Sedentary and Active Time in Toddlers with and without Cerebral Palsy

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ABSTRACT

OFTEDAL, S., K. L. BELL, P. S. W. DAVIES, R. S. WARE, and R. N. BOYD. Sedentary and Active Time in Toddlers with and without Cerebral Palsy. *Med. Sci. Sports Exerc.*, Vol. 47, No. 10, pp. 2076–2083, 2015. **Introduction/Purpose**: To evaluate differences in sedentary time and compare levels of physical activity and sedentary behavior to the Australian physical activity recommendations between toddlers with cerebral palsy (CP) according to functional capacity (Gross Motor Function Classification System [GMFCS]) and age-matched children with typical development (CTD). **Methods**: Children (2.4 ± 0.5 yr old) were split into CTD (n = 20), GMFCS I–II (n = 32), GMFCS III (n = 14), and GMFCS IV–V (n = 12) groups and wore a triaxial ActiGraph® for 3 d. Validated cut points were applied to identify sedentary and active time and the number and duration of sedentary bouts and breaks for each group. Analysis of variance (ANOVA) with *post hoc* testing, chi-square analysis, and the Fisher exact test were used to compare groups. **Results**: No difference between the CTD group (49%) and GMFCS I–II group (52%) was found for sedentary time as a percentage of wear time. The GMFCS III group was more sedentary than both these groups (62%, $P < 0.05$). The GMFCS IV–V group was more sedentary than all the other groups (74%, $P < 0.05$). The CTD group and GMFCS I–II group was more likely to spend 180 min or longer in active play on all 3 d than the GMFCS IV–V group ($P < 0.05$). The GMFCS IV–V group was more likely to have sedentary bouts ≥60 min or longer than all other groups ($P < 0.05$). **Conclusion**: Differences in sedentary behavior between the CTD and mildly impaired children with CP (GMFCS I–II) are not evident in the toddler years. Children with moderate-to-severe functional impairment are progressively more sedentary and less likely to meet physical activity guidelines. Further research into the health implications of high levels of sedentary behavior in toddlers is required. **Key Words:** HABITUAL PHYSICAL ACTIVITY PERFORMANCE, YOUNG CHILDREN, MOTOR IMPAIRMENT, DISABILITY

Physical activity is important for the health and development of children (36). There is a scarcity of knowledge regarding how young children with a disability compare to children with typical development (CTD) in sedentary behavior and habitual physical activity (HPA), and the subsequent implications for health outcomes. Cerebral palsy (CP) is the most common cause of physical disability in childhood, with an incidence of two per 1000 live births (23), and is associated with lifelong motor impairment (27). Although the brain damage in CP is static and therefore "nonprogressive" (27), after developmental gains in early childhood (28), functional abilities decline during adolescence and young adulthood (13).

The International Classification of Functioning, Disability and Health (ICF) model defines activity as the execution of a task or action by an individual, whereas participation is considered involvement in a life situation or habits of daily life. The domain of "activity" is divided into the concepts of "capacity" and "performance." Capacity refers to the execution of a task in a controlled environment and is often measured using the gross motor function measure (GMFM-66) in children with CP. Performance is the execution of a task in a natural environment, or what the child actually does in their day-to-day life, and HPA performance can therefore be used to describe their average daily activity pattern. Participation and HPA have been highlighted as crucial to maintaining function as persons with CP age (12). Factors identified as potentially increasing the severity of functional impairment throughout the lifespan are high levels of sedentary behavior, obesity, and premature muscle wasting (26). A recent study explored the relationship between participation, performance, and capacity in children with CP (5). Authors found that what an ambulatory and marginally ambulatory (Gross Motor Function Classification System; GMFCS I–III) child with CP age 2–9 yr had the capacity to do in a clinical setting and their participation in life was significantly mediated by their performance in day-to-day life (5). It follows that interventions focused on improving what a child habitually does, regardless of capacity, may positively influence participation in life (5).

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Australian physical activity recommendations for children age 1 to 5 yr state that children should participate in active play for at least 180 $min \cdot d^{-1}$, and any periods of sedentary behavior should be less than 1 h (2). These recommendations do not stipulate that a certain activity level needs to be achieved; and active play therefore includes light, moderate, and vigorous activity. Sedentary behavior is defined as "any waking behavior characterized by an energy expenditure 1.5 or less metabolic equivalent of task (MET) while in a sitting or reclining posture" (30). This means energy expenditure is 1.5 times that of resting energy expenditure or lower. *Sedentary* is distinct from the term *inactive*, which is used to describe those who do not achieve the recommended amount of moderate-to-vigorous physical activity (MVPA; MET > 3.0) (35). It is important to note that the MET values have not been validated in young children in estimating energy expenditure but can be used as a guide when classifying behaviors as sedentary behavior, light physical activity, or MVPA as per the compendium of physical activity (1). Emerging evidence suggests sedentary behavior has an independent influence on health, separate to that due to lack of sufficient MVPA (35). In adults, an increased number of breaks in sedentary time, specified as any interruption to sedentary behavior over the specified accelerometer cut point, was associated with beneficial improvement in health measures independent of total sedentary time and time in MVPA (14).

Even the least physically impaired school-age children and adolescents with CP, classified as GMFCS I–II, have consistently been found to be less physically active than their typically developing peers (8). They have also been found to participate in significantly longer bouts of sedentary behavior and have less frequent breaks in sedentary time (20). Objective measurement of the HPA levels and time spent sedentary in CTD and children with CP age 1 to 3 yr of age, referred to as the toddler period, have only recently become available (21,38). Emerging studies in CTD in this age group differ widely in their conclusions possibly because of the use of accelerometer cut points not validated for the toddler population (39) and the use of cut points with poor predictive validity for determining sedentary time (18). A better understanding of HPA and sedentary behavior throughout the lifespan and its impact on health outcome trajectories in the CP population may assist in the development of specific, targeted, and evidence-based interventions from a younger age when children are gaining most of their functional abilities (8).

The aims of this study were to compare children with CP according to functional capacity and CTD in the following: (i) sedentary time, (ii) duration of sedentary bouts and breaks in sedentary time; and (iii) levels of HPA and sedentary behavior compared to Australian physical activity recommendations.

METHODS

Participants. Children were assessed as part of two overlapping Australian prospective longitudinal cohort studies: the Queensland CP Child Study of Motor Function and Brain Development (NHMRC 465128; n = 227) (7) and the Queensland CP Child Study of Growth, Nutrition and Physical Activity (GNPA; NHMRC 569605; n = 182) (4). Detailed descriptions of study design and inclusion and exclusion criteria have been published elsewhere (4,7). Written informed consent was obtained from the children's primary caretaker. For the present study, only children who (i) participated in both of the aforementioned studies (n = 182), (ii) completed an assessment between 18 ± 1 and 36 ± 1 months corrected age (age from expected date of delivery if born preterm or less than 37 wk of gestation (11); n = 169), and (iii) completed an assessment after the use of triaxial (as opposed to uniaxial) accelerometers commenced were eligible for inclusion (n = 111). Ethical approvals were received from The University of Queensland Medical Research Ethics Committee (2008002260), the Children's Health Services District's Ethics Committee (HREC/ 08/ QRCH/ 122) and the CP League of Queensland (CPLQ 2008/ 2010 1029).

Children with typical development age 18 ± 1 to 36 ± 1 months were recruited through staff from The University of Queensland and Royal Children's Hospital. Ethical approvals were received from the University of Queensland Medical Research Ethics Committee (2008002260 amendment 7/3/13) and the Children's Health Services District's Ethics Committee (HREC/ 08/ QRCH/ 122/ AM05). Children were eligible for inclusion if they were born at term (>37-wk gestation), had no admissions to the neonatal care unit, no diagnosis receiving medical/allied health care, and were not on regular medications (n = 38).

Children with CP were divided into groups based on gross motor capacity (GMFCS) (25): ambulatory (GMFCS I–II), marginally ambulatory (GMFCS III), and nonambulatory (GMFCS IV–V). The participant's weight was measured to the nearest 100 g using portable electronic scales (Homemaker, Australia) or chair scales (Seca Ltd, Germany). Height or recumbent length was measured to the last completed millimeter with a portable stadiometer (Shorr Productions, LLC, MD). Where a height/length measure could not accurately be obtained, height was estimated from knee height (34).

Activity monitoring. Children wore an ActiGraph® GT3X for 3 d: two weekdays and one weekend day. The accelerometer was worn around their waist, centered at their lower back. The hip or lower back has been suggested as the best placement of an accelerometer in children (37). The lower back placement was chosen for this group of toddlers, as it was deemed less obtrusive for the variety of ambulation methods used, and to minimize the effect of asymmetry due to physical impairments. A study assessing the number of days required for reliably measuring percentage of active time in preschoolers (3–5 yr) using the uniaxial ActiGraph® GT1M found 3 d of 10 h of wear time gave a satisfactory reliability (intraclass correlation coefficient [ICC] > 0.7) (16). Authors stated that compared to studies in older children,

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it seems that younger children, using a percentage of active time as opposed to counts per minute, and using shorter epochs (15 s vs 60 s) led to fewer required days to reach satisfactory reliability (16). The cohort in this present study was younger, used percentage of sedentary/active time and a shorter sampling epoch (5 s). It was therefore determined that 3 d of measurement including one weekend day was to be used to minimize the burden of participation for the families involved. Parents filled out a wear-time log, indicating when the child was awake, when the monitor was put on, if it was taken off for any period of time (e.g., nap or water activities such as bathing), when it was taken off at the end of the day, and when the child was asleep. Accelerometry data were checked against parents' diaries, and any discrepancies were checked with parents by telephone. Accelerometer files were cleaned to only include wear time (excluding naps and water activities) and exported to MATLAB (The MathWorks Inc, version R2012b) for data extraction.

The GT3X is a triaxial accelerometer measuring magnitude of movement in three planes (vertical, *X*; anteroposterior, *Y*; and mediolateral, *Z*) and computes a composite vector magnitude (VM: $\sqrt{(X^2 + Y^2 + Z^2)}$) of the three axes. Data are reported as counts per user-specified epoch; and in the current study, a 5-s epoch was used. The GT3X triaxial cut points used to determine sedentary/nonsedentary time have been validated in toddlers with CP across the spectrum of functional abilities and CTD (21). The cut points were developed in a sample of 45 children (GMFCS I–III, *n* = 21; GMFCS IV–V, *n* = 21; CTD, *n* = 18) and validated in 33 children (GMFCS I–III, *n* = 16; GMFCS IV–V, *n* = 7; CTD, *n* = 10). The children participating in the validation study overlaps with the cohort in this current paper. To develop and validate the cut points, an ActiGraph® GT3X was worn during a videotaped play–based assessment and subsequently coded as sedentary/nonsedentary. Receiver operating characteristic area under the curve analysis determined the classification accuracy of accelerometer data and was used to identify the cut point with the highest sensitivity and specificity. Predictive validity was determined using Bland-Altman analysis. For the children with typical development, and ambulatory and marginally ambulatory children with CP (GMFCS I–III), a cut point of 40 counts per 5-s epoch was identified; and in nonambulatory children, a cut point of 10 counts per 5-s epoch was identified. Both cut points were found to have good classification accuracy and to provide accurate group-level measures of time spent sedentary (21).

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Sedentary time, sedentary bouts, and breaks in sedentary behavior. The 3-d average of time spent sedentary as a percentage of wear time, and the total number of sedentary bouts and breaks over the 3 d measured as well as their duration were determined based on accelerometer cut points validated in toddlers with and without CP (21). Breaks in sedentary behavior were defined as any interruption in sedentary time in which the activity count was more than 40 per 5-s epoch for CTD or ambulatory children with CP or more than 10 counts per 5-s epoch for nonambulatory children with CP. Sedentary bouts and breaks in sedentary time were grouped by duration (fewer than 60 s; 1–5 min; 5 min 1 s to 10 min; and 10 min or greater) to enable a description of the nature of the active and sedentary behaviors of toddlers.

Physical activity recommendations. The percentage of children achieving the recommendation of 180 min or longer of total physical activity (light, moderate, and/or vigorous) for none, 1, 2, or all 3 d was assessed by deducting total sedentary time from total wear time for each measured day. The percentage of children who met the recommendation of limiting sedentary periods to less than 60 min for none, 1, 2, or all 3 d was determined by identifying the longest sedentary period for each day.

Analysis. Between-group differences in age, sex, height, and weight were investigated using a one-way ANOVA with a Bonferroni *post hoc* test for continuous variables and the Fisher exact test for categorical variables. The influence of age, sex, height, weight, wear time, and ambulatory status on time spent sedentary was explored using a stepwise multiple linear regression, and variables were entered into the model in the order previously listed. Differences between weekdays and weekend days with regard to sedentary time and wear time were explored using a repeated-measures ANOVA. The agreement between the 3-d average measure of sedentary time and the individual measured days (two weekdays and one weekend day) was assessed using a Bland–Altman plot for repeated measures, where the true value varies, calculating bias and 95% limits of agreement (LoA) (6). To do this, three pairs of possible comparisons for each child were included comparing the 3-d mean to each individual day (two weekdays and one weekend day). The reliability of the 3-d average as a measure sedentary time was assessed using a one-way random ICC analysis (19).

Differences between groups in wear time, sedentary time, number and duration of bouts of sedentary behavior, and breaks in sedentary time were assessed using a one-way ANOVA with a Bonferroni or Games-Howell *post hoc* test after testing for equal variances using the Levene test. Differences between groups in likelihood of meeting the two Australian physical activity recommendations (2) on all 3 d were assessed using the Fisher exact test. Significance was set at 5% for all *a priori* analysis and 1.6% for all *post hoc* analysis.

RESULTS

A total of 58 children with CP and 20 CTD were included in the study. Fifty-three of the 111 children with CP eligible for inclusion were excluded from analysis owing to completing zero (*n* = 36), 1 (*n* = 3), or 2 (*n* = 10) d of ActiGraph® measurement or due to wearing the ActiGraph® for less than 50% of waking hours (*n* = 4) (15). Eighteen of the 38 CTD were excluded owing to completing zero (*n* = 10), 1 (*n* = 6) or

2 (n = 2) days of ActiGraph® measurement. There were no differences in age, height z-score, weight z-score, GMFCS level, or GMFM score between those children with CP who completed 3 d of ActiGraph® measurement (n = 58) and those who were excluded (n = 53). A significantly larger proportion of boys were able to complete the 3 d of assessment (66%) compared to girls (46%). There was no difference in age, height z-score, weight z-score, or sex in the CTD who completed 3 d of ActiGraph® measurement (n = 20) and those who were excluded (n = 18). Characteristics of the study population who completed 3 d of ActiGraph® measurement are found in Table 1. Children with typical development were significantly younger and heavier than children in the nonambulatory CP group. There were more boys than girls in the ambulatory and marginally ambulatory CP groups and more girls than boys in the nonambulatory CP group. Age, sex, height, weight, and wear time did not significantly contribute to the variance in sedentary time. Ambulatory status (CTD; GMFCS I–II, III, and IV–V) was the only significant contributor to the model (r^2 = 0.56, df = 76, P < 0.001).

There was no difference in daily wear time or sedentary time between weekdays and weekend days for any group (P > 0.480). The Bland–Altman plot (Fig. 1) of the differences between the 3-d mean of sedentary time and individual days shows the mean difference is zero percent, whereas the 95% LoA were ±9.6%. On any given individual day, a child might therefore be 9.6% more or less sedentary than the 3-d mean. The ICC for the reliability of the 3-d mean of sedentary time was 0.84 (95% confidence interval, 0.77–0.89).

There was no difference in daily wear time between the groups with the mean wear time close to 10 h·d^{-1} (Table 2). No difference was found in sedentary time between the CTD and the ambulatory children with CP, whereas the marginally ambulatory children with CP spent significantly more time sedentary than these two groups. The nonambulatory CP group spent significantly more time sedentary than all the other groups. In assessing the variability within the sample (Fig. 2), it may be observed that the least active CTD and ambulatory children with CP (highest quartiles) overlap with the most active nonambulatory children with CP (lowest quartile).

TABLE 1. Participant characteristics of CTD and ambulatory (GMFCS I–II), marginally ambulatory (GMFCS III) and nonambulatory (GMFCS IV–V) children with cerebral palsy.

Study Group	CTD (n = 20)	GMFCS I–II (n = 32)	GMFCS III (n = 14)	GMFCS IV–V (n = 12)
Age, yr	2.2 (0.5)	2.5 (0.5)	2.4 (0.7)	2.8 (0.4)*
GMFM-66, score, %	n/a	61 (9)	44 (8)	30 (9)
GMFM-66, range, %	n/a	38–81	25–53	20–47
Sex, n				
Girls	9	9**	2**	9**
Boys	11	23**	12**	3**
Anthropometry				
Height, cm	86.6 (5.7)	84.9 (18.6)	85.7 (7.4)	80.9 (29.2)
Height z-score	−0.2 (1.1)	−0.8 (2.1)	−1.1 (1.4)	−1.5 (2.8)
Weight, kg	13.2 (1.5)	12.6 (1.8)	11.8 (2.2)	10.7 (6.6)
Weight z-score	0.3 (0.9)	−0.7 (2.1)	−1.0 (1.6)	−1.6 (2.8)*

Statistics are reported as mean (SD) unless otherwise noted.
*Difference between GMFCS IV–V and CTD groups; ANOVA, Bonferroni *post hoc*, P < 0.05.
**Difference in distribution of boys and girls; Fisher exact test, P < 0.016.
GMFM, gross motor function measure.

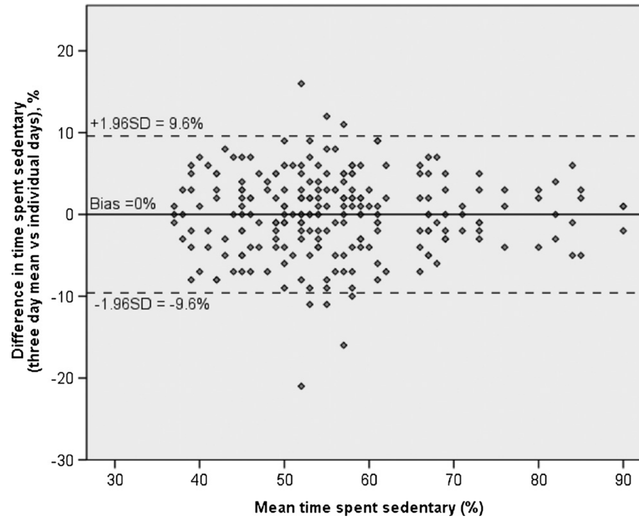

FIGURE 1—Bland–Altman plot showing difference between time spent sedentary (%) on individual days versus the 3-d mean.

The results relating to the number and duration of sedentary bouts and breaks are shown in Table 3. There was no difference in the number of sedentary bouts less than 1 min in duration between any of the groups. The mean duration of sedentary bouts lasting more than 10 min was significantly longer in the nonambulatory group compared to all the other groups. No differences in the number of sedentary breaks less than 1 min long were identified between any of the groups. The number of sedentary breaks lasting longer than 10 min was significantly higher for the nonambulatory CP group than for the CTD and the ambulatory CP groups. The apparent difference in the duration of these sedentary breaks lasting more than 10 min between the nonambulatory CP group and the CTD and ambulatory CP groups was not statistically significant after unequal variances were taken into consideration.

The children with typical development and the ambulatory children with CP were significantly more likely to meet the physical activity recommendation of participating in at least 180 min of active play on all three measured days than the nonambulatory children with CP (Table 2). All children in the CTD, ambulatory, or marginally ambulatory groups met the sedentary recommendation (sedentary bout <60 min), whereas a third of the children in the nonambulatory CP group had only 1 d where a sedentary bout did not exceed 60 min (Table 2).

DISCUSSION

School-age children and adolescents with CP (primarily GMFCS I–II) have previously been identified as being less physically active and having longer sedentary bouts and less frequent breaks in sedentary time (8,20). The present study

TABLE 2. Comparison of sedentary time and physical activity recommendations between CTD and ambulatory (GMFCS I–II), marginally ambulatory (GMFCS III), and nonambulatory (GMFCS IV–V) children with cerebral palsy.

Study Group		CTD (n = 20)	GMFCS I–II (n = 32)	GMFCS III (n = 14)	GMFCS IV–V (n = 12)
Wear time, mean (SD), min		571 (72)	580 (89)	591 (78)	589 (126)
Daily sedentary time,[a] %					
Range (%)		39–58	37–67	44–73	57–90
Mean (SD)		49 (5)	52 (7)	62 (9)*	74 (11)**
95% confidence interval of mean		46–51	49–55	57–67	67–80
Physical activity recommendation[b]					
Active play ≥180 $\text{min}\cdot\text{d}^{-1a}$, n	No days	—	—	2	7
	1 d	—	—	1	1
	2 d	3	6	4	—
	3 d	17	26	7	4***
Sedentary bout ≤ 60 $\text{min}\cdot\text{d}^{-1a}$, n	No days	—	—	—	—
	1 d	—	—	—	4
	2 d	—	—	—	—
	3 d	20	32	14	8***

[a]Time spent sedentary per day as a percentage of total wear time.
[b]Number of children meeting the active play and sedentary bout duration guideline on none to all measured days.
*Difference between GMFCS III and both CTD and GMFCS I–II, ANOVA, Bonferroni *post hoc*, $P < 0.016$.
**Difference between GMFCS IV-V and all other groups, ANOVA, Bonferroni *post hoc*, $P < 0.016$.
***Difference between GMFCS IV–V and all other groups, Fisher exact test, $P < 0.016$.

found no difference between typically developing toddlers and ambulatory toddlers with CP on any sedentary behavior or HPA measure. However, marginally and nonambulatory children with CP spent increasingly more time sedentary compared to CTD and ambulatory children with CP. These results may indicate that the differences in HPA and sedentary behavior between the ambulatory children with CP and CTD occur at a later age, whereas for children with moderate to severe functional impairment, these differences are present from a younger age.

The finding that ambulatory children with CP do not significantly differ from CTD in HPA and sedentary behavior does not necessarily mean there is no cause for concern. Despite having the capacity to partake in more activities, some CTD and ambulatory children with CP are almost as sedentary as the nonambulatory children with CP (Fig. 2). There is a paucity of research into the health implications of high levels of sedentary behavior and low levels of HPA in toddlers. Links have been made to adiposity (24), cognitive development (24), bone and skeletal health (32), and psychosocial health (9,24) in populations of CTD; but this is an area in need of further research using the validated objective measures of HPA and sedentary behavior, which have recently become available for the toddler age group (21,38).

Few studies to date have explored typically developing toddlers' sedentary behavior and HPA patterns, and little is known about how they compare to the physical activity guidelines. A recent Australian study reported that over an average of measured days, 90.5% of 19-month-old toddlers met the physical activity recommendation of 180 min or longer of active play per day (18). In this present study, all children would meet the active playtime recommendation if a mean of all three measured days was used. However, when looking at individual days, whereas most of the CTD and ambulatory children with CP met the recommendation on all 3 d, only 50% of the marginally ambulatory children and 33% of the nonambulatory children met the recommendation. Different studies should be compared with caution, as different ActiGraph® models and cut points have been used (vertical axis only vs the composite VM measure). Whereas the cut point for MVPA used in the aforementioned study showed good predictive validity, the light physical activity/sedentary behavior cut point showed significant overestimation of time spent sedentary (38). This may have skewed results by underestimating light activity and therefore total physical activity time leading to a lower number of children meeting the active play recommendation. Two recent studies assessing typically developing preschool (3- to 5-yr-old) children's HPA patterns have found similar results to those identified in the typically developing toddlers and ambulatory toddlers with CP in this present study, with approximately half of waking hours spent sedentary (10,33). In contrast, a recent Australian study found only 16.4% of a preschool child's day was spent being active, and only 5.1% met the Australian

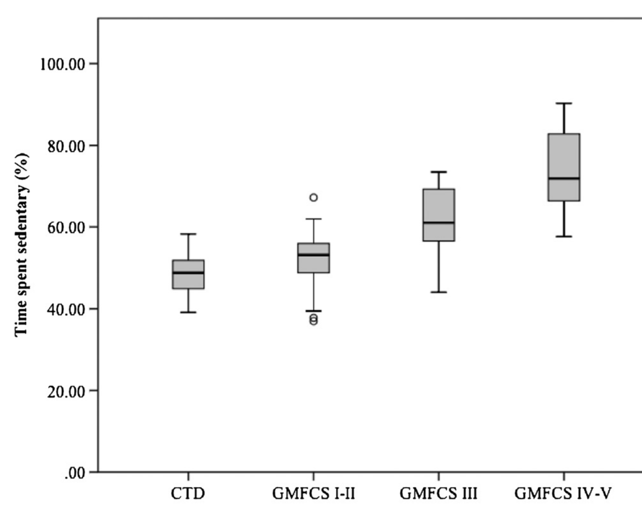

FIGURE 2—Box-and-whiskers plot of time spent sedentary in the four samples (children with typical development, GMFCS I–II; III; and IV–V).

TABLE 3. Comparison of number and duration of sedentary bouts and breaks in sedentary behavior between CTD and ambulatory (GMFCS I–II), marginally ambulatory (GMFCS III) and nonambulatory (GMFCS IV–V) children with cerebral palsy.

Study Group	CTD (n = 20)		GMFCS I–II (n = 32)		GMFCS III (n = 14)		GMFCS IV–V (n = 12)	
Duration (min:s)	Number (n)	Duration (min:s)	Number (n)	Duration (min:s)	Number (n)	Duration (min:s)	Number (n)	Duration (min:s)
Sedentary bout[a]								
<1:0	592.3 (126.9)	0:15 (0:1)	622.0 (140.4)	0:15 (0:1)	649.1 (158.2)	0:14 (0:1)	560.4 (258.7)	0:13 (0:7)
1:0–4:59	65.6 (13.1)	1:47 (0:7)	61.3 (14.9)	1:45 (0:6)	51.2 (15.0)*	1:38 (0:7)	38.3 (12.1)	1:39 (0:10)
5:0–9:59	2.8 (1.8)	6:38 (0:36)	2.5 (1.2)	6:31 (0:33)	2.2 (1.0)	6:44 (0:38)	2.3 (1.5)	6:37 (0:31)
≥10:0	0.6 (0.6)	15:35 (5:9)	0.7 (0.9)	14:28 (3:20)	1.1 (0.9)	16:22 (3:26)	2.0 (1.1)	23:31 (7:4)**
Sedentary break[b]								
<1:0	599.5 (107.6)	0:14 (0:1)	630.2 (116.3)	0:14 (0:1)	615.7 (122.6)	0:14 (0:1)	531.5 (174.2)	0:14 (0:1)
1:0–4:59	57.3 (11.2)	1:50 (0:5)	59.2 (12.2)	1:49 (0:6)	56.8 (9.5)	1:45 (0:8)	48.4 (1.9)	1:48 (0:12)
5:0–9:59	3.1 (1.8)	6:38 (0:26)	3.3 (1.8)	6:38 (0:27)	3.4 (1.9)	6:25 (0:34)	4.8 (2.4)	6:57 (0:30)
≥10:0	1.1 (0.7)	15:11 (2:45)	1.1 (0.9)	15:48 (4:1)	2.3 (1.8)	16:38 (3:59)	4.0 (2.9)***	22:34 (10:28)

All numbers are mean (SD).
[a]Sedentary bout is time spent below sedentary cut point.
[b]Sedentary break is time spent above sedentary cut point.
*Difference between GMFCS III, and CTD and GMFCS I–II, ANOVA, Bonferroni *post hoc*, $P < 0.016$.
**Difference between GMFCS IV–V and all other groups, ANOVA, Games-Howell *post hoc*, $P < 0.016$.
**Difference between GMFCS IV–V and GMFCS I–II, ANOVA, Games-Howell *post hoc*, $P < 0.016$.
min, minutes; s, seconds.

active playtime guideline (17). All three studies used different cut points and/or accelerometers, which may have influenced results.

Most sedentary bouts and sedentary breaks were less than 1 min in duration, followed by bouts and breaks of 1- to 5-min duration. The number of sedentary bouts and breaks longer than 5 min was low. These results agree with two previous small studies of children with typical development (3,22). A study of 3- to 4-yr-olds found that children spent 75% of a free play session in one intensity level for less than 5 s, and 94% of activity bouts were shorter than 15 s (22). A study of older children (6- to 10-yr-old), where a full day of activity was observed found low (sedentary and light activity combined), and medium-intensity activity bouts lasted a median time of 6 s (3). High-intensity bout lasted a median of 3 s, with 95% lasting less than 15 s (3). Recognizing the typical physical activity pattern of young children, the physical activity guidelines therefore do not stipulate that active periods are required to be any specific duration. In contrast, the recommendation of minimizing sedentary behavior to less than 1 h seems to be less applicable to the HPA patterns of young children than the active play recommendation. They do not seem to spend long periods of time completely sedentary but still spend approximately 50% of their day in sedentary pursuits. The mean time of sedentary bouts and breaks of less than 60 s was approximately 15 s, which also demonstrates that a 15-s epoch for data collection as used in other studies (17,18,38) is possibly not small enough to capture the active and sedentary behaviors of toddlers, as a significant amount of bouts and breaks in sedentary behavior would be shorter in duration. Future research into the health consequences of total sedentary and active time and the number and duration of sedentary bouts would further inform and refine these recommendations for young children.

To the best of our knowledge, this is the first study to report sedentary behavior and HPA for toddlers with CP and the comparison to children with typical development. A major strength of this study is the inclusion of the full range of functional abilities within the CP population, and the comparison to a typically developing reference group. Further strengths of this study is the use of accelerometer cut points with good predictive validity specific to this population and the 3-d mean of sedentary time demonstrated a high level of agreement between measured days and satisfactory level of reliability. Limitations to this study include the smaller sample size of the GMFCS III and IV–V group compared to the GMFCS I–II group; however, the sample was recruited from a population-based study, and this distribution is representative of the CP population as a whole (31). Some of the findings may also reflect the methodological difficulty of measuring physical activity in children who are nonambulatory. Periods of being carried by parents or other caretakers may not be recorded in the diary and therefore produce periods of movement that the child is not responsible for. The finding that nonambulatory children with CP had more sedentary breaks longer than 10 min than all the other groups demonstrates this and is likely due to parent movement. Consequently, time spent sedentary may be underestimated, whereas total active time may be overestimated. Further work to improve the use of accelerometers in this subgroup is required and may include the use of an inclinometer function to detect postural changes and an upper cut point for what is likely to be self-initiated versus parent movement. This concept was explored but not validated in a recent study (29). A limitation of the ActiGraph® itself is that it does not measure water activities, and it might not register movement above the sedentary threshold for activities when the trunk is relatively still such as bike riding.

CONCLUSION

Typically developing toddlers and ambulatory toddlers with CP spend approximately 50% of their waking hours sedentary, with marginally ambulant and nonambulatory children with CP spending an additional 10% and 20% of their waking hours sedentary, respectively. Nonambulatory children with CP are less likely to meet the active play recommendations than all the other groups. There is a need to identify factors that contribute to the observed differences in HPA and sedentary behavior between CTD and ambulatory children with CP as they reach school age and adolescence so these can be addressed. Identifying ways in which sedentary behavior in marginally and nonambulatory children with CP can be reduced is also of importance, as they display higher levels of sedentary time at a young age.

Measurement of physical activity and sedentary behavior in toddlers is still in its infancy. Research into the consequences of the amounts of sedentary and total active time, and the number and duration of sedentary bouts and breaks on the development and health outcomes in young children both with and without disabilities is required to further inform public health recommendations. Specific to the CP population, longitudinal studies comparing how sedentary behavior and HPA affect health outcomes such as gross motor attainment and retention of gross motor skills, body composition, bone and skeletal health, hip displacement, participation, cognitive development, and psychosocial well-being in their toddler years and as they grow older will enable an understanding of where interventions can most efficiently be targeted.

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EPIDEMIOLOGY

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