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Sedentary time, physical activity and compliance with IOM recommendations in young children at childcare

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ABSTRACT

The aim of this study was to report patterns of sitting, standing and physical activity (PA) and compliance with Institute of Medicine (IOM) recommendations for sedentary behavior (SB) and PA among children aged 1 to 5 years at childcare, and examine sociodemographic variations.

Sitting, standing and PA time was assessed using an activPAL inclinometer over a period of 1 to 5 days in 301 children (49% boys; mean age = 3.7 ± 1.0 years) across 11 childcare services in Illawarra, NSW, Australia. Breaks and bouts of sitting and standing were calculated and categorized. Height and weight were assessed and parents completed a demographic survey. Differences by sex, age category (<3 vs ≥3 years), weight status and SES were examined.

Children spent 48.4% of their time at childcare sitting, 32.5% standing, and 19.1% in PA. Boys spent significantly more time in PA compared to girls (20.8% vs 17.7%; $P = 0.003$). Toddlers (<3 years) spent significantly more time in PA compared to preschoolers (≥3 years) (22.2% vs 18.3%; $P < 0.001$). Children who were underweight spent significantly more time sitting compared with their overweight peers (52.4% vs 46.8%; $P = 0.003$). 56% and 16% of children met the IOM SB and PA recommendations, respectively. Girls (odds ratio [OR]; 95%CI = 0.26; 0.13 to 0.55) and preschoolers (0.16; 0.07 to 0.38) were less likely to meet the IOM PA recommendation compared to boys and toddlers. Young children spent ~50% of their time at childcare sitting. Girls and preschoolers sit more and are less likely to meet PA recommendations, making them important groups to target in future interventions.

1. Background

Young children are showing high levels of sedentary behavior (SB) and low levels of physical activity (PA) (Okely et al., 2008; Reilly, 2010). There is growing evidence that spending excessive time in sedentary pursuits, independent of the amount of moderate- to vigorous-intensity physical activity (MVPA) undertaken, may be adversely associated with adiposity and cardio metabolic health outcomes in children, particularly among those overweight, obese or at-risk of overweight and obesity (Cliff et al., 2014; Saunders et al., 2013). Furthermore, studies in adults have shown that standing and breaking up sitting time are beneficial for cardio-metabolic health (Healy et al., 2015; Júdice et al., 2016). Participation in PA during early childhood has been shown to be beneficial for health and development (Carson et al., 2015; Janssen and LeBlanc, 2010). However, among preschoolers it has been reported that around 73% of their waking hours are spent in SB (Salmon et al., 2011), and that this particular behavior tracks from early childhood (aged 3–5 years) into childhood (aged 5–8 years) (Jones et al., 2013).

Several countries and organisations have acknowledged the importance of limiting sedentary time and increasing PA in young children (Canadian Society for Exercise Physiology, 2012; Department of Health, 2011; Department of Health and Aging, 2010). More recently, the Institute Of Medicine (IOM) in the US has provided specific recommendations around SB and PA for childcare or preschool; stating that young children should be allowed to move freely and that sitting or standing still should be limited to 30 min at one time, and providing opportunities for children to participate in PA for at least 15 min per hour while in care (Institute of Medicine, 2011). Few studies have objectively examined the prevalence of sitting, standing and PA time among children while they attend childcare (Brown et al., 2009), however none have examined how sitting varies by socio-demographic factors, which is important to determine if targeted interventions are required. Furthermore, limited data are available on compliance with current IOM recommendations (Pate et al., 2015). Only one study has objectively assessed PA at childcare, and it was conducted in the USA (Pate et al., 2015). Reporting data from other countries is important to understand prevalence rates across different countries. Accelerometers worn on the waist are currently the most common method to measure SB and

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PA in children, however this approach has difficulties discriminating between sitting and standing still (Kozey-Keadle et al., 2011), which is important for accurately assessing SB. The activPal is a unique device that is capable of detecting postures, particularly sitting and standing due to its placement on the thigh (De Decker et al., 2013).

The purpose of this study was to 1) report sitting, standing and PA among children aged 1–5 years in childcare; 2) investigate the differences in sitting, standing and PA and sitting and standing breaks and bouts by sex, age, weight-status and socio-economic status; and 3) determine the compliance with IOM recommendations for SB and PA among young children while they attend childcare using a posture-based motion sensor.

2. Methods

2.1. Study design

The Standing Preschools Project was a cross-sectional study of 11 childcare services within the Illawarra and Shoalhaven regions of NSW, Australia (population. 0.4 million). Five of the 11 services were located in middle/high socio-economic status (SES) suburbs and six in low SES suburbs. The SES status of the centre suburb was based on the 2011 Socio-Economic Indices for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (Australian Bureau of Statistics, 2011). If the score of a suburb was located below the fourth decile, it was categorized as low SES, otherwise middle/high SES. Recruitment and data collection took place over a 6-month period (February–July 2013).

2.2. Participants

All parents/guardians of 1- to 5-year-old children attending the services were invited to participate via written information letters and provided consent for their child to participate. To be eligible, a child needed to be independently mobile. This study received approval by the Human Research Ethics Committee at the University of Wollongong (HE13/406).

2.3. Measures

Total time spent in sitting, standing and PA were assessed on each weekday that the child attended the service using an activPAL inclinometer during a 1-week period. The activPAL has shown to be a valid measurement tool for discriminating between different postures in young children (Janssen et al., 2014). The activPAL was placed on participants' upper thigh (Davies et al., 2012; Janssen et al., 2014). Trained research assistants attached the activPAL as each child arrived at the service. The staff or parent/guardian removed the monitor when the child departed childcare in the afternoon. On and off times were recorded by the research assistant or staff. After the monitors were collected from each service, data were downloaded and entered using activPAL software (v7.2.32). Fifteen second epoch files were used with the Centre for Physical Activity and Health Research (CPAHR) MATLAB program to calculate sitting/lying, standing, PA and non-wear time for each participant per day (Dowd et al., 2012). Times before arrival and departure were manually removed from the total minutes monitored. Naptime was excluded for toddlers and so considered non-weartime, as it was shown that over 90% of children this age still nap (Blair et al., 2012). This was not done for preschoolers as research suggests that nearly three-quarters of preschoolers do not sleep during nap time (Pattinson et al., 2014). For a day to be considered valid, children needed to wear the activPAL ≥180 min and needed >1 valid day to be included in the analyses (Byun et al., 2013). Sitting breaks and bouts were determined from activPAL outputs. Mean breaks per hour of sitting were calculated as the total sum of all the number of bouts (Dowd et al., 2012). Bouts of sitting were categorized as: <1 min, 1–4 min, 5–9 min, 10–19 min, 20–29 min, or ≥30 min (Carson et al., 2014). Compliance with the IOM SB recommendation was derived by calculating the combined sitting and standing bouts ≥30 min from the eventfile. Children without a sitting and standing bout ≥30 min were categorized as complying with the recommendation. To report if children spent 15 min in PA per hour, their percentage needed to be ≥25% per hour.

Children aged 1.0 to 2.9 years were categorized as toddlers, and 3.0 to 5.9 years as preschoolers. Each child's date of birth and sex were collected on the consent form. Height and weight were measured and body mass index (BMI: kg/m^2) was calculated using a portable stadiometer (PE87; Mentone Educational Centre) and a calibrated electronic weight scale (Tanita BF-681; Tanita Corporation of America), according to standardised protocols (Wake et al., 2002). Weight status was calculated using LMSGrowth (Medical Research Council, United Kingdom) and UK reference curves (Cole et al., 1995). Children >2 years were categorized as underweight, normal weight, overweight, or obese based on the IOTF (International Obesity Task Force) age- and gender-specific cut-points (Cole et al., 1995). For children <2 years, percentiles were calculated and categorized in weight statuses using UK reference curves (Cole et al., 1995).

2.4. Sample size and power

The sample size calculated was based on the ability to provide a reliable estimate of the time spent sitting and to detect differences between demographically defined groups. These estimates were calculated based on a relative standard error of <25% (Booth et al., 2005) using the formula: $N = pq/s^2$, where N = sample size; p = estimated prevalence; q = 1 − p; and s = required SE of the prevalence statistic. Based on our feasibility study, it was highly unlikely that a child would spend <10% of the day in childcare sitting, requiring 144 children per day to be sampled. As the childcare service was the unit of observation, the sample size was increased by a design effect of 1.5 – to 216 children – to account for clustering.

2.5. Statistical analyses

Analyses were performed in STATA 13 and SPSS21. Descriptive statistics were calculated using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. To determine if differences existed in proportion of sample size within sex, age, weight status and SES, independent samples *t*-tests or Mann-Whitney *U* tests were used. Mixed linear regressions were used to examine the difference between sitting, standing and PA time by sex, age, weight status and SES of center and to calculate the intraclass correlation coefficient across the centers. To account for the clustered nature of the data, the models included childcare service as a random effect. Fixed effects such as age, sex and weight status were included as covariates in the mixed models when they were not the predictor being tested. Differences in breaks and bouts between boys and girls; toddlers (1–2 years) and preschoolers (3–5 years); underweight, normal weight, overweight and obese; and low and medium SES groups were examined using linear regression and repeated measures ANOVA. To interpret the differences in percentages of children meeting SB and PA recommendations, odds ratios were calculated by using a logistic regression.

3. Results

Descriptive characteristics are reported in Table 1. Of the 799 eligible 1- to 5-year-old children from 11 childcare services, 550 children (68%) provided parental consent. Of these, 3 children were absent and 28 children declined to participate on the day of testing, 81 children did not have height and weight measured, and 6 monitors were not returned. Data from 145 children were excluded due to no monitor data, a

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Table 1
Descriptive characteristics of participants, Illawarra NSW, Australia, July 2013.

Characteristics	Total (n = 301)	Boys (n = 145)	Girls (n = 156)
Age (y), mean (SD)	3.7 (1.0)	3.7 (1.0)	3.7 (0.9)
Toddlers (1–2.9) (n = 68), mean(SD)	2.2 (0.5)	2.2 (0.6)	2.3 (0.4)
Preschoolers (3.0–5.9) (n = 233), mean (SD)	4.1 (0.6)	4.2 (0.6)	4.1 (0.6)
Weight status[a]			
Underweight (n, %)	19 (6)	10 (7)	9 (6)
Normal weight (n, %)	215 (72)	98 (68)	114 (73)
Overweight (n, %)	51 (17)	30 (21)	23 (15)
Obese (n, %)	14 (5)	5 (4)	9 (6)
Socio-economic status			
Low-income (n, %)	155 (52)	82 (57)	73 (47)
Middle/high-income (n, %)	146 (48)	63 (43)	83 (53)
Wear time			
Days (n ± se)	1.8 (0.9)	1.8 (1.0)	1.8 (0.8)
Wear time (min)/d	309 (76)	307 (79)	310 (74)

[a] Under 2 years: underweight <5 percentile, normal weight 5–85 percentile, overweight 85–95 percentile, obese >95 percentile.

download error, monitor malfunction or children not meeting criteria of wearing monitor for at least 50% of their time spent at childcare, which left data for 301 children (55% response rate; 52% girls, 23% overweight/obese) for analysis. No significant differences were found in socio-demographic characteristics between the included and excluded groups (P = 0.89). Among 301 participants, the average monitor wear time was 1.8 days (±0.9) and 308.6 (±76) minutes/day. Boys and girls wore the inclinometer on average for 1.8 days (±1.0) and 1.8 days (±0.8), respectively. No significant differences were found in wear time between boys (307.3, 56% minutes/day) and girls (309.8, 57% minutes/day).

3.1. Sitting, standing and physical activity

The estimated time spent in sitting, standing and PA by sociodemographics are presented in Table 2. On average, children spent 48.3% of their day sitting, 32.5% standing and 19.1% in PA. Boys spent significantly more time in PA per day compared to girls (P = 0.03). Toddlers spent significantly less time sitting and significantly more time standing and being physically active compared to preschoolers (P < 0.001). Children who were underweight spent significantly more time sitting than their overweight peers (P = 0.03).

3.2. Sitting breaks and bouts

The total number of sitting breaks and bouts per hour are shown in Table 3. On average, children accumulated 11.9 ± 3.0 breaks per hour. Breaks per hour did not differ by demographic characteristics. On average, 95% of children's sitting bouts were <10 min. The average number of <1 min sitting or lying bouts/h was significantly higher in boys compared to girls (P < 0.001), toddlers compared to preschoolers (P < 0.001), low and middle/high SES children (P < 0.05), obese compared to normal weight children (P = 0.003), and overweight compared to normal weight children (P = 0.01). Underweight children had significantly more <1 min bouts compared to normal weight, overweight and obese children (P < 0.01). The number of 5–9 min bouts was significantly greater in preschoolers compared to toddlers (P = 0.02). The number of 10–19 min, 20–29 min or ≥30 min sitting bouts per hour did not differ by demographic characteristics.

Compliance with IOM recommendations is shown in Table 4. Of the 301 children, 56% met the IOM recommendation for SB. Only 16% of children met the IOM PA recommendation. Girls (0.26; 0.13–0.55), preschoolers (0.16; 0.07–0.38) and children from middle/high SES (0.71; 0.36–1.41) were less likely to meet the IOM PA recommendation compared to boys, toddlers and participants from low SES, respectively.

4. Discussion

To our knowledge, this is one of the first studies to report on both objectively measured sedentary time, where sitting is distinguished from standing, PA in young children at childcare and to report compliance with both the IOM SB and PA recommendations. We found that children aged 1 to 5 years spent around half of their total time at childcare sitting, one-third standing, and one-fifth being physically active. We also found significant differences in sitting, standing and PA by socio-demographic factors. Specifically, boys spent more time in PA compared to girls, and toddlers spent less time sitting and more time standing and being physical active compared to pre-schoolers. Further, preschool children had significantly greater 5–9 min sitting bouts compared to toddlers. Approximately half of the children met the IOM recommendation for SB, but less than one in five children met the IOM recommendation for PA.

Previous studies have reported children's sitting or sedentary time during childcare (Brown et al., 2009; Carson et al., 2016; Pate et al., 2004; Tandon et al., 2015), one of which also examined standing time (Brown et al., 2009). Using hip-mounted accelerometers, Carson et al. (2016) reported that young Australian children were

Table 2
Time spent in sitting, standing and physical activity (PA) (mean %, SE), Illawarra NSW, Australia, July 2013.

Characteristics	No.	Sitting	P	95% CI	Standing	P	95% CI	PA	P	95% CI
ICC		0.11			0.02			0.14		
Total sample	301	48.3 (0.7)			32.5 (0.5)			19.1 (0.4)		
Sex[a]										
Boys	145	47.2 (1.5)	0.22	43.9–50.8	32.0 (0.8)	0.34	30.2–33.8	20.8 (0.5)	<0.003	18.5–22.9
Girls	156	49.3 (1.5)		45.8–52.5	33.0 (1.0)		30.9–35.2	17.7 (0.4)		16.2–19.4
Age[b]										
Toddlers (1–2.9)	71	40.3 (1.4)	<0.001	35.0–39.9	37.4 (1.1)	<0.001	34.9–39.9	22.2 (1.1)	<0.001	20.1–24.2
Preschoolers (3.0–5.9)	230	50.6 (0.7)		29.2–33.0	31.1 (0.5)		29.2–32.9	18.3 (0.4)		16.6–20.1
Weight status[c]	299									
Underweight	19	52.4 (2.0)		47.9–56.9	28.8 (1.7)		26.3–33.6	17.2 (1.5)		13.7–21.7
Normal weight	215	48.2 (1.3)		45.4–51.1	32.8 (0.7)		31.0–34.3	19.1 (0.8)		17.4–20.8
Overweight	51	46.8 (2.3)	0.03[e]	41.8–51.8	33.0 (1.2)		29.6–36.8	20.3 (0.9)		17.9–22.3
Obese	14	46.7 (3.8)		39.2–54.8	33.7 (2.3)		29.1–37.4	19.6 (1.8)		15.3–24.3
Socio-economic status[c]										
Low-income	155	46.5 (0.9)	0.93	41.8–51.3	33.6 (0.7)	0.67	31.4–35.8	19.9 (0.5)	0.45	17.2–22.6
Middle/high income	146	50.1 (1.2)		47.5–52.6	31.5 (0.5)		29.9–33.0	18.5 (0.5)		16.8–20.15

Analyses adjusted for clustering; ICC = Intraclass Correlation Coefficient.
[a] Adjusted for age category.
[b] Adjusted for sex.
[c] Adjusted for sex, age.
[e] Underweight compared to overweight.

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Table 3
Differences in mean (SD) number of breaks and bouts of sitting per hour by demographics, Illawarra NSW, Australia, July 2013.

Characteristics	Breaks in sitting per hour	Bouts of sitting per hour					
		<1 min	1–4 min	5–9 min	10–19 min	20–30 min	>30 min
Total sample	11.9 (0.3)	6.3 (2.1)	4.1 (1.3)	0.9 (0.4)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)
Sex							
Boys	12.0 (0.3)	6.5 (2.4)*	4.0 (1.3)	0.9 (0.4)	0.5 (0.3)	0.1 (0.1)	0.0 (0.1)
Girls	11.9 (0.4)	6.1 (1.9)	4.2 (1.4)	1.0 (0.4)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)
Age							
Toddlers (1–2.9)	12.0 (0.3)	6.8 (2.4)*	4.0 (1.7)	0.7 (0.4)*	0.3 (0.3)	0.08 (0.1)	0.0 (0.1)
Preschoolers (3.0–5.9)	11.9 (0.3)	6.2 (2.0)	4.1 (1.2)	1.0 (0.4)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)
Weight status							
Underweight	11.5 (0.4)	5.6 (2.1)**	3.9 (1.4)	0.9 (0.5)	0.6 (0.1)	0.2 (0.2)	0.1 (0.1)
Normal weight	12.0 (0.3)	6.3 (2.1)***	4.1 (1.3)	0.9 (0.4)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)
Overweight	12.1 (0.4)	6.5 (2.2)	4.2 (1.3)	0.8 (0.5)	0.5 (0.5)	0.1 (0.5)	0.1 (0.1)
Obese	11.7 (0.5)	6.9 (1.8)	4.1 (1.3)	0.8 (0.6)	0.3 (0.2)	0.2 (0.2)	0.0 (0.1)
Socio-economic status							
Low-income	12.2 (0.2)	6.7 (2.2)*	4.1 (1.4)	0.9 (0.4)	0.4 (0.3)	0.1 (0.1)	0.1 (0.1)
Middle/high income	11.7 (0.2)	5.9 (2.0)	4.1 (1.3)	1.0 (0.4)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)

Analyses (linear regression and repeated measures ANOVA) adjusted for clustering
* $P < 0.001$.
** $P < 0.001$ underweight vs normal weight, overweight, obese.
*** $P = 0.01$ normal weight vs obese.

sedentary for 48% of their time at childcare, which is consistent with the current study. Brown et al. (2009) used direct observation and reported a lower proportion of time sitting (43%) and standing (15%) than the current study (Brown et al., 2009). Methodological differences might explain the contrasting findings for standing time. The current study and Carson et al. (2016) used accelerometry, whereas Brown et al. (2009) used a momentary time sampling strategy to collect data via direct observation. Accelerometers collect data on each individual child while direct observation typically collects data on a randomly selected subset of children. Additionally, only standing still was coded as standing in Brown et al.'s (2009) study. If children were standing stationary but performing another activity, such as throwing, dancing or climbing, they categorized it as an alternative activity rather than standing. However, in the current study the activPAL would have coded this as standing. Collectively, these studies indicate that young children spend close to half their time sitting and between 20 and 30% of their time standing while at childcare.

Few studies examined the time spent in PA among children at childcare. However, given that stepping (output activPAL) represents activity of a similar intensity to light-moderate- and vigorous-intensity physical activity (LMVPA), which is the intensity identified in PA recommendations for young children (Canadian Society for Exercise Physiology, 2012; Department of Health, 2011; Department of Health and Aging, 2010), the results can be compared with other studies that have reported the proportion of time spent in LMVPA at childcare. Brown et al. (2009) reported that 8% of total intervals by activity levels was spent in light activity and 3% in MVPA, resulting in a

Table 4
Percentage of children achieving the IOM recommendations for sedentary behavior (SB) and physical activity (PA) by socio-demographic factors, Illawarra NSW, Australia, July 2013.[b]

Characteristics	No.	Number of sitting and/or standing bouts >30 min/day mean (SD)	IOM recommendation SB (%)	OR (95% CI) unadjusted	OR (95% CI) adjusted	IOM recommendation PA (%)	OR (95% CI) unadjusted	OR (95% CI) adjusted
Total sample	301	0.4 (0.7)	56			16		
Sex								
Boys	146	0.4 (0.6)	59	1.00 (ref)	1.00 (ref)[a]	24*	1.00 (ref)	1.00 (ref)[a]
Girls	155	0.5 (0.7)	53	0.78 (0.49, 1.23)	0.78 (0.50, 1.30)[a]	8	0.29 (0.14, 0.57)	0.26 (0.13, 0.53)[a]
Age								
Toddlers (1–2.9)	71	0.3 (0.8)	63	1.00 (ref)	1.00 (ref)[b]	37**	1.00 (ref)	1.00 (ref)[b]
Preschoolers (3.0–5.9)	230	0.4 (0.6)	54	0.68 (0.39, 1.19)	0.53 (0.23, 1.21)[b]	10	0.19 (0.09,0.36)	0.16 (0.07, 0.38)[b]
Weight status	299							
Underweight	19	0.5 (0.5)	58	1.11 (0.43, 2.86)	1.28 (0.34, 4.74)[c]	11	0.64 (0.14, 2.91)	0.95 (0.19, 4.50)[c]
Normal weight[d]	215	0.4 (0.4)	55	1.00 (ref)	1.00 (ref)[c]	16	1.00 (ref)	1.00 (ref)[c]
Overweight	53	0.4 (0.4)	55	0.97 (0.53, 1.78)	0.82 (0.35, 1.92)[c]	19	1.27 (0.58, 2.77)	1.15 (0.48, 2.73)[c]
Obese	14	0.3 (0.3)	64	1.45 (0.47, 4.47)	0.98 (0.16, 6.21)[c]	21	1.49 (0.39, 5.62)	1.61 (0.36, 7.14)[c]
Socio-economic status								
Low-income	155	0.3 (0.5)	63	1.00 (ref)	1.00 (ref)[c]	19	1.00 (ref)	1.00 (ref)[c]
Middle/high income	146	0.5 (0.7)	49	0.58 (0.37, 0.92)	0.59 (0.37, 0.94)[c]	13	0.65 (0.35, 1.22)	0.71 (0.36, 1.41)[c]

CI = confidence interval; OR = odds ratio.
Logistic regression with unadjusted and adjusted analyses.
[a] Adjusted for age category.
[b] Adjusted for sex.
[c] Adjusted for sex, age category.
[d] Normal weight compared to other weight statuses.
* Significant difference between sexes ($P < 0.001$).
** Significant differences between age category ($P < 0.001$).

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total proportion of time in LMVPA of 11% (Brown et al., 2009), which is 7% less compared to the current study. Pate et al. (2008) used the Actigraph over two weeks and showed that children in preschool spent 17.5% of their hour in light activity and 13% in MVPA, which is a total of 30.5% spent in LMVPA per hour. This is 12% more compared to the present study. Differences in sample characteristics may explain the differences in findings between the current study and Pate et al. (2008, 2015, 2004). One other study (Pate et al., 2015) reported the prevalence of compliance with IOM PA recommendation for preschool children in two independent samples (41.6% and 50.2%), which is roughly three times higher than the current study. Methodological differences might explain these large differences. Pate et al. (2015) used a hip-mounted Actigraph to measure PA, while the current study used an activPAL. Pate et al. (2015) also measured PA across the whole day during and outside of childcare hours, whereas assessments in the current study were completed only during childcare hours. As such, the results for our sample suggest that PA levels during childcare were low and may require intervention.

Consistent with previous studies, boys were more active than girls (Finn et al., 2002; Jackson et al., 2003; McKenzie et al., 1992). Furthermore, boys were more likely to meet the IOM PA recommendation compared to girls, which is consistent with Pate et al. (2015). An explanation for these findings is that certain observational studies of preschool children indicate that boys engage in more vigorous intensity activities, play in larger groups in more open settings, and engage in more risk-taking behavior (Eaton and Enns, 1986; Hoffmann and Powlishta, 2001). This could explain why boys in our sample spent more time in PA. This finding is useful for educators and pediatricians in their role of promoting PA for young children, with an additional focus on girls during the early years.

No studies have looked at the difference in activity levels between toddlers and preschoolers in childcare. Gubbels et al. (2011) showed activity levels of 2- and 3-year-old children, without any differences. However, a previous study has reported that 3 year old children were more active compared to 4- and 5-year-olds (Pate et al., 2008). Pate et al. (2008) showed that in particular, 3 year old boys were more active than 4- and 5-year-old children: however, this difference was not observed for girls. Children aged 4 and 5 years also spent more time in sedentary pursuits compared to 3-year-old children (Pate et al., 2008). A possible explanation could be that 4- and 5-year-old children undertake more structured activities; to prepare them for elementary school, resulting in more time spent sitting and less time being physically active. This could explain our other findings that preschoolers accumulated more 5–9 minute bouts compared to toddlers, and that toddlers are more likely to meet the PA recommendation. These results suggest that a balance is needed between meeting children's educational and health needs to reduce sitting. At this stage the optimal length of a bout of sitting time and how frequently sitting time should be broken up in young children is not known. However, providing children with the choice to break-up sitting time while at childcare may be important. Possible modifications could involve children working at standing-desks to complete academic activities such as writing, drawing or reading.

To the authors' knowledge no studies have measured differences in sitting time by weight status in young children at childcare. There were no differences between normal weight and other weight groups. We found that underweight children ($n = 19$) had higher levels of sitting compared to overweight children ($n = 51$), although the small number of children included in each group may have contributed to these findings. Another possible explanation for this counterintuitive result might be potentially poorer physical and motor development, which supports participation in active play among underweight children compared to normal weight children (Roberts et al., 2012). Young children with poorer motor skills demonstrate more time in SB and less time in PA (Williams et al., 2008).

Recent recommendations around SB at childcare from the IOM suggest that young children should be allowed to move freely and sitting or standing should be limited to 30 min at a time (Institute of Medicine, 2011). Only just over half of the children (56%) met the IOM recommendation for SB. No other studies confirm this finding. This reinforces that childcare services should implement activities to encourage children to move and walk more frequently as part of their daily routines. Furthermore, the current IOM recommendation for SB is different compared to the widely accepted definition of SB from the Sedentary Behaviour Research Network (2012). The SBRN (2012) defines SB as "any waking activity characterized by an energy expenditure of ≤1.5 metabolic equivalents *and* a sitting or reclining posture" (p. 540), whereas the IOM includes standing still in their SB recommendation. This presents a challenge for researchers and practitioners in the assessment and operationalization of these recommendations in practice. It is suggested that this inconsistency is resolved in the near future.

The strengths of the current study include the use of an objective and direct measure to assess sitting, standing and PA, thus overcoming some of the limitations in other assessment methods. Second, the large and diverse sample from different geographical areas including children aged less than three years, for which there is limited evidence in the literature, strengthens the generalizability of the findings. Third, SB and PA were only assessed in the childcare setting, which allowed the assessment of compliance with the IOM recommendation. Limitations include the low response rate, because a considerable proportion of the consented children had to be excluded due to not having all required valid data. Furthermore, the inclusion of nap time for the small proportion of pre-schoolers who might still nap may have impacted on the estimates of their behaviors.

5. Conclusions

In conclusion, young children in our sample spent approximately half of their time sitting while at childcare, and only a small proportion meet childcare based PA recommendations. Strategies to replace or break-up sitting time with more standing and LMVPA are warranted, particularly in girls and preschool aged children. Implementing changes in policies, practices, and environments within the childcare service are imperative to reduce total sitting time and increase PA.

Abbreviations

BMI	Body Mass Index
SES	Socio-Economic Status
MVPA	Moderate to Vigorous Physical Activity
PA	Physical Activity
SB	Sedentary Behavior.

Availability of data and materials

The dataset(s) supporting the conclusions of this article will not be shared as the data is still being used for other analyses during my PhD. This will be available for the public at the end of my PhD.

Conflict of interests

The authors declare that they have no conflict of interests.

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Author contributions

All authors were involved in the development of the research questions and the design of the study. YE had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. YE conducted data manipulation and analyses and drafted the manuscript. All authors contributed to the interpretation of data and were involved in the writing and critical revising of the manuscript. All authors read and approved the final version.

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