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Interval setting selection affects ambulatory activity outputs in children with cerebral palsy

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ABSTRACT

Introduction: Accelerometer based devices have been widely used to assess the ambulatory activity of children with and without functional disabilities. Many researchers who utilize the StepWatch Activity Monitor (SAM) collect at a 60 second (60sec) interval setting. The purpose of this study was to assess the effect of SAM interval settings on ambulatory activity outputs in children with cerebral palsy (CP) and typically developing youth.
Methods: Participants wore a SAM which recorded the number of strides every 10 seconds (10 s) for one week. Raw 10 s data was downsampled to combine strides into 60sec intervals. Strides were ensembled into walking bouts with the Intensity/Duration calculated as a percentage of Total Ambulatory Time (TAT).
Results: Twenty-eight children with CP (14 boys; avg. 12 yrs. 4 mths.; GMFCS Level I n = 4, Level II n = 19, Level III n = 5) completed testing and 28 age matched typically developing youth (14 boys; avg. 12 yrs. 6 mths.) were included. Using the 10sec interval, ~80% of walking bouts in both groups were less than or equal to 60 s. Data recorded at 60sec intervals had higher daily TAT but fewer walking bouts. In children with CP, daily steps were higher using the 60sec interval. At the *Easy* intensity, the 60sec interval reported an increased volume of *Long* duration walking, and it rarely identified any *Moderate+* intensity activity.
Conclusions: 60sec interval data overestimated low intensity and long duration ambulatory activity. It is imperative that investigators choose a finer interval setting (10sec) to maximize the detection of gait transitions and rest periods which are critical in describing community ambulation of patients with cerebral palsy.

1. Introduction

The StepWatch Activity Monitor (SAM, Modus Health, Washington, DC, USA) has been used as a device to measure daily ambulatory activity in children [1–5]. The application of the SAM in young children with cerebral palsy (CP) has shown reductions in the average daily total strides and the percentage of time spent at various ambulatory level intensities when compared to their typically developing peers [3,6–12].

The internal memory of the SAM is limited based on the data recording interval setting. In an early study demonstrating the utility of the SAM, researchers recommended the use of 60 second (60sec) intervals, stating that it provides a balance between data resolution/volume of data and thus has become the most common setting reported in the literature [1–3,6–11,13–20].

At a 60sec interval, the SAM outputs a summation of the number of strides taken each minute. If any strides are recorded in that minute, the software assumes that the patient is ambulating for the full 60 s, and will count the entire 60 s as active time. Research has shown that the majority of walking bouts are 60 s or less in both typically developing children (80% of total walking bouts) and nondisabled adults (81% of total walking bouts), with the greatest percentage of walking bouts being 10 s and 20 s in duration (20% and 26% of total walking bouts, respectively) [5,21]. Longer interval settings may miss intermittent rest periods that occur between shorter activity bouts thus creating one continuous ambulatory bout. Intensity definitions that are based on a step rate would be greatly affected by this overestimation of the duration of the activity bout, resulting in a lower intensity categorization of the bout. This suggests that shorter intervals, less than 30 seconds, should be used to evaluate community ambulation.

Previous research utilizing other devices has shown significant differences in activity outputs based on interval settings. Rowlands et al. (2006) assessed the activity of twenty-five 7–11 year old children when wearing two RT3 activity monitors (Stayhealthy, Inc., Monrovia, CA, USA) set to record at 60sec and 1sec intervals [22]. The 60sec interval setting was shown to report a greater number of minutes spent at “moderate” and “vigorous” activity while the 1sec interval setting reported a greater number of minutes spent at “more vigorous” and “very hard”, activity levels.

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It is critical to consider the implications of the above findings when assessing patients with CP who have an increased physical strain of walking which causes them to take more rest breaks when compared to their typically developed peers [23–25]. A large multicenter study showed a decrease in walking velocity, cadence and an increase in oxygen cost for patients with decreased functional abilities, classified using the Gross Motor Function Classification System (GMFCS) [26,27]. Research has shown that children with CP spend a greater percentage in low intensity walking activity and corresponding lower percentage in medium and high intensity walking activity [6,10,12].

Although a longer interval period allows for more days of data to be stored on the internal memory of the SAM, it could potentially miss short rest periods that may occur when a patient with CP has been ambulating for 60 s or longer. No published study has investigated the effect of interval settings on intensity and other ambulatory activity measures when using the SAM in a cohort of children with CP.

The purpose of this study was to evaluate the effect of short and long SAM interval settings on ambulatory output variables including steps (strides x 2), number of walking bouts, total ambulatory time and ambulatory bout intensity/duration in children with CP and typically developing children. It was hypothesized that the longer 60sec interval setting would result in a higher percentage of total ambulatory time categorized as easy intensity/long duration walking bouts.

2. Methods

Children with CP who were referred for clinical gait analysis were invited to participate in an IRB approved prospective study. Written consent was obtained from legal representatives along with assent from the child when appropriate. Inclusion criteria were community and/or household ambulatory subjects within GMFCS levels I, II and III. A group of age and gender matched typically developing youth (TDY) from previously published data were included in this analysis [5].

A SAM was administered to each subject using the StepWatch 3.1 software and calibrated per the subject's height. At the time of SAM data collection, recommendations for the programming protocol of the SAM in children were not published.

The initial programming settings for all SAM were as follows: Quick Stepping − No, Walking Speed − Normal, Range of Walking Speeds − Moderate, and Leg Motion − Normal.

Under the advance programming settings, the sampling rate for the SAM was set to 10sec intervals, which allowed the device to have a maximum storage memory time of eight days.

Children were instructed on proper wear of the device and asked to demonstrate its placement on the right ankle. Children were encouraged to wear the monitor throughout the day, excluding the periods spent sleeping or performing activities involving submersion in water. Raw 10sec interval data were exported in Excel file format from the StepWatch software for further analysis. A custom-written MATLAB (MATLAB 2008b, The Mathworks, Inc., Natick, Massachusetts, United States) code was run on the raw 10sec interval data to combine the number of strides taken every 60 s. The number of strides taken for each day between the 10sec and 60sec interval data was verified to be equal prior to any post-processing analyses.

Post-processing analyses were conducted using a custom-written MATLAB code [5]. Single strides within any one interval (10sec or 60sec interval) which had no strides in the previous or subsequent intervals, were classified as singletons, and were removed [21]. Right sided strides counted by the SAM were doubled to account for the left leg, and a total number of steps (strides x 2) were determined for each interval. Steps in sequential intervals were then grouped into ambulatory bouts. Intensity levels were defined using the average cadence of healthy age-matched children by taking 60% as the lower cut-off limit, defined as *Easy* and *Moderate+* defined as anything equal or greater than 60% of cadence [5]. Duration of ambulatory bouts less than 2 min were defined as *Short*, 2–5 min bouts were *Intermediate* and bouts longer than 5 min were defined as *Long* [5]. This resulted in six intensity-duration combination bins (*Easy/Short*, *Easy/Intermediate*, *Easy/Long*, *Moderate+/Short*, *Moderate+/Intermediate*, *Moderate+/Long*) reported as a percentage of total ambulatory time (TAT). The daily averages of these six variables, along with total steps, TAT and total number of walking bouts were analyzed for the 10sec and 60sec interval data. A paired *t*-test was conducted to compare the overall 10sec vs. 60sec interval data and for both the children with CP and TDY, with alpha set at 0.05. When appropriate the percentage difference was calculated: $\frac{60sec\ interval - 10sec\ interval}{60sec\ interval} x100$. The frequency of ambulatory bouts based upon bout duration was determined for both the CP and TDY groups using the 10sec interval data.

3. Results

There were thirty-six children with CP that agreed to participate in this study. Seven children were excluded either because they did not wear the SAM or the SAM was worn upside down and did not record any strides. One child was excluded due to the SAM being lost in the mail. Twenty-eight children with CP (boys n = 14) at an average age of 12 years 4 months (range 7–18y) completed the testing. The majority of children were classified as GMFCS Level II (n = 19) while four children were GMFCS level I and five children were GMFCS level III. A total of 219 days of data were recorded with a mean of 7.8 ± 2.3 days per child. Twenty-eight TDY (boys n = 14) at an average age of 12 years 6 months were included in this analysis (total number of days n = 460, average number of days n = 16.4 ± 4.3 days per control).

Overall assessment of the average daily number of steps showed a 3.6% difference (12389 ± 3322 steps 10sec int. vs. 12852 ± 3749 steps 60sec int., p = 0.098) in the TDY, and a 2.3% difference (4876 ± 3307 steps 10sec int. vs. 4992 ± 3341 steps 60sec int., p < 0.001) in the CP cohort (Table 1). The 60sec interval data identified less than half the average total number of ambulatory bouts per day in the TDY, with 76 ± 27 bouts in the 60sec int. compared to 269 ± 69 bouts in the 10sec int. (p < 0.001). Similar findings were observed in the children with CP (54 ± 16 bouts 60sec int. vs. 153 ± 81 bouts 10sec int., p < 0.001). The difference in the average daily TAT in TDY was 49% with 441 ± 166 min in the 60sec int. compared to 223 ± 58 min in the 10sec int. (p < 0.001). Within the CP cohort the difference in the average daily TAT was 51% with

Table 1
Comparison of average total steps (TS), total number of ambulatory bouts (TB) and total ambulatory time (TAT) for children with CP and typically developing youth (TDY) using 2 different interval settings with the StepWatch Activity Monitor; Mean ± SD; p < 0.05.

Interval Setting	TDY			CP		
	TS (steps)	TB (bouts)	TAT (mins.)	TS (steps)	TB (bouts)	TAT (mins.)
10sec int.	12389 ± 3322	269 ± 69	223 ± 58	4876 ± 3307	153 ± 81	108 ± 60
60sec int.	12852 ± 3749	76 ± 27	441 ± 166	4992 ± 3341	54 ± 16	220 ± 108
p-value	0.098	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Diff (%)10sec vs. 60sec	3.6	−253.9	49.4	2.3	−183.3	50.9