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Physical activity levels of Reception children in the North-East of England: a cross-sectional analysis of seasonal, daily and hourly variation

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ABSTRACT: Children's early years are a key time for development, with research suggesting that engaging in physical activity (PA) can have positive health effects. The aim of this study was to describe the cross-sectional PA levels, PA guideline compliance, and how PA varies according to temporal, demographic, and anthropometric factors in Reception children in the North-East of England. Accelerometer measured PA data was recorded and processed according to time spent in sedentary behaviour (SB), light, moderate, moderate to vigorous PA (MVPA) and total PA and analyses were performed according to individual and environmental variations. 265 children provided valid PA data (defined as 8 hours of wear time on three days). 51% of the sample were boys. Children engaged in 261.6 minutes/day of SB, 99.5 minutes/day of MVPA and 271.6 minutes/day of light PA. Significant differences were observed according to season, day of the week, time of the day, sex, socioeconomic status, age, and body mass index-z (BMI-z). This study found that on average, 4–5-year-old children in the North-East of England met the UK PA guidelines. However, there were temporal, sex and socioeconomic differences in PA, highlighting opportunities to promote PA at schools and at home.

Keywords: *physical activity, early years, reception*

Introduction

Early childhood is a key time for physical, emotional and cognitive development, and when the opportunity to be physically active is greatest, as behaviours are less structured than older children and adults (Fisher, 2009; Mirkhil, 2010; White & Sharp, 2007). There is evidence that in the early years, children who are more physically active have better health outcomes in relation to adiposity, motor development, psychosocial health, cardio-metabolic indicators (Timmons et al., 2012) and cognition (Carson, Hunter, Kuzik, Wiebe et al., 2016), compared to their less active peers. The most profound benefits to health in early years in terms of adiposity, cardiovascular health and cognitive performance can be gained from engaging in moderate to vigorous physical activity (MVPA) (Tomporowski, et al., 2011). Sedentary behaviour (SB), however, can bring about both positive and negative impacts on health (LeBlanc et al., 2012). There is some evidence that SB is associated with obesity in preschool children (te Velde et al., 2012), particularly television viewing (LeBlanc et al., 2012). Likewise, a systematic review found that watching television for more than 2 hours a day was associated with decreased fitness, decreased academic achievement and increased body mass index (BMI) in early childhood (Carson, Hunter, Kuzik, Gray et al., 2016). However, time spent in SB has been associated with school readiness (Jones et al., 2021), and behaviours such as reading, and storytelling have been demonstrated to benefit cognitive development in early years (Carson et al., 2015). There is also evidence that physical activity (PA) and SB track over time (Janz et al., 2005; Jones et al., 2013), highlighting the importance of early years as a critical time to promote engagement in PA. Accordingly, the UK government recommends that children under 5 should engage in 180 minutes of PA, including 60 minutes of MVPA per day. The guidelines for children aged 5–18 however, state that children need to engage in 60 minutes of MVPA per day, on average, over the course of a week (Chief Medical Officer [CMO], 2019).

Despite the well evidenced benefits of engaging in PA (Timmons et al., 2012), studies investigating PA in early years have documented low PA levels (Timmons et al., 2007; Tucker, 2008). In the UK, Roscoe et al. (2019) found that none of the 178 3 and 4-year-old children met the recommended PA level of 180 minutes of PA per day. Similarly, Scholes and Mindell (2015) found that just 9% of 2–4-year-old children engaged in 180 minutes of PA per day, as reported by their parents in a country wide survey. Similarly, low levels of physical activity in early years have been demonstrated outside of the UK. A study combining accelerometer data from different European countries found that on average 1,043 four to five-year-old boys and girls achieve 42 and 33 minutes of MVPA per day respectively (Konstabel et al., 2014). However, research findings for PA levels vary, with some studies reporting, high levels of PA. Hesketh et al. (2014) found that all 593 4-year-

old children met the guideline for achieving 180 minutes of activity per day, and Jago et al. (2014) found that 62% of 5–6-year-old children, met guidelines of 60 minutes of MVPA per day. Contrasting findings are also seen within countries; studies from Canada demonstrated contrasting levels of preschool children engaging in 60 minutes of MVPA per day. Chaput et al., (2017) found that 62% met the guidelines, whereas Colley et al. (2013) found that just 13% of children were sufficiently active (Colley et al., 2013). Finally, a review of 40 articles on preschool physical activity found the proportion of children meeting the MVPA recommendations vary from 27%-100% (Hnatiuk et al., 2014).

It is important to explore what enables or prevents early years children from being physically active, as this knowledge allows targeted interventions to be developed to promote healthy behaviours. Research suggests that PA in early years varies according to temporal factors, such as season, day of the week and time of the day. Research has found that early years children engage in significantly more MVPA in summer compared to other seasons (Hesketh et al., 2014; Nilsen et al., 2019). Several studies have explored variations in early years PA levels according to day of the week. However, these findings vary between, more MVPA on a weekend (Collings et al., 2020), to no difference between weekday and weekend MVPA (Foweather et al., 2015; Roscoe et al., 2019). The time of the day is also an important predictor for PA, van Cauwenberghe et al. (2012) and O'Dwyer et al. (2014) found that children engage in more MVPA, and less SB during lunchtimes compared to other times in the school day. Research has also found that early years PA levels vary according to demographic and anthropometric factors such as sex, age, socioeconomic status and BMI (Bingham et al., 2016; Hinkley et al., 2008).

Although some studies have explored the PA levels of children aged 3-6 years old, limited studies have described only the activity levels of Reception children in the UK. In England, the majority of children attend reception full time (often 9am – 3pm) in the September following their fourth birthday. Reception is part of the Early Years Foundation Stage; it focusses more on play-based learning and precedes formal schooling (Fisher, 2009). As a result, it may provide children greater freedom to be active. Therefore, the aim of this observational epidemiological study was to describe the cross-sectional PA levels, PA guideline compliance, and how PA varies according to temporal, demographic, and anthropometric factors in Reception children in the North-East of England.

Methods

The study received ethical approval from Teesside University's School of Health and Social Care Research Ethics Committee. Recruitment for the study began in September

2018. Schools (n = 86) in the North-East area of England were contacted via email, those who expressed an interest in taking part were given study materials to distribute to parents of Reception children. Parents were asked to return their consent forms to the school, and children were asked to provide verbal assent to take part.

Physical activity

Physical activity data was collected at one time point for each participant, between October 2018 and July 2019. Children wore a hip mounted GT1M ActiGraph (ActiGraph, Pensacola, FL, USA). Uniaxial accelerometers were used as they have proven validity in this age group (Pate et al., 2006). Data were processed with Actilife version 6.5.4 software (ActiGraph, LLC, Pensacola, FL). To capture the spontaneous nature of young children's activity, data were recorded in 15 second epochs. The cut-points used in the study were developed by Janssen et al. (2013). Given the sporadic nature of young children's movements, non-wear time was defined as 20 minutes of consecutive zeros. Children were required to wear the accelerometers for eight consecutive days (e.g., Monday-Monday), for all waking hours, except any water-based activities (e.g., bathing or swimming). To be included in the analysis children were required to wear the accelerometer for a minimum of eight hours on three days (Iivonen et al., 2013; van Cauwenberghe et al., 2011). Children who did not meet this wear time criteria were excluded from the analysis.

Demographic and anthropometric

A questionnaire was used to obtain demographic details in this study, which were parent or guardian postcode, and the child's date of birth. The child's home or school postcode, depending on what was provided, with home as the preference, was used to determine socio-economic status, using the Index of Multiple Deprivations (IMD) 2019. Season of data collection was defined as the month the children first wore the accelerometer (Spring = March, April and May; Summer = June, July and August; Autumn = September, October and November; Winter = December, January and February). Children's height (to the nearest 0.1 cm) and weight (to the nearest (0.1 kg) were recorded whilst the children were wearing their school uniform and school shoes. Digital scales (SECA scales, Hamburg, Germany) and a portable stadiometer (SECA 213, Hamburg, Germany) were used in order to calculate BMI (kg/m^2), which was converted to BMI-z.

Statistical analysis

Statistical analyses were carried out using IBM SPSS Statistics v.26 software. Physical activity data was tested for normality using SPSS histograms and the interquartile range. Descriptive statistics (mean and standard deviation (SD)) were calculated for all activity intensities: SB, light PA (LPA), moderate PA (MPA), vigorous PA (VPA), moderate to

vigorous PA (MVPA) and Light to MVPA (LMVPA) which were reported in minutes/day and total PA (TPA) which is reported in counts per minute (CPM). The percentage of children who met the UK under and over 5 years old physical activity guidelines was calculated for all participants, and boys and girls separately.

Sex differences in activity variables between were calculated using independent t-tests. Pearson bivariate correlations were used to explore the correlation between all activity variables and age, BMI-z and SES (IMD 2019 ward score), while one-way ANOVA analyses and post-hoc Tukey tests were conducted to explore differences in all activity variables by season.

Mean difference between weekday and weekend activity was calculated for children that had data for at least one eligible weekend day using paired t-tests. Differences in children's weekday daily physical activity was assessed by dividing the data into segments of, before school (6am–8.59am), during school (9am–3.00pm) and after school (3.01pm–9pm). Differences in activity between time segments were tested for using a repeated measures ANOVA test with a Greenhouse-Geisser correction. Post-hoc tests using the Bonferroni correction were used to examine differences within time segments. Average physical activity on each day of the week was calculated, as well as average minutes per hour of activity for weekdays at each hour of the day.

Results

The study recruited 329 children from 26 primary schools. Of the 329 children recruited, 268 met the accelerometer wear time criteria. Data from three children were deemed outliers (PA levels lay beyond three standard deviations from the mean), and therefore excluded from the analysis. Therefore, a sample of 265 participants were included in the analysis (80.5% compliance), all 26 schools were still represented. The average number of days accelerometers were worn was 5.3 (SD = 1.4), 4.3 (SD = 0.9) of which were weekdays. The average hours worn per day was 10.6 (SD = 0.9) and 172 children (64.9%) wore the accelerometer on at least one weekend day (mean = 1.6, SD = 0.5 days).

Of the participants included in the analysis, 51.3% (n = 137) were boys, and the average age was 5.0 years (SD = 0.3). Average BMI-z was 0.5 (1.1), which is considered a healthy weight for four and five-year-old children. Concerning SES, on average, the sample was in the 50th percentile. 19.4% of the children lived or attended school in the 10% most deprived areas of England, while 9.7% of the children lived or attended school in the 10% most affluent areas of England. Regarding the time of data collection, 41.1% (n = 109) of children had their physical activity data collected in spring, 12.1% (n = 32) in summer, 22.6% (n = 60) in autumn and 24.2% (n = 64) in winter.

Table 1 shows the average activity levels of participants for different PA intensities and sex differences. The majority of children's time was spent being sedentary (41.3%) or in LPA (42.9%). Extrapolating the average activity for these children over 7 days would show that on average children meet the UK 2019 PA guidelines for children aged over 5, with an average 99.6 ± 23.6 minutes of MVPA per day. Sex differences existed between boys and girls, with boys engaging in significantly more PA at all intensities compared girls. Girls engaged in more SB than boys, but this difference was not significant.

TABLE 1 Percent of time and average for total sample and sex differences at physical activity intensities

	% Time	Total Mean (SD)	Boys (n = 137) Mean (SD)	Girls (n = 128) Mean (SD)	*p*
SB (min/day)	41.3	261.6 (45.4)	256.2 (46.7)	267.3 (43.5)	0.05
LPA (min/day)	42.9	271.6 (34.0)	276.1 (36.9)	266.8 (30.1)	0.03
MPA (min/day)	11.2	70.6 (14.5)	73.4 (14.2)	67.7 (14.4)	<0.01
VPA (min/day)	4.6	29.0 (12.1)	30.7 (13.3)	27.2 (10.6)	0.02
MVPA (min/day)	15.8	99.6 (23.6)	104.1 (24.1)	94.8 (22.2)	<0.01
LMVPA (min/day)	58.7	371.2 (45.9)	380.2 (47.4)	361.7 (42.3)	<0.01
TPA (CPM)	-	771.7(154.4)	791.6 (162.9)	750.4 (142.3)	0.03

SB=sedentary behaviour, LPA=light physical activity, MPA=moderate physical activity, VPA =vigorous physical activity, MVPA=moderate to vigorous physical activity, LMVPA=light to moderate to vigorous physical activity, TPA=total physical activity, CPM =counts per minute.

Regarding compliance with PA guidelines, 97.4% (n = 258) of all children met the over 5's guideline, by engaging in an average of 60 minutes of MVPA per day on valid days. High compliance was found for both boys and girls, with a higher proportion of boys meeting the guidelines (98.5% vs 96.9%), however, this difference was not significant (p = 0.31). For the under 5's guidelines, only 66% (n = 175) of all children engaged in 180 minutes of physical activity including 60 minutes of MVPA every valid day the accelerometer was worn. Similar to the over 5's guidelines, a higher percentage of boys than girls met the guidelines (71.5% vs 62.3% for girls), but this difference was also not significant (p = 0.12). Exploring the compliance data according to guidelines for respective ages, 64% (n = 78) of 4-year-olds and 97.2% (n =139) of 5-year-olds met their respective guidelines, equating to 82% of children meeting the guidelines for their respective age.

Table 2 shows the association between PA intensities and demographic and anthropometric variables. Age and BMI-z were associated with VPA, with older children and children with lower BMI-z being significantly more likely to engage in more VPA.

Socio-economic status was negatively associated with SB, but positively associated with MPA, MVPA, VPA and TPA. Children from higher SES areas engaged in less sedentary behaviour and more MPA, MVPA, VPA and TPA than children from lower SES areas. SES was negatively associated with BMI-z, with children from lower SES areas, having higher BMI-z.

TABLE 2 Associations between activity and demographic and anthropometric factors for total sample

	Age	SES	BMI-z
BMI-z	-0.04	-0.29**	-
SB min/day	0.11	-0.19**	-0.01
LPA min/day	-0.07	0.15	-0.05
MPA min/day	-0.01	0.15*	0.02
VPA min/day	0.19**	0.22**	-0.13*
MVPA min/day	0.09	0.21**	-0.06
LMVPA min/day	-0.01	0.12	-0.07
TPA (CPM)	0.09	0.23**	-0.08

*<0.05, **<0.01. BMI-z=Body Mass Index -z, SES=socioeconomic status, SB=sedentary behaviour, LPA=light physical activity, MPA=moderate physical activity, VPA =vigorous physical activity, MVPA=moderate to vigorous physical activity, LMVPA=light to moderate to vigorous physical activity, TPA=total physical activity, CPM =counts per minute.

Seasonal activity

Table 3 shows the average activity during each season of data collection. Seasonal differences in activity existed, with autumn being the most sedentary season, and winter being the least sedentary. Children engaged in the most VPA in spring, and MVPA levels were consistent across spring, summer, and winter, but significantly less in autumn compared to spring (p = 0.01). Children engaged in significantly more LPA in autumn than summer (p = 0.01), and significantly less VPA (p=<0.01) and TPA (p = <0.01) in autumn than summer.

TABLE 3 Seasonal variation in PA intensities

	Spring Mean (SD) n=109	Summer Mean (SD) n=32	Autumn Mean (SD) n=60	Winter Mean (SD) n=64	*p*
SB (min/day)	264.4 (42.5)	262.9 (40.0)	272.7 (52.4)	245.7 (42.5)	0.01
LPA (min/day)	274.4 (32.8)	255.7 (37.1)	278.3 (35.4)	268.5 (31.1)	0.01
MPA (min/day)	73.2 (14.5)	68.8 (15.2)	67.0 (14.9)	70.5 (13.3)	0.05
VPA (min/day)	103.3 (23.5)	102.9 (25.9)	91.3 (22.0)	99.4 (22.6)	0.01
MVPA (min/day)	30.2 (11.5)	34.2 (15.8)	24.3 (9.5)	28.9 (12.1)	<0.01
LMVPA (min/day)	377.8 (45.9)	358.7 (52.4)	369.6 (46.8)	367.9 (40.3)	0.17
TPA (CPM)	784.6 (150.6)	818.7 (168.4)	704.2 (137.5)	789.6 (152.4)	<0.01

SB=sedentary behaviour, LPA=light physical activity, MPA=moderate physical activity, VPA =vigorous physical activity, MVPA=moderate to vigorous physical activity, LMVPA=light to moderate to vigorous physical activity, TPA=total physical activity, CPM =counts per minute.

Physical activity on weekdays and weekends

Table 4 shows the differences in activity between weekdays and weekends. Children engaged in significantly more SB on a weekday than they did on a weekend. They engaged in similar amounts of MVPA on average. However, MVPA on a Saturday (107.5 min/day, SD = 46.4) was higher, and on Sunday (91.4 min/day, SD = 34.6) was lower than the weekday average (101.3 min/day, SD = 23.5). LPA was also significantly less on a weekend than a weekday, however TPA was significantly higher on a weekend.

TABLE 4 Average activity on weekdays and weekends

	Weekday Mean (SD) n = 172	Weekend Mean (SD) n = 172	Mean Difference (95% CI)
SB min/day	277.4 (48.1)	246.9 (66.6)	30.5 (21.2 : 39.6)**
LPA min/day	280.6 (35.4)	268.6 (49.5)	12.0 (4.3 : 19.7)**
MPA min/day	72.3 (14.9)	71.8 (25.0)	0.5 (-3.0 : 3.9)
MVPA min/day	101.3 (23.5)	103.2 (40.9)	-1.9 (-7.2 : 3.3)
VPA min/day	28.9 (11.8)	31.3 (19.3)	-2.4 (-4.8 : 0.0)
LMVPA min/day	381.9 (46.8)	371.8 (72.6)	10.1 (-0.7 : 20.8)
TPA (CPM)	753.1 (149.3)	826.0 (275.2)	-72.9 (-107.2 : -38.6)**

**<0.01. SB=sedentary behaviour, LPA=light physical activity, MPA=moderate physical activity, VPA =vigorous physical activity, MVPA=moderate to vigorous physical activity, LMVPA=light to moderate to vigorous physical activity, TPA=total physical activity, CPM =counts per minute.

Physical activity throughout the day

Table 5 shows there were significant differences in children's before, during and after school activity. Post-hoc tests using the Bonferroni correction revealed children were significantly more sedentary before school, than during or after. Children engaged in significantly more LPA during school than before or after school and engaged in significantly more MVPA and TPA after school than before or during school.

TABLE 5 Mean (SD) activity per hour before, during and after school

	Before School	**School**	**After School**	*p*
	Mean (SD)	Mean (SD)	Mean (SD)	
	06.00-08.59	9.00-15.00	15.01-21.00	
SB min/hour	26.2 (6.0)	25.0 (4.5)	24.1 (5.2)	<0.01
LPA min/hour	24.7 (4.4)	26.2 (3.3)	25.2 (3.6)	<0.01
MPA min/hour	6.7 (3.0)	6.3 (1.7)	7.5 (2.1)	<0.01
MVPA min/hour	9.2 (4.8)	8.8 (2.4)	10.7 (3.9)	<0.01
VPA min/hour	2.5 (2.7)	2.5 (1.2)	3.2 (2.2)	<0.01
LMVPA min/hour	33.8 (6.0)	35.0 (4.5)	35.9 (5.2)	<0.01
TPA (CPM)	719.9 (297.6)	727.2 (158.8)	852.6 (278.6)	<0.01

SB=sedentary behaviour, LPA=light physical activity, MPA=moderate physical activity, VPA =vigorous physical activity, MVPA=moderate to vigorous physical activity, LMVPA=light to moderate to vigorous physical activity, TPA=total physical activity, CPM =counts per minute.

Figure 1 shows children's average SB, LPA, and MVPA at different time points throughout the day. Children's MVPA spiked to its highest point (average 15 minutes) of the day between 12-13.00, which corresponds with the time in which they are least sedentary. During the 'before school' period children's MVPA peaks at 08.00, and at 15.00 for the 'after school' period. Whilst SB peaks between 09-10.00 during school. Children engage in mostly LPA throughout the school day.

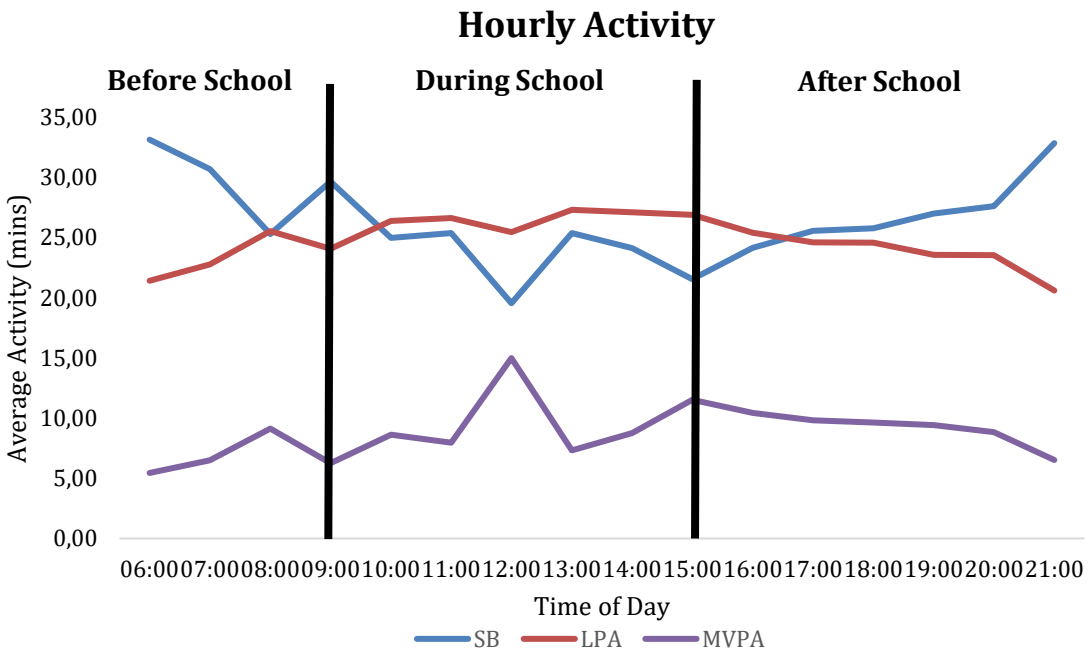

FIGURE 1 Children's minutes of activity per hour across weekdays

Discussion

To the authors knowledge this is the first study to exclusively measure the PA levels of Reception children in England. It has shown how PA differs according to time of the day, day of the week, season, and demographic and anthropometric factors. The study found that contrary to previous research in early years (Roscoe et al., 2019; Foweather et al., 2015; Poitras et al., 2017), Reception children in the North-East of England do not spend the majority of their time in SB. Instead, they spend on average 58% (371.2 mins/day SD = 45.9) of their time being active, mostly in LPA, which constitutes on average 73% (271.6 mins/day SD = 34.0) of their active time. On average, the children exceeded the UK PA over 5's guidelines (average of 60 minutes of MVPA a day over a week) (CMO, 2019), engaging in an average of 99.6 minutes of MVPA per day (SD = 23.6). The study found that 66% of the total sample met the guidelines for under 5's (180 minutes of PA including 60 minutes of MVPA every day) and 97.4% met the guidelines for over 5's (60 minutes of MVPA every day). When the sample was divided according to their individual age group (<5 years and > 5 years), 82% met the guidelines for their respective ages.

This study found that average MVPA (99.6 min/day) is higher than what has been previously observed in other studies (Barnett et al., 2016; Foweather et al., 2015, Hesketh et al., 2014; Roscoe et al., 2019). However, the evidence on compliance with the early

years PA guidelines is inconsistent. Roscoe et al. (2019) measured guideline compliance in 3 and 4-year-old UK children and found that none of the children met the recommended PA levels when using accelerometers to measure children's compliance with 180 minutes of TPA per day. However, Hesketh et al. (2014) found that 100% of UK 4-year-old children met the guideline for achieving 180 minutes of activity per day when assessed using accelerometers. Furthermore, in another UK population, Jago et al. (2014) found that 71% of 5–6-year-old boys and 53% of girls met PA guidelines of 60 minutes of MVPA per day. Studies in different countries also show variable findings. A Canadian study measured 4–5-year-old children's compliance with meeting both the 180 minutes of TPA guideline and the 60 minutes of MVPA guideline, finding 69% and 47% met the guidelines, respectively (Caldwell et al., 2016). Conversely, Stone et al. (2019) found results similar to this study, as they found that 97% of Canadian early years children met the guidelines on average. The prevalence of different findings for early years PA levels may be somewhat explained by the varying data processing procedures used in studies, especially for PA cut-points. Further research could be conducted to provide early years specific cut-points that can be used consistently throughout early years research, to improve the replicability of findings.

The findings of this study provide an assessment of PA guideline compliance in Reception children and suggest that the majority of children at Reception age are sufficiently active. However, given the differences between the guidelines for under and over 5's within the same school year group (i.e., Reception), future consideration should be given to how the guidelines will be operationalised when measuring compliance with guidelines. Guidelines that fit with academic school years may be more appropriate, for example, having guidelines that refer to children in Reception and above, instead of children who are under and over 5 years old. Particularly as children attend Reception full-time, meaning their activity patterns are different from younger children who attend nursery or preschool.

This study found that early years children do not spend the majority of their time in SB. Given the negative health outcomes associated with sedentary behaviours such as screen time (Poitras et al., 2017), this is encouraging. However, in early years, time spent in sedentary behaviours such as reading, writing, storytelling and fine motor activities may be beneficial for development (Carson, Hunter, Kuzik, Gray et al., 2016; Poitras et al., 2017). However, as this study did not explore the context of children's sedentary time, further research should be conducted to explore how children spend their time being sedentary, and to quantify how much sedentary time is spent in behaviours associated with positive health outcomes, such as reading (Carson et al., 2015) and storytelling (Poitras et al., 2017).

Anthropometric and demographic factors were also associated with activity levels. SES was negatively associated with SB, and positively associated with MPA, MVPA, VPA and TPA, meaning that children from more affluent areas engaged in more PA and less SB. This contrasts with previous research which has found no significant association between SES and habitual PA (Bingham et al., 2016; Kelly et al., 2006; King et al., 2011). However, the social gradient of health is well documented and suggests people from lower SES have more negative health outcomes than people from higher SES (Marmot & Wilkinson, 2005). Research has shown that children from more affluent areas have greater access to organised physical activities (Voss et al., 2008), which may somewhat account for the significant differences demonstrated in this study.

Age and BMI-z were also associated with VPA, with older children and children with lower BMI-z engaging in more VPA. Many studies have echoed the association between early years PA and BMI (King et al., 2011; Kwon et al., 2011), but very few have measured the association with VPA. There is currently limited research into the impact of VPA on early year's health outcomes. Further research should be conducted to explore whether the health benefits associated with MVPA are a result of the VPA rather than MVPA. This is particularly pertinent given that parents have a large influence on children's PA levels, and parental time constraints are frequently described as a barrier to engagement (Hesketh et al., 2017). An at-home intervention that focusses on bringing about small increases in children's VPA levels may be more acceptable for parents, than a longer intervention focusing on increasing MVPA.

Concurrent with previous literature, boys engaged in significantly more PA than girls for all intensities (Bingham et al., 2016; Hesketh et al., 2014; Nader et al., 2008). This finding, combined with the evidence that girls MVPA levels begin to decline from the age of 5 (Janz et al., 2005), and that decline is greater than the decline for boys (Farooq et al., 2020), highlights the importance of specific interventions to be developed to increase the PA levels of girls at an early age in order to reduce gender inequalities in activity.

Seasonal differences in physical activity

This study found significant differences in PA between seasons at all intensities except MPA and LMVPA. Children were most sedentary and least active in terms of MVPA and TPA in the autumn. These findings are similar to a study by van Sluijs et al. (2013) with 4-year-old British children. The lack of activity in autumn may be explained due to children starting a new school class in the month of September, and the initial months may involve more SB whilst the children familiarise themselves with their new environment and ways of learning.

Perhaps surprisingly, children were least sedentary in winter, when traditionally the weather is colder and more indoor activities are performed, which may not provide the same opportunities for MVPA as outdoor activities (Pate et al., 2013). This is in contrast to previous UK research, such as the Gateshead Millennium Study which monitored physical activity prospectively in 7-year-old children and found that SB was highest in winter (King et al., 2011). King et al. (2011) also found contrasting findings to this study in terms of MVPA, with children in the Gateshead Millennium Study engaging in significantly more MVPA in summer than any other season. However, in the present study MVPA was consistent among all seasons, except autumn. The findings from King et al. (2011) are echoed by a Norwegian prospective study in early years (Nilsen et al., 2019) and a UK cross-sectional study in 3-4-year-old children (Hesketh et al., 2014).

This study found significant differences in PA between seasons, however, some of the findings contrast with previous research (King et al., 2011). It is important to highlight that this data was generated from between-participant comparisons of cross-sectional data, with varying sample sizes for each season, which may be subject to bias. Prospective studies that assess the same UK children's PA in different seasons would allow causal inferences to be made.

Variations in weekday and weekend PA

There is contrasting data on whether early years children's PA differs between week and weekend days (Bingham et al., 2016). Average week and weekend findings in this study suggest that children engage in more SB during the week, more TPA on the weekend and equal amounts of MVPA on week and weekend days. Collings et al. (2020) found that in a sample of 3 and 4-year-old UK-based children, accelerometer derived TPA was also higher on a weekend than during the week but found that MVPA was significantly higher on a weekend than during the week. Other UK studies that assessed PA in early years using accelerometery contrast these findings. Foweather et al. (2015) found no significant difference between weekday and weekend PA and Roscoe et al. (2019) found that children engaged in significantly more MVPA during the week than on a weekend. These contrasting findings warrant further research to explore reasons why week and weekend PA varies across research findings.

Furthermore, this study showed that children engage in higher than average MVPA on a Saturday, and lower than average MVPA on a Sunday, which may account for the lack of difference between week and weekend MVPA. This finding should also be explored further to investigate if children are compensating on Sundays for the higher than average MVPA levels engaged in on Saturdays.

Variations in physical activity throughout the day

When exploring before (06.00-08.59), during school (09.00-15.00) and after school (15.01-21.00) activity, this study found that children spent the majority of their time in SB before school, while during and after school children spent the majority of their time in LPA. Children engaged in the most MVPA after school. However, on average the highest amount of MVPA and lowest amount of SB was recorded between 12.00-13.00, which correlates with children's lunch times, these findings are echoed by van Cauwenberghe et al. (2012) and O'Dwyer et al. (2014).

Research has shown that play time or recess and lunchtime can be valuable opportunities for promoting PA and can provide up to 40% of children's daily PA (Ridgers et al., 2006). In this study, on average, children engaged in 40 minutes of LMVPA during lunchtime, which equates to 10.8% of their daily LMVPA. Other spikes in MVPA occurred during the hours of 8.00-9.00 and 15.00-16.00 suggesting that children are engaging in large amounts of MVPA, immediately before entering, and immediately after leaving school, which may be explained by active travel to and from school. However, data on children's means of transport to and from school were not collected in this study.

Children who walk or cycle to school have higher levels of PA than children who travel by car or bus (Schoeppe et al., 2013), and research has shown active travel may have benefits for children's weight (Mendoza & Liu, 2014). However, active travel is not always practical for many families (Aranda-Balboa et al., 2020). Furthermore, a large part of a child's lunchtime is spent eating lunch, and children's activity during playtimes and lunchtimes is largely weather dependent (Ridgers et al., 2010). Given the barriers to activity that can arise even when children tend to be most active, it is important to focus on increasing the provision for activity when children are at their least active. In the present study children were least active throughout the school day between 9.00-10.00. Strategies such as physically active learning have demonstrated efficacy for increasing children's PA levels and may improve academic test scores (Daly-Smith et al., 2018) and should be more widely used in early years education.

Furthermore, the fact that the children engage in the most MVPA during lunchtimes and potentially through active travel suggests that children are getting the majority of their MVPA in an unsupervised and unstructured way, which is not as effective for developing motor skills, as structured activity (Robinson & Goodway, 2009). Motor skills are important for school readiness (Jones et al., 2021) and future PA levels, as engagement in activity at a young age can drive the development of motor skills, which drive engagement in PA in older ages (Stodden et al., 2008). In order to help children be active throughout their life, it is important to promote skill acquisition within the school day, particularly

given the evidence that the time children spend in MVPA during PE lessons can be limited (Hollis et al., 2016).

Strengths and limitations

A strength of this study is that it is the first study to exclusively explore the PA levels of Reception children. The study also describes the effect of anthropometric, demographic, and temporal variables on PA. The large sample size from an under-researched age group from a range of socio-economic backgrounds, increases the studies generalisability. The study also benefits from using an objective measure of PA, which had a high compliance rate (80.5%).

However, several limitations of this study should be noted. Despite the high compliance rate, some of the participants did not wear the accelerometers on a weekend, meaning that only a proportion of the population could be used to explore the differences between weekday and weekend PA. Furthermore, the cross-sectional nature of the study means that PA was measured in different children across seasons, therefore causal inferences cannot be made. It is also important to consider that this study only took place during school terms. It would be beneficial to study children's activity levels during school holidays, to obtain an accurate representation of children's habitual PA across the calendar year. Whilst accelerometers are seen as the gold standard PA measurement tools in children (Esliger & Tremblay, 2006), they fail to accurately capture movement intensity during activities such as cycling (Troiano et al., 2014) and were removed for water-based activities, therefore may have under-estimated physical activity levels.

A further limitation to consider in this study is the sampling strategy, as parents volunteered their children to take part in the research. This may have biased the sample, as parents with an interest in the research area, may encourage their children to engage in more PA, this may make the sample unrepresentative of the wider population. The fact that this sample has higher than previously documented levels of MVPA and lower than previously documented levels of SB (Roscoe et al., 2019) may be indicative of this.

Conclusions

This study measured Reception children's PA guideline compliance, it found that 97.4% of children in Reception in the North-East of England meet the UK PA guidelines for 5–18-year olds, but only 66% of children met the under 5's guidelines. Children engaged in less SB and more MVPA than documented in previous studies, and the majority of children's activity was of light intensity. Differences exist between children's seasonal PA. Children were least active and most sedentary in autumn, whereas MVPA was consistent across

other seasons. Children were significantly more sedentary during weekdays and engaged in more TPA on a weekend. Lunchtime and school commutes appear to be important times for children to engage in MVPA on school days. The majority of a child's school day was spent in SB and LPA. Time spent in activities of SB and LPA intensities may be a beneficial time for targeted PA interventions to increase MVPA.

In line with previous research, boys were more active than girls, and were more likely to comply with the guidelines, whilst girls engaged in more SB than boys (Bingham et al., 2016; Hesketh et al., 2014; Nader et al., 2008). Children from more affluent areas engaged in significantly less SB and more physical activity than children from less affluent areas. This finding should be explored further, and targeted interventions could be developed to prevent inequalities in PA widening.

This study found that on average, this sample engaged in significantly more MVPA than has been recommended in the UK PA guidelines. This perhaps indicates that public health funding should be allocated to improving other areas of children's development, such as motor skills and school readiness; both of which have low levels of achievement in early years (Foulkes et al., 2015; Hardy et al., 2013; Public Health England, 2019; Okely & Booth, 2004).

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