Duration and Patterns of Habitual Physical Activity of Adolescents and Young Adults with Cerebral Palsy

by

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ABSTRACT

AIM Adolescents and young adults with cerebral palsy (CP) show reduced motor function and gait efficiency and lower levels of habitual physical activity (HPA) compared to children with CP and typically developing peers. This study examines activity durations and patterns of this population by long term monitoring of a large sample in the Middle East with accelerometers.

METHOD Adolescents and young adults with bilateral CP (Gross Motor Function Classification System-GMFCS-E&R-levels II; III; IV) were monitored in their habitual environment for four consecutive days with ActivPAL^{3}™ monitors. Time spent in sedentary, standing and walking activity, and frequency of walking steps and transitions were analyzed for each GMFCS level.

RESULTS Measurements were made on 222 participants (132 males, 90 females; age range 13.3 – 22.0 yr). The Mann-Whitney test demonstrated significant differences ($p<0.05$) between GMFCS levels, showing reduced walking and standing activities and increased sedentary duration at higher GMFCS levels ($p<0.001$), except for standing time between levels II and III ($p = 0.07$). Participants in educational facilities had less sedentary behavior than those homebound ($p<0.05$).

INTERPRETATION These descriptions of duration and frequency of active and sedentary activities may serve as a basis for recommendations to minimize inactivity in this population. Adolescents and young adults with CP in the Middle East demonstrate similar patterns of HPA to their peers elsewhere.

Short title: Daily Physical Activity of Youth with CP

What this paper adds?

- Event-based analysis gives insights into habitual physical activity
- There are fewer and longer sedentary behavior events at higher GMFCS levels
- HPA of Middle East youths with CP is the same as elsewhere
- Students with CP had less sedentary behavior than those homebound

INTRODUCTION

Habitual physical activity (HPA) may be defined as the magnitude and pattern of body movements during the usual activities of daily living, including sleep and rest (sedentary), work and leisure. Sedentary behavior refers to activities that do not increase energy expenditure > 50% above the resting level and includes activities such as sleeping, sitting, lying down and watching screen-based entertainment [1,2]. Regular and intensive physical activity, even in individuals with disabilities, is directly associated with physical fitness, improved quality of life and psychological function[3]; low levels of activity contribute to the risk for chronic cardiovascular disease[4] and other health issues[5].

Adolescents and young adults with cerebral palsy (CP) face many difficulties with functional mobility in their transitional growth stages because, as teenagers, they decline in gross motor function capacity and gait efficiency[6]. Additionally, adolescents with CP face a discontinuity of care, as pediatric rehabilitation ends and they age out of pediatric services, leaving little adult rehabilitation services to meet their health needs[7]. Adolescents and young adults with CP have lower levels of physical activity than younger children with CP, with less walking and more sedentary behavior[8], and activity decreases as gross motor function deteriorates[8,9]. Although sedentary behavior may not be very dissimilar, adolescents and young adults are less physically active than their peers without disabilities, because of fewer structured activity programs and the physical activity restrictions and co-morbidities associated with CP[8,10].

The HPA patterns can now be monitored over hours and days in normal daily living conditions because of the technological development of accelerometer-based monitors. These monitors are affordable, simple to operate, small and light weight, and ideally suitable for long-term monitoring of HPA[11]. In addition to step counts by pedometers, accelerometers respond to the inclination and magnitude of movement of monitored body segments and can identify different postures and create a more detailed profile of the wearer's HPA[12,13]. The ActivPAL^3 monitor does not require a full vertical position in order to classify the position as standing or to identify a transition. One study validated the ActivPal for hemiplegic children with CP at GMFCS levels I, II and III and concluded that it was capable of measuring the number of steps and the time spent walking for the less complex hemiplegic gait patterns[14].

There is growing evidence that event-based analysis of HPA, in addition to analysis of the total volume of HPA, may provide important information regarding physical activity patterns. When the time and duration of sequences of physical activities and sedentary pattern are examined it is clear that much activity occurs in short bursts at certain times of the day and short activity periods are separated by long periods of inactivity. The analysis of activity events (walking, standing, transitions, sedentary behavior) and their temporal patterns can add additional information regarding mobility status. These patterns of physical activities and sedentary behavior may be related to risk factors for disease[13,15] and adjustments may be recommended to reduce inactivity. Obeid et al. reported that children and teenagers with CP and typically developing peers demonstrated different patterns of sedentary behavior[16]. Therefore, it seems important to describe in detail the activities and patterns of a population of adolescents and young adults with CP.

The primary aim of this study was to document the HPA of adolescents and young adults with CP, based on accelerometer analyses, in terms of the duration and frequency of sedentary and walking events in normal daily living and compare the number and frequency of these events between different levels of mobility dysfunction. This detailed long term monitoring may provide useful descriptions regarding sedentary behavior and the function and activity level of the participant[17]. A secondary aim was to document long term HPA of adolescents and young adults with CP in Jordan, Israel and Palestine, and also to compare those in educational institutions with those homebound. A description of the HPA levels of

this population will enable comparison with peers in other, mainly developed, countries. This information may assist and encourage authorities in the Middle East to invest in facilities and education to promote a more physically active lifestyle for these individuals.

METHODS

Participants

Participants were recruited from clinical centers and schools by telephone and personal interviews by the researchers in each center in Israel, Jordan and Palestine. Adolescents and young adults with CP were included in the study if they met the following criteria: (a) diagnosis of bilateral (diplegia, quadriplegia) spastic/mixed type CP, (b) age 13-22 yr, (c) gross motor function classification system (GMFCS)[18] at levels II, III or IV (see GMFCS levels defined below), classified with their usual shoes, orthotics and assistive mobility devices, (d) cognitive level sufficient to comprehend and cooperate with measurements, (e) no orthopedic surgery or other spasticity management in last six months. There was no restriction on treatments of any kind after the 4 days of monitoring. Participants were excluded if they had: (a) progressive degenerative condition of the CNS or musculoskeletal system, (b) experienced an injury of lower extremity (reported fracture, sprain, strain) in the last six months or (c) experienced exercise-induced asthma, cardiac problems or uncontrolled seizure disorders.

Ethical approval was granted from the national and local ethical review boards for each of the three participating centers. Written informed consent to participate in the study was obtained from participants or parents/guardians after a detailed explanation of the study.

Procedures

Researchers from the participating centers conducted joint training workshops on the use and placement of accelerometers and downloading and sending data to the Department of Biomedical Engineering at Ben-Gurion University of the Negev. Researchers and pediatric physical therapists that classified participants at particular GMFCS levels had at least seven years experience working with children with CP.

Demographic and anthropometric characteristics (weight, height, and calculated BMI) were noted and a socioeconomic questionnaire was completed by interview with the participant and his guardian/family member. The questionnaire pertained to education level of participant and father and mother, income level and occupation of family members, number of people living in the home, home type-private residence/apartment floor level/city/town/village, accessibility to home/school/work (stairs, elevator, transportation type). The parents/guardians and participants were given verbal and written instructions and a demonstration of the placement of the monitor.

The participants came for one visit to the laboratory where they received specific instructions and the monitor was placed on the appropriate body site. The participants' activity was monitored for a period of approximately 96 continuous hours in their habitual environment. The majority of the records included two weekend days, but occasionally four weekdays when monitors or personnel were not available on weekends. On several occasions the monitoring was repeated because the ActivPal had not been placed in the correct position. Participants were asked to wear the monitor on their less affected leg for the whole period, except when bathing and swimming. They were asked to maintain a structured daily diary describing their general activity and unusual events to validate adherence to the instructions and to explain problematic events data.

Measurements

The GMFCS level was determined by following the GMFCS – E & R (Gross Motor Function Classification System Expanded and Revised). The GMFCS for CP is based on self-initiated movement, with emphasis on sitting, transfers and mobility. The expanded GMFCS[19] includes an age band for youth 12 to 18 years of age. The focus of the GMFCS is on determining which level best represents the child's or youth's present abilities and limitations in gross motor function. Emphasis is on usual performance in home, school, and community settings, i.e., what they do, rather than what they are capable of doing[20]. The levels of mobility are: I - walks without limitations; II - walks with limitations; III - walks using a hand-held mobility device; IV - self-mobility with limitations; may use powered mobility; V - transported in a manual wheelchair.

Physical activity was recorded using an ActivPAL$^{3™}$ (PAL Technologies, Glasgow, UK) tri-axial accelerometer-based activity monitor. It is a small device (15 g, 3.5 x 5.3 x 0.7 cm), placed on the mid-line of the anterior aspect of the thigh, attached using a Nitrile sleeve and conformable dressing. The capacitive accelerometer responds to gravitational acceleration, indicating the posture of the wearer (horizontal or upright), and to acceleration due to movement of the thigh, indicating walking activity. The validity of ActivPAL has been demonstrated for healthy adults[17], children and adolescents[21] and children with CP[22]. Teenagers at level IV mostly use wheelchairs. However, about 25% transfer themselves using a walker or furniture in their home environment. Wheelchair mobility in this study was considered to be sedentary. In this group we placed the accelerometer on their thigh exactly as done with the other participants.

Data analysis

The average duration and average frequency of bouts of activity were calculated for each participant. Short consecutive bouts of walking (corresponding to a single step) were accumulated and represented as a single walking event. Apparently, there is no conclusive definition of the maximal duration of a standing event that can be considered a short pause in an ongoing walking event. Chastin et al.[23] chose a maximal duration of 10 sec, which is consistent with the ActivPAL default value for the minimal duration of a standing event. Sellers et al.[24] suggested a threshold of 30 sec. With these considerations, a threshold of 20 sec was chosen for this study. Therefore, standing events disrupting a continuous walking event and lasting 20 sec or less, were coded as walking and considered part of a walking event.

The acceleration data were downloaded to a computer, where it was processed with ActivPAL$^{3™}$ software, providing activity measures such as time spent in sedentary activity (sitting or lying), standing, walking, step frequency, and the number of bouts of activity (events). These results were analyzed using MATLAB (Mathworks) and Prism (GraphPad).

Participants were divided according to three GMFCS (II, III, IV) levels and analyses were within, and comparison between, these groups. A nonparametric outlier test (based on Chebyshev's theorem) was conducted for each GMFCS level in order to identify conspicuous results in every measured activity. In this test, an outlier value is more than 4 SDs from the mean, allowing a wide range for natural diversity of the population.

The distributions of the results were significantly skewed, making assumptions of a normal distribution invalid. Therefore, the Mann-Whitney non-parametric test was applied for testing differences between groups. This test is based on the median of the data set. However, because many studies have presented means and SDs for activities, these are also presented for comparison with other studies. Statistical significance was determined as $p<0.05$.

RESULTS

A total of 429 adolescents and young adults were approached. Of these, 107 did not meet the inclusion criteria and 88 were not interested. Data from 10 were outliers and removed from the data set and data from two were lost. The analyzed activity data consists of 222 participants, with age, anthropometric and disability characteristics listed in **Table I**.

The HPA measures for an average recording duration of 4 days (SD = 5 hr) are shown as a percentage per 24 hr in **Table II**. Significant differences ($p<0.001$) between all GMFCS levels were found for each of the three activity durations, except for standing time between GMFCS II and III ($p = 0.07$). As expected, participants with higher GMFCS levels (lower motor function) had significantly longer sedentary duration and shorter durations of standing and walking. They also took fewer steps per day, and had fewer transitions from standing to walking. These results confirm the expected inverse relationship between GMFCS level and physical activity.

The median duration and frequency of each event bout per 24 hr are presented in **Figure 1**. The number of sedentary, standing and walking events decreased as GMFCS level increased. For level IV, the duration of each sedentary event was highest, at a median of 100 minutes, while the walking events were the shortest, at approximately 16 sec. The duration of each standing event was not significantly different between levels II and IV, at about 49 sec. The distributions of the durations of sedentary and walking events for different levels of GMFCS are shown in **Figure 2**. The plots show that 50% of the sedentary events are shortest for level II, and longest for level IV. Conversely, walking events are longest for level II and shortest at level IV.

The difference in HPA between participants who attend educational institutions (students) and those who remained at home was also tested as above at each GMFCS level. Only participants at GMFCS level III exhibited significant differences in HPA between students and those homebound, with no other significant differences found between these two categories at levels II and IV. However, when all participants at all three levels were combined, the students were more active, spending significantly less time being sedentary and more time walking and taking more steps ($p<0.05$) than those remaining at home.

DISCUSSION

To our knowledge, this is the first study to present a detailed analysis of HPA levels and patterns in adolescents and young adults with CP in terms of the bouts of activities investigated (sedentary, standing, walking duration, walking steps and transitions), and the inclusion of GMFCS III and IV as separate groups. This study also describes the daily HPA of adolescents and young adults with CP in the Middle East. As expected, those who were more disabled were less physically active during the day, being more sedentary and spending less time standing and walking with fewer transitions. Additionally, this study suggests that educational facilities benefit students with CP by decreasing sedentary behavior compared to homebound participants.

These results generally agree with findings of studies of similar populations in Australia[8], Canada[10] and the USA[9]. Bjornson et al., using a Step Watch monitor, reported an average number of 8,400 daily steps for 81 youths with CP (GMFCS levels I, II and III), age 10-13 yr in the USA, and an average of 13,400 steps for a typically developing age-matched group[9]. Although their average number of steps for youths with CP is higher than that found here (6,282 steps per/24 hr for GMFCS II), this can be accounted for by the younger population sample in the USA study (mean age 11.8 yr) and the inclusion of 38% of their subjects at GMFCS level I. Stevens et al. reported a lower and more similar number of 6,342 steps per day for 27 children and adolescents with CP (levels I and II and age 4-18 yr, from the USA[7]. Tang et al., using the ActivPal monitor, measured an average of 6,659 daily steps

for five participants with CP (GMFCS level not stated), age 14-17 yr[25]. Recently, the HPA of adults with CP, average age 36yr, from the Netherlands was reported, using the Activity Monitor (AM-TEMEC Instruments BV, Kerkrade, Netherlands)[26]. Those participants exhibited less time in sedentary behavior and a larger part of the day in standing and walking activity, with 134 transitions, making them more physically active than subjects with GMFCS II in the present study. Adults in the Netherlands with GMFCS III and IV also demonstrated higher levels of physical activity (in terms of walking and transitions) than the participants in the present sample. The Netherlands results conflict with other studies claiming reduced function and activity with age[6]. The differences may be due to different activity monitors being used, or less accessibility to appropriate physical environment and structures for participants in the present study that would facilitate more activity in their habitual environment. Another explanation may be that, although adults with CP experience a decrease in fitness and motor function, they often live independently and are therefore required to be more active, in comparison to participants in this study, who predominantly live with their parents. The Netherlands sample[26] included 60% living on their own and 70% who were working.

Most previous studies of HPA report levels of activity in terms of step count and duration of each measured posture or activity. However, a new approach has been suggested, based on the analysis of events of sedentary behavior and activity[15]. Obeid et al. compared the sedentary pattern between 16 children and adolescents with CP (mean age 13.1 yr, GMFCS levels I, II and III) and typically developed peers. These groups showed different patterns, where youths with CP had longer duration of sedentary behavior and fewer activity breaks[16]. These results agree with the present study, where the median duration of sedentary events was significantly longer for higher GMFCS levels, and the number of separate events (equivalent to the number of breaks) was significantly smaller. Grant et al. measured the distribution of sedentary and walking events in older adults, grouped as hospital in-patients, day-patients and general population[27]. The distribution of activities in those three groups approximates that noted in GMFCS levels in this study; the group with lower mobility function displayed a wider distribution of sedentary events (50% of events are relatively long) and a narrower distribution of walking or upright events (50% of events are relatively short).

The proportion of participants who attend an educational facility and those who stay at home differed between GMFCS II, III and IV (Table I). However, only participants at GMFCS III exhibited significant differences in HPA between students and those home bound. We speculate that these differences in GMFCS III occur due to mobility differences between these groups. Compared to home living in the Middle East, the school is a motivating, structured and physically accessible environment, with flat surfaces and wide pathways that offer improved mobility for those who use walkers and crutches. In our sample 97% of participants with GMFCS II do not use walking aids and 84% of participants with GMFCS IV use wheelchairs as their main mobility aid. Therefore, the advantages of supportive facilities are likely most advantageous for participants at level III because 78% of them use crutches or walkers as their primary mobility aid.

Clinical implications

Increasing emphasis is being placed on the definition of sedentary behavior and the negative influence its excess on health and wellness[1,2]. This study contributes to the body of knowledge of sedentary behavior of teenagers and young adults with CP by measuring and describing the duration and patterns HPA. This behavior event analysis of HPA suggests consideration be given to interventions that promote physical activity and a healthier lifestyle in this population. In addition to recommendations that encourage a minimal amount of

physical activity per day, this study can support recommendations regarding breaks in sedentary behavior and the duration and amount of activity bouts and the importance of accessibility to structured physical facilities, such as those found in schools.

Sedentary behavior in typically developed teenagers has been measured and guidelines have been issued in Canada that recommend: (a) limiting sedentary transport and extended sitting throughout the day and (b) limiting recreational screen time to less than 2 hr/day[28]. As this might not be realistic for this population with CP, each bout of daytime sedentary activity should at least be limited to 60 minutes. Moreover, health authorities, might consider adding more specific recommendations for children and adults with CP by incorporating the events concept. Reporting activity data in bouts has the potential to match reported activity against guidelines, e.g., WHO recommendations that physical activity should be accumulated in at least 10-minute bouts[29]**.** These might include the number and duration of breaks in sedentary periods and the duration and amount of activity bouts. Promoting these goals would be especially beneficial for population with motor disabilities in the Middle East, where such policies do not exist. In addition, this study provides evidence that the physical structure of educational facilities is beneficial for this population.

Limitations

Recording of HPA during four consecutive days, with very limited control over the compliance of the participants during the trial probably resulted in some faulty records (e.g., misplacing the monitor, prolonged removal after bathing, etc.). Some of these issues were identified as problematic in the early stages of data collection and only a few were encountered during the statistical analysis. Also, the ActivPAL does not monitor any physical activity when self-propelling a wheelchair for participants classified as GMFCS level IV and any activities performed in the swimming pool for the whole study population.

CONCLUSION

A novel method for the analysis of HPA, based on the duration and frequency of activity events, was utilized. The results suggest that the event concept within HPA may be considered in updating recommendations for promoting more healthy lifestyles in persons with CP . This study measured the HPA of a large sample of adolescents and young adults with CP in the Middle East, a population that has never been examined with these measurements.

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Table I. Characteristics of 222 participants.

	Mean	**SD**	**Range**	
Age (yr)	16.8	2.0	13.3 - 22.0	
Ht (cm)*	155	10	125-180	
Wt (kg)#	52.6	11.9	24.0-86.0	
BMI (kg/m^2)	22.0	3.7	11.7 – 31.1	
	n	**%**	**n (%)**	**n (%)**
GMFCS			**School/Univ.**	**Home**
Level II	137	62	118 (86)	19 (14)
Level III	60	27	45 (75)	15 (25)
Level IV	25	11	12 (48)	13 (52)
Total			175 (79)	47 (21)
Gender				
female	90	41		
male	132	59		
Country				
Israel	55	25		
Jordan	71	32		
Palestinian Authority	96	43		
Walking Aids				
none	139	63		
stick	7	3		
crutches	19	8		
walker	33	15		
wheelchair	24	11		

*: n=217; #: n=220

Table II: Daily activity duration, number of steps and transitions per 24 hr for 222 participants.

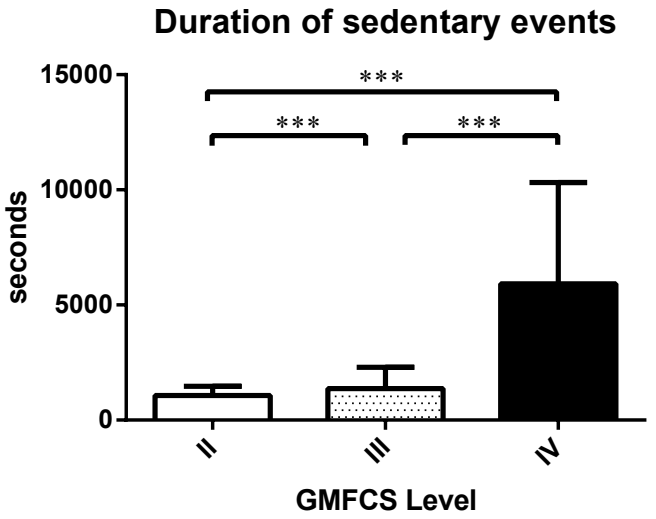
	GMFCS Level					
	II (n=137)		III (n=60)		IV (n=25)	
Characteristics	median (IQR)	mean (SD)	median (IQR)	mean (SD)	median (IQR)	mean (SD)
Duration of activity (% of 24hr)						
Sedentary	82.5 (10)	82.1 (7.2)	87.0 (8.4)[a]	86.6 (6.2)	97.7 (4.9)[a,b]	95.7 (5.4)
Standing	11.4 (7.2)	11.9 (5.3)	10.4 (7.0)	10.5 (5.1)	2.0 (4.3)[a,b]	3.9 (5.2)
Walking	6.1 (4.8)	6.0 (3.3)	2.6 (2.3)[a]	2.9 (2.3)	0.3 (0.6)[a,b]	0.4 (0.5)
Steps per day	5899 (5804)	6282 (3756)	1956 (2144)[a]	2574 (2411)	120 (495))[a,b]	317 (382
Transitions per day	66.2 (35.4)	70.0 (29.0)	50.0 (31.0)[a]	54.7 (28.4)	14.5 (31.2)[a,b]	22.5 (18.6)

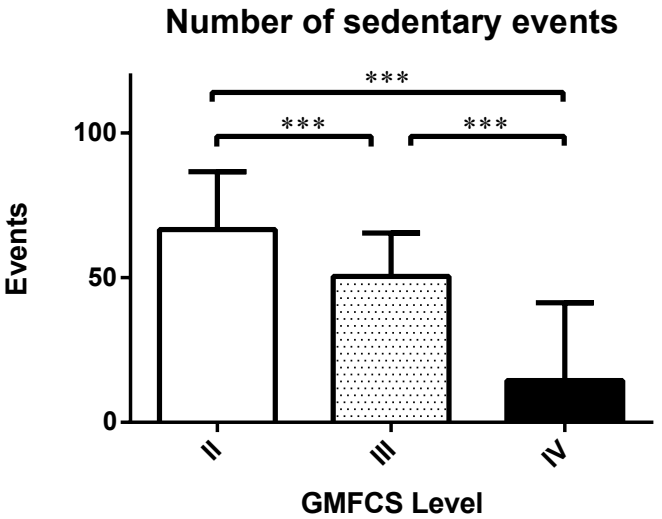
[a]: Significantly different from GMFCS II (p<0.001); [b]: significantly different from GMFCS III (p<0.001); IQR: interquartile range; SD: standard deviation

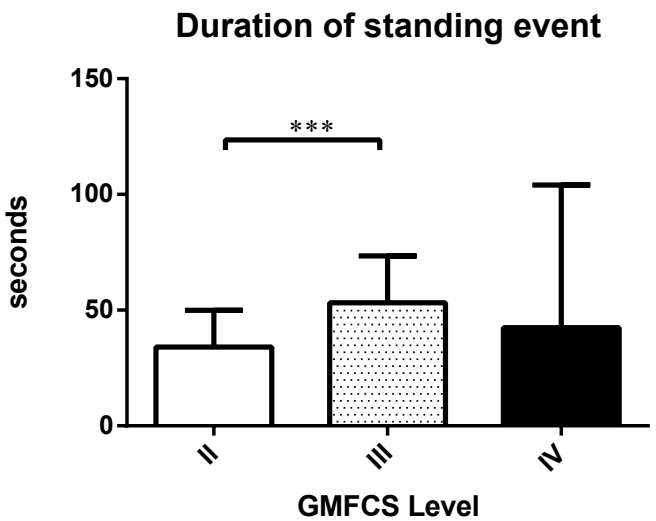
Legends for Figures

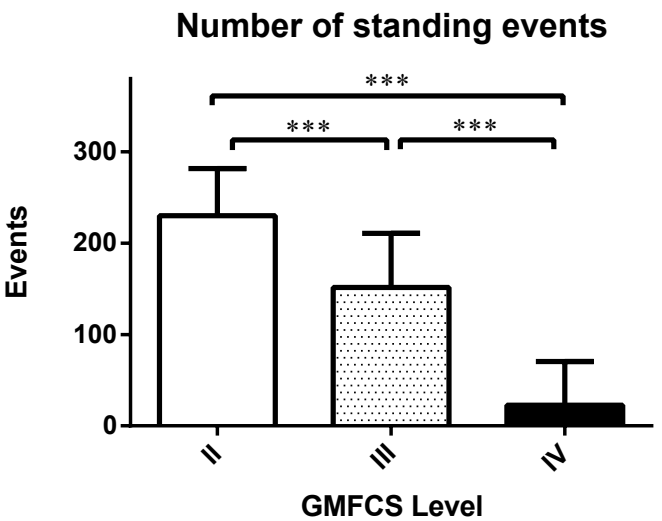
Figure 1. Median and IQR (interquartile range) of the duration of events for each activity (sedentary, standing and walking) and the number of events per day, for GMFCS (Gross Motor Function Classification System) levels II, III and IV. ***: $p<0.001$.

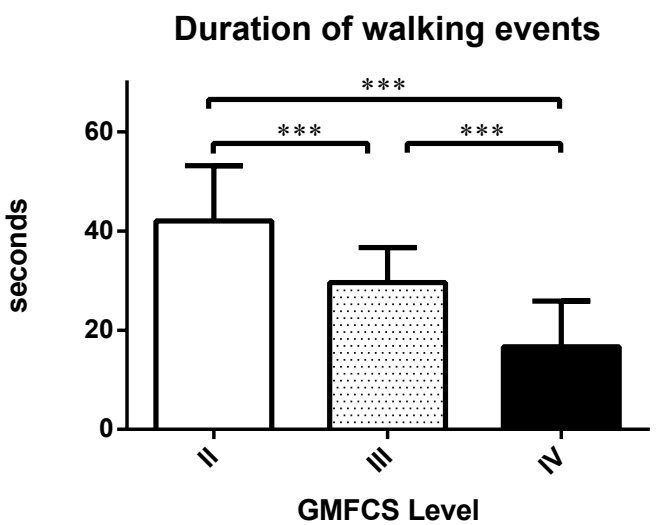
Figure 2. Distributions of duration of sedentary and walking events. The Y-axis is the cumulative time spent in activity normalized to a sum of 1. The X-axis is the duration of the event in minutes. The horizontal line at 0.5 indicates 50% of the distribution, and the X-value (duration) at which each curve meets this line is indicated. Each curve represents a GMFCS level, and includes all sedentary or walking events taken by all participants at that level.

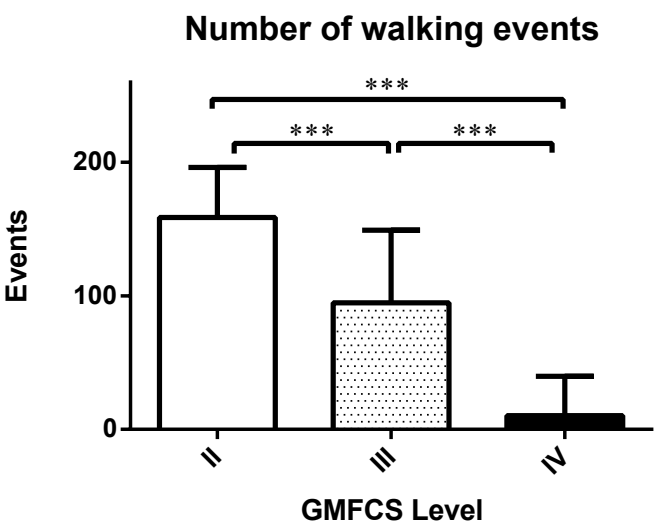

Duration of sedentary events
15000
10000
5000
0
seconds
***
***
***
II
III
IV
GMFCS Level

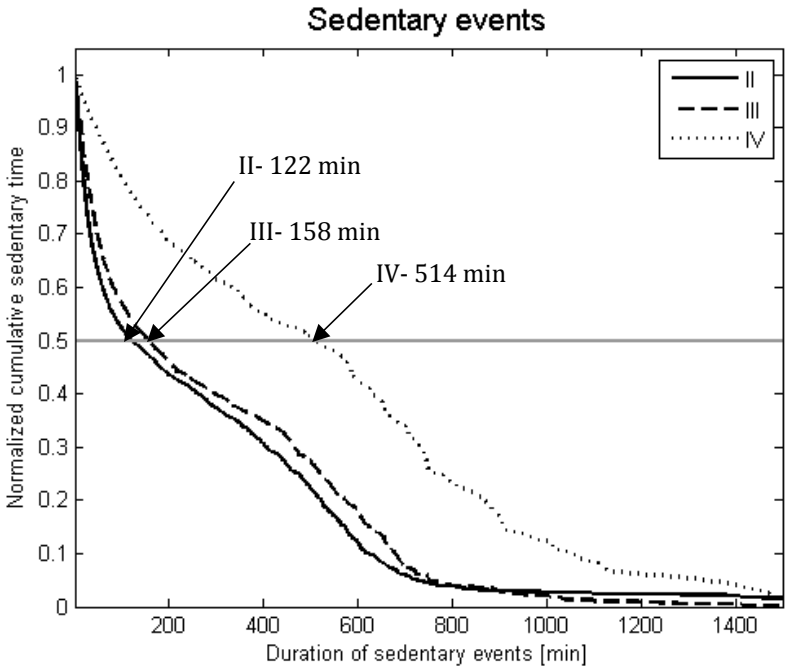

Number of sedentary events
100
50
0
Events
***
***
***
II
III
IV
GMFCS Level

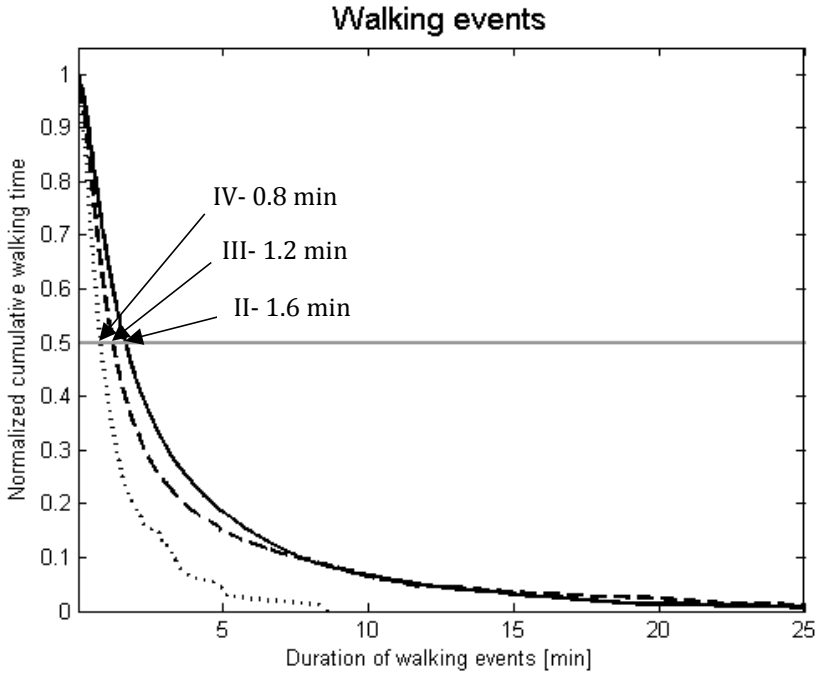

Duration of standing event
150
100
50
0
seconds
***
II
III
IV
GMFCS Level


Number of standing events
300
200
100
0
Events
***
***
***
II
III
IV
GMFCS Level


Duration of walking events
60
40
20
0
seconds
***
***
***
II
III
IV
GMFCS Level


Number of walking events
200
100
0
Events
***
***
***
II
III
IV
GMFCS Level


Sedentary events
II
III
IV
II- 122 min
III- 158 min
IV- 514 min
Normalized cumulative sedentary time
Duration of sedentary events [min]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
200
400
600
800
1000
1200
1400


Walking events
IV- 0.8 min
III- 1.2 min
II- 1.6 min
Normalized cumulative walking time
Duration of walking events [min]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
5
10
15
20
25