit from further study, particularly with a longitudinal approach.

Strengths and limitations

To our knowledge, this is the first population based study to report levels of objectively measured physical activity in Irish children. This is one of few population based studies which included objectively measured height, weight, sedentary time and physical activity along with 3 day food diaries. Parent reported data were also collected which allowed a variable to reflect ST recommendations to be constructed.

This study also has a number of limitations. As the study is cross-sectional, the direction of the relationships between activity, ST and BMI cannot be proven, and may be reciprocal throughout childhood. Decisions made during data processing of accelerometers can have a methodological influence on whether children are found to comply with recommendations (Cain, Sallis, Conway, Van Dyck, & Calhoun, 2013). Data processing decisions can also influence whether time is categorised as either sedentary or non-wear time. Further, the classification thresholds for the non-dominant wrist may overestimate sedentary time (van Loo et al., 2016). The parental questionnaire did not collect data on all electronic devices that can be used for ST purposes. Furthermore, information on sedentary multi-tasking was not collected as part of the study. Though the ST variables in the study were based on parent reported weekday ST patterns, it is arguably appropriate for ranking individuals. However, children typically have more ST on weekends than weekdays (Bucksch et al., 2016). Finally, the validity and reliability of the food diary needs to be tested though we assessed for measurement error in energy intake reporting in this study.

Conclusions

Less than one quarter of schoolchildren met international physical activity (22.1%) recommendations and less than one-fifth (17.5%) met ST recommendations. Overall, two-thirds (65.5%) of children met 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 $\pm$ SD/ Median (IQR)	Mean $\pm$ SD/ Median (IQR)
Age (continuous)	9.9 $\pm$ 0.7	9.9 $\pm$ 0.6
Height (cm)	139.7 $\pm$ 7.3	139.9 $\pm$ 6.9
Weight (kg)	34.4 (29.9, 40.8)	34.8 (30.0, 39.5)
BMI (kg/m²)	17.7 (16.1, 20.0)	17.4 (16.1, 19.5)
Average daily energy intake (kcal)	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 $\pm$ 65.7	518.8 $\pm$ 67.1
(hours/day)	8.5 $\pm$ 1.1	8.6 $\pm$ 1.1
Week days (mins/day)	517.8 $\pm$ 66.1	524.1 $\pm$ 68.4
(hours/day)	8.6 $\pm$ 1.1	8.7 $\pm$ 1.1
Weekend days (mins/day)	489.8 $\pm$ 87.2	505.7 $\pm$ 93.4
(hours/day)	8.2 $\pm$ 1.5	8.4 $\pm$ 1.6
Time spent at MVPA**		
Total week (mins/day)	78.7 $\pm$ 31.3	99.9 $\pm$ 36.7
Week days (mins/day)	80.4 $\pm$ 30.1	101.4 $\pm$ 37.1
Weekend days (mins/day)	74.3 $\pm$ 45.2	96.1 $\pm$ 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)

Footnotes: MVPA= moderate to vigorous physical activity, ST= screen time. Values are either presented as means and SD, medians and IQR or N and %. Data on ST was missing for 26 children.

*Weight status calculated from BMI and categorised using IOTF definitions, **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 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 1¹	Model 2²	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:** ¹Model 1 adjusted for gender, child age, highest level of maternal education, and
4 accelerometer wear month. ²Model 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. ³Partially 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

