Variability in Measuring Physical Activity in Children with Cerebral Palsy

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ABSTRACT

MITCHELL, L. E., J. ZIVIANI, and R. N. BOYD. Variability in Measuring Physical Activity in Children with Cerebral Palsy. *Med. Sci. Sports Exerc.*, Vol. 47, No. 1, pp. 194–200, 2015. **Introduction**: This study aimed to establish the variability in the measurement of habitual physical activity using the ActiGraph® GT3X+ accelerometer in children with cerebral palsy (CP). **Method**: *Repeated measures:* Independently ambulant children with unilateral CP (n = 30; age, 11 yr 3 months (2 yr 4 months)) completed standardized tasks over two consecutive days, wearing an ActiGraph® GT3X+ accelerometer and HR monitor. Testing protocol comprised 5 min of seated rest (REST), walking at light, moderate, and vigorous pace, and rapid stepping on/off a step. Agreement was calculated between days using intraclass correlation coefficients (ICC) (two-factor mixed agreement model). Minimum detectable difference was calculated (minimum detectable difference = $[SD\sqrt{1 - ICC}] \times 1.96\sqrt{2}$). *Performance variability:* Participants (n = 102) wore an ActiGraph® GT3X+ accelerometer for 4 d in the community. Activity counts were converted into activity intensity using uniaxial-derived cut points to classify the time spent in moderate-to-vigorous physical activity (MVPA). Between-day intraclass reliability coefficients (R) and Spearman–Brown prophecy formula ($[ICC_{desired}/(1 - ICC_{desired})][(1 - ICC_{estimated})]/ICC_{estimated}]$) were calculated. **Results**: Agreement between repeated measures was strong for light physical activity and MVPA (ICC, 0.80). For MVPA, the minimum detectable difference was 1412 counts per minute. In the community, 345 d (87%) were recorded. Three days of monitoring produced acceptable variability estimates of MVPA (R = 0.63–0.73). Spearman–Brown prophecy analysis estimated that 3 d would achieve a reliability coefficient of 0.7 and 11 d would achieve 0.9. **Conclusions**: Measurement of habitual physical activity using the ActiGraph® GT3X+ accelerometer is reliable under controlled walking and stepping conditions as well as in a community environment in independently ambulant children and adolescents with CP. **Key Words:** MEASUREMENT, PSYCHOMETRICS, PHYSICAL ACTIVITY, HEMIPLEGIA

Cerebral palsy (CP) describes a group of disorders of development of movement and posture, causing activity limitations, attributed to nonprogressive disturbances that occur in the developing fetal or infant brain and accompanied by progressive musculoskeletal conditions (23). CP is the most common physical disability in childhood, with an incidence of approximately two per 1000 live births (19). There remains no cure for CP, meaning that an infant born with this condition will require a lifetime of investigations, interventions, and equipment. This highlights the need to optimize health, function, and fitness of individuals to promote lifelong health. Participation in regular physical activity is an important determinant of physical, mental, and social health in children and adolescents. Benefits can be seen in the development and maintenance of bone, muscle, and joint health, in body composition and weight control, and in increasing cardiorespiratory fitness and cognitive performance (32). There are some suggestions that additional benefits may also be afforded to persons with CP. These include the maintenance of physical function (22) and reduced incidence of chronic pain, fatigue, and osteoporosis (13). However, associated activity limitations and accompanying musculoskeletal conditions mean that children and adolescents with CP typically do not perform sufficient physical activity to meet international health recommendations (16,33). This may place these individuals at risk for secondary health problems associated with physical inactivity.

Physical activity is described as any body movement using skeletal muscles that results in energy expenditure (6). According to the International Classification of Functioning, Disability, and Health framework, it is necessary to distinguish between an individual's capacity (what they can perform at their best in a standardized controlled environment) and their performance (how they actually perform in the real world) (14,31). When considering physical activity measurement within the International Classification of Functioning, Disability, and Health framework, physical activity capacity and performance are to be considered separate constructs. Measurement tools should be valid and reliable

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at measuring these constructs. Previous systematic reviews of the clinimetric properties of measures of habitual physical activity (HPA) suggest that accelerometers are a valid means of measuring HPA in children and adolescents with CP. A method based on the RT3 accelerometer has demonstrated excellent criterion validity to HR (17). In previous research, the ActiGraph® accelerometer has been strongly correlated to direct observation and is more accurate than HR during structured activity and free play (5). Previous research methods have confirmed that the ActiGraph® has excellent classification accuracy against oxygen consumption during standardized tasks (8). In this study, children and adolescents wore an ActiGraph® accelerometer and a COSMED portable indirect calorimeter during four activities: quiet sitting, comfortable walking, brisk walking, and fast-paced walking. Receiver operating curve analysis indicated that of four sets of cut points evaluated, the cut points in the study of Evenson et al. (12) had the highest classification accuracy for sedentary (92%) and moderate-to-vigorous physical activity (MVPA) (91%) and second highest classification accuracy for light activity (67%) (8). Accelerometers have excellent clinical use because they can provide the user with information on activity intensity, frequency, duration, energy expenditure, and step counts over multiple days using a small and relatively inexpensive (USD 250 per unit) device that is acceptable to most wearers. Accelerometers therefore seem ideal for measuring HPA in children and adolescents with CP (7,18). A major limitation, however, is the lack of documented evidence of their reliability in individuals with CP.

Accelerometer reliability can be determined by research, which uses either a mechanical apparatus or a subject-mounted design. Using mechanical apparatus, such as hydraulic shaker tables, researchers have demonstrated strong reliability and small intrinsic measurement error among accelerometer devices (11). The ActiGraph® GT1M (ActiGraph Corp., Pensacola, FL) has previously demonstrated good reliability for measuring both activity counts and steps using a mechanical shaker platform (intrainstrument coefficient of variation, 2.9% for counts and 1.1% for steps; interinstrument coefficient of variation, 3.5% for counts and 1.2% for steps) (24). In contrast, subject-mounted designs require the devices to be worn by a participant in either a free-living activity assessment or a laboratory-based activity assessment. These designs therefore test the variability in measurement of physical activity in the population of interest rather than the device *per se*. Under controlled laboratory-based assessments, collecting repeated measures of a standardized series of tasks allows variations in the recording of physical activity to be measured, which can then be attributed to the participant. This seems particularly important for children with a movement disorder such as CP because alterations in gait biomechanics may influence the ability of an accelerometer device to consistently record physical activity. To date, this has not been established in children or adolescents with CP. The reliability of accelerometers has been well documented in children with typical development (TDC). Reliability improves with increased recording days (intraclass correlation coefficient (ICC) ranges from 0.45 for 1 d to 0.9 for 8 d) (10) and has been found to be acceptable with 4 d of monitoring (r = 0.75–0.78) (15). Reliability is influenced by season, with less activity performed in winter months (ICC, 0.54) (10), and age, with primary school-age TDC participating in more MVPA on weekends and exhibiting less day-to-day variability in activity across weekends and weekdays (28). Although the evidence from TDC could be used to estimate the reliability of accelerometers in independently ambulant children and adolescents with CP, differences in the energy cost of walking and alterations in gait patterns may mean that accelerometers record HPA differently in this population. It is essential, therefore, that the reliability of accelerometers be established during both laboratory-based and free-living activity assessments in children and adolescents with CP.

This study aimed to determine i) the variability in recording physical activity from repeated measurements under standardized laboratory-based conditions to establish the minimum detectable difference (MDD) and ii) the variability in MVPA and number of days of monitoring required to measure HPA performance in the community using the ActiGraph® GT3X+ triaxial accelerometer in independently ambulant children and adolescents with unilateral CP.

METHODS

Sample

This study describes 102 children from the Mitii™ Australia study (3). The study is a waitlist controlled randomized trial investigating the effect of the web-based training program, Mitii™ (move it to improve it). Children were age 8–17 yr with unilateral CP (impacting one side of their body) classified at a Gross Motor Functional Classification System (GMFCS) I (walks independently without limitations) or II (walks independently but with some limitations to gross motor abilities and balance and requires external upper limb support on stairs) (20). Children were excluded if they had undergone upper limb botulinum toxin type A injections or surgery in the previous 2 or 6 months, respectively, or had unstable epilepsy or medical conditions that would prohibit them to complete the Mitii™ training. For the collection of repeated measures under laboratory-based assessment conditions, a sample of 30 children was selected from the full cohort using consecutive series sampling. Sample size was calculated *a priori* on the basis of a test–retest scenario with two repeated observations, α at 0.05, β at 0.2, to detect an ICC of $\rho_1 > 0.6$ (against a null hypothesis of $\rho_0 = 0.2$), and it was determined that 27 participants were required (30). Data were collected from 30 participants to account for attrition. A written and informed consent was obtained from parents or guardians and all participants greater than 12 yr of age before entering the

trial. Ethical approval was obtained by the medical ethics committee of the University of Queensland (2011000608) and the Royal Children's Hospital Brisbane (HREC/11/QRCH/35). The trial registration number for this study was ACTRN12611001174976.

Instrumentation

For recording the agreement between repeated measurements under controlled laboratory-based assessment conditions, participants were fitted with an accelerometer and HR monitor. For measurement of performance variability in the community, participants were fitted with an accelerometer.

Accelerometer. Accelerations were recorded using the ActiGraph® GT3X+ triaxial accelerometer (ActiGraph® Corp., Pensacola, FL). This device uses a three-axis accelerometer and ActiGraph® proprietary digital filtering algorithms to measure the amount and frequency of human movement. The ActiGraph® GT3X+ records accelerations ranging in magnitude from ±6*g*. The accelerometer output is sampled by an analog-to-digital converter according to user settings, set to 100 Hz. Raw ActiGraph® data were postprocessed in ActiLife™ software to convert activity counts in user-defined time intervals, known as epochs, set to 5 s. Activity counts provide a real-time index of the intensity of physical activity performed. Greater intensity is reflected by higher activity counts. Before each trial, the ActiGraph® was initialized according to manufacturer specifications and placed on an elastic belt worn by the participant around the waist. The ActiGraph® was positioned on the midaxilla line at the level of the iliac crest on the side of the body not affected by neurological impairment. The same ActiGraph® unit was worn on two consecutive days; however, units varied between participants.

HR monitor. HR was recorded in 5-s epochs using a Polar RS400® monitor (Polar Electro Oy, Kempele, Finland). The monitor was positioned according to the manufacturer's instructions, with the chest strap moistened and placed around the chest in line with the middle of the sternum.

Agreement between Repeated Measurements

Procedure. The agreement between repeated measurements of physical activity was collected by completing a standardized series of tasks on two consecutive days (approximately 45 min·d^{-1}) while wearing an ActiGraph® accelerometer and concurrently measuring HR, fitted by an experienced physiotherapist using anatomical landmarks. Both devices were synchronized to an external timepiece, and video recordings of the standardized tasks were taken to allow time coding. This occurred during the 2-d assessment and Mitii™ training portion of the study (3). All testing was performed in a climate-controlled facility. Before data collection, all participants were familiarized with the protocol. The testing protocol is composed of an initial 5-min seated rest period (REST), followed by standardized tasks (Table 1). Walking tasks were performed on a clearly defined linear 10-m track (return lap, 20 m). The speed at which the participant walked in each trial was verbally cued. For light-paced walking (LW), participants were asked to walk for 5 min at a "slow and comfortable walking speed—like you do with friends at school"; for moderate-paced walking (MW), participants walked for 5 min at a pace "like you are hurrying to get back to class after the bell has rung"; and for vigorous-paced walking (VW), participants were asked to walk for 6 min "as fast as you possibly can without falling over or running." Where required, during the walking trials, study personnel walked with the participant to monitor comfort and assist them to maintain a constant speed. Walking speed was calculated in real time by researchers noting the time taken to complete each 20-m lap of the walking track. When variations in walking speed occurred, this was noted and study personnel asked the participant to increase or decrease walking speed accordingly. After the walking trials, participants completed a stepping task for 3 min using a 20-cm aerobic step block, being instructed "to step on and off the step block as quickly as possible" (STEP). Between each task and at the conclusion of the protocol, participants rested for 5 min in a seated position, watching a movie on a tablet device. The current procedure was based on that described in the study of Clanchy et al. (8). The walking speed for these tasks was coded into activity intensity on the basis of the available literature using predefined MET levels (8,21) and confirmed in real time using direct observation and during analysis using HR monitoring. MET intensity of physical activities was classified as follows: sitting while watching TV, 1.2 METs; walking with light effort, 2.9 METs; walking with moderate effort, 3.6 METs; walking with hard effort, 4.6 METs; and climbing stairs with moderate effort, 7.0 METs (21).

Data reduction. After completion of the 2 d of testing, data from the respective instruments were downloaded to a personal computer. ActiGraph® activity counts were downloaded in ActiLife™ software version 6 (ActiGraph® Corp., Pensacola, FL). HR data were downloaded using Polar ProTrainer5™ software (Polar Electro Oy, Kempele, Finland). Activity counts and HR data were synchronized using direct observation from the video recordings and data collated in Microsoft® Excel™ 2010 (Microsoft Corp.). Synchronized activity counts and HR data from each participant were manipulated in MATLAB R2011a (MathWorks, Natick, MA) to extract 2 min (48 epochs) of data from the end of each standardized task from each day, from between 30 s and 2 min 30 s from the completion of each task. This

TABLE 1. Standardized movement protocol and corresponding activity level.

Activity Intensity Level	MET Level	Task	Time (min)	Lap Speed (20-m Lap per 30 s)
Sedentary	<1.5	REST	5	N/A
Light	>1.5–3	LW	5	0.5
Moderate	3–6	MW	5	<2
Vigorous	>6	VW	6	>2.5
		STEP	3	N/A

N/A, not applicable.

time interval was chosen to allow for slight alterations in task time, and HR is known to plateau at this time as steady state is reached (2). Axis 1 (*y*-axis) activity counts were converted to activity intensity using cut points in the study of Evenson et al. (12) (sedentary, 0–100 counts per minute; light, 101–2295 counts per minute; moderate, 2296–4011 counts per minute; vigorous, ≥ 4012 counts per minute) to provide an activity intensity cut point level for each 5-s epoch.

Statistical analysis. Agreement between repeated measurements was calculated using ICC between days for each task (two-factor mixed effects agreement model) from days 1 and 2, within each activity intensity bracket (sedentary and light, LW; moderate, MW; vigorous, VW; and STEPS; and MVPA combining MW, VW, and STEPS). SEM was calculated as follows: SEM = SD$\sqrt{1 - \text{ICC}}$. MDD was calculated as follows: MDD = SEM × 1.96$\sqrt{2}$ (1,9). The correlation between activity counts obtained by the ActiGraph®, increase in HR for each task relative to resting HR, and walking speed from video recordings were calculated using Pearson correlation coefficients (ρ). Classification accuracy was calculated by the percentage of agreement between ActiGraph® activity intensity and predetermined task intensity.

Performance Variability

Procedure. Children received a calibrated ActiGraph® GT3X+ triaxial accelerometer (ActiGraph® Corp., Pensacola, FL) to record physical activity. Children were instructed to wear the device for all waking hours for 4 d (comprising two weekend and two weekdays where possible). During this time, parents registered the wear time of the device and recording activity patterns on an activity diary provided.

Data reduction. After 4 d, the device and activity diary were returned for data extraction and analysis. Data from the ActiGraph® were downloaded to a personal computer. ActiGraph® activity counts were downloaded in ActiLife™ software version 6 (ActiGraph® Corp., Pensacola, FL). All representative and complete data (where >8 h of data was recorded each day) were included in the analysis. Device wear time was determined by visually inspecting the activity diary and comparing with ActiLife™ output. Where there were obvious differences in the accelerations recorded by the device and the diary, the data in the diary were deemed to be incorrect and amended to reflect the new times. Where actual wear time was unable to be determined from the activity diary and activity count values of zero occurred for >20 min, this was set as nonwear time and excluded from the analysis. Days and times of device wear were noted in a log file and processed in ActiLife™, with nonwear time as determined by software algorithms excluded from the analysis. Axis 1 (vertical axis) activity counts were converted to activity intensity using the cut points in the study of Evenson et al. (12) (vertical counts per minute: sedentary, 0–100; light, 101–2295; moderate, 2296–4011; vigorous, ≥4012), providing a total of daily time spent in each level of activity intensity.

Statistical analysis. Variability was calculated using between-day intraclass reliability coefficients (*R*) and 95% confidence intervals using repeated-measures ANOVA. The required days of monitoring needed to achieve reliabilities of 0.70, 0.80, and 0.90, respectively, were calculated using the Spearman–Brown prophecy formula (where days of monitoring needed for desired reliability = $[\text{ICC}_{\text{desired}}/(1 - \text{ICC}_{\text{desired}})][(1 - \text{ICC}_{\text{estimated}})/\text{ICC}_{\text{estimated}}]$) (26). Subanalyses were conducted to determine the difference in reliability estimates between children (age 8–12 yr) and adolescents (age 13–18 yr). Data are mean (SD) and activity counts are in counts per 5-s epoch, unless stated otherwise. Data were analyzed using IBM SPSS version 22 (IBM Corp., Armonk, NY).

RESULTS

Sample characteristics. Participants were children and adolescents with congenital hemiplegia (52 males (51%); mean (SD) age, 11 yr 3 months (2 yr 4 months); range, 8–17 yr) classified at GMFCS levels I (n = 44) and II (n = 58). Of the 102 participants enrolled in the study, 99 completed a baseline assessment. Of those, 93 returned ActiGraph™ recordings (94%), and 357 of potentially 396 d was collected (90%). In 12 instances, wear time was less than 8 h and excluded from the analysis, providing 81 children and 345 d (87%) for analysis of performance variability in the community. On average, children wore the device for 11 h 44 min (1 h 56 min) daily. The sample of participants for the repeated measurement study was representative of the larger sample. This sample was age 8–17 yr (mean (SD), 11 yr 11 months (2 yr 7 months)) classified at GMFCS levels I (n = 16) or II (n = 14), contained 16 males (53%), and 13 with right hemiplegia (43%). Activity counts and HR data were collected from all 30 participants, with no missing data.

Agreement between repeated measurements. Standardized task speed, axis 1 activity counts, and HR increased significantly with increasing task intensity compared with REST levels (Table 2). The average speed on days 1 and 2 for SW was 1.43 and 1.41 km·h^{-1}, respectively, with an ICC of 0.98; for MW, the average speed was 2.53 and 2.51 km·h^{-1}, with an ICC of 0.86; for VW, the average speed was 3.95 and 3.89 km·h^{-1}, with an ICC of 0.90; and for STEPS, the average speed was 64 and 67 repetitions, with an ICC of 0.94. With the exception of HR during VW and STEP tasks, these were strongly and significantly correlated between days, indicating that the standardized tasks were consistent across days (Table 2). Agreement between ActiGraph® calculated and standardized task activity intensity for each 5-s epoch was 80%–98% during REST, LW, VW, and STEP tasks but only 17% during MW (Table 2). The overall agreement for MVPA was 64%. Mean counts per minute and walking speed correspond to the expected level of activity intensity of the standardized tasks (Table 2). Agreement between repeated measures was strong for axis 1 activity counts under LW (ICC, 0.80) and MVPA (ICC, 0.80).

TABLE 2. Correlations between days for ActiGraph® axis 1 activity counts, speed, and HR by standardized tasks.

Task	Axis 1 Counts		Speed	HR (bpm)	Agreement (%)	Correlation, Days 1 and 2 (ρ)		
	Counts per Epoch	Counts per Minute				Axis 1 Counts	Walking Speed	HR
REST	0.5 (5.3)	6.0	N/A	87.8 (12.7)	98	N/A	N/A	N/A
LW	52.9 (61.5)*	634.8	1.4 (0.5)	105.5 (14.1)*	80	0.82	0.98	0.78
MW	125.2 (82.4)*	1502.4	2.5 (0.4)	110.4 (15.1)*	17	0.82	0.86	0.78
VW	355.9 (107.1)*	4270.8	3.9 (0.5)	139.8 (18.4)*	94	0.78	0.90	0.51
STEP	286 (110.6)*	3432.0	64.8 (9.5)	139.6 (16.2)*	81	0.84	0.94	0.45
MVPA	254.57 (139.5)	3054.0	N/A	129.9 (20.9)*	64	0.83	0.90	0.81

Data are mean (SD).
Agreement, percent agreement between ActiGraph calculated and standardized task intensity; MVPA, combination of MW, VW, and STEP tasks; speed, speed of walking in kilometers per hour or stepping in repetitions.
*$P < 0.05$ compared with REST level.
N/A, not applicable.

When MVPA was broken down into standardized tasks, the agreement between repeated measures was strong under MW (ICC, 0.80) but reduced for VW (ICC, 0.70) and STEP tasks (ICC, 0.66) (Table 3). Reliability for REST was unable to be calculated because activity counts were primarily 0 counts per epoch. MDD was 179 counts per minute for REST, 926 counts per minute for LW, and 1412 counts per minute for MVPA (Table 3).

Performance variability. Between-day intraclass reliability coefficients indicated that between 3 and 4 d of monitoring produced acceptable estimates of daily MVPA (R = 0.69–0.73) (Table 4). Two days of monitoring produced more variability (R = 0.63 (0.44–0.76)). Spearman–Brown analysis estimated that approximately 3 d of monitoring would be necessary to achieve a reliability coefficient of 0.70, and to achieve a reliability coefficient of 0.90, between 10 and 11 d of monitoring would be necessary. When comparing the variability estimates between children and adolescents, there were considerable differences between groups. Adolescents 13 yr and older were much less variable in their HPA performance between days, with 2 d providing acceptable estimates of daily MVPA (R = 0.72 (0.48–0.87)). Reliability estimates increased with increasing numbers of days monitored (Table 4). Children produced much more variable estimates of daily MVPA, with 4 d of monitoring required to produce acceptable estimates of daily MVPA (R = 0.73 (0.58–0.83)). Spearman–Brown analysis estimated that between 3 and 4 d of monitoring would be necessary to achieve a reliability coefficient of 0.70 in children with unilateral CP and between 1 and 2 d for adolescents.

DISCUSSION

This study aimed to establish variability of measurement of HPA performance in the community, determine the number of days of monitoring required using the ActiGraph® GT3X+ triaxial accelerometer, and establish underlying variability in recording physical activity in independently ambulant children and adolescents with unilateral CP through the collection of repeated measurements in a controlled environment. To our knowledge, this is the first time that reliability accelerometers have been established in children or adolescents with CP. Results indicate that 3 d of monitoring is necessary to produce reliable estimates of MVPA. Furthermore, using the current research methods, the ActiGraph® has moderate-to-strong agreement between repeated measures during standardized walking and stepping tasks in a controlled environment. This information is critical because to accurately measure population-based interventions to increase physical activity for young persons with CP, valid and reliable measurement tools are required.

Agreement between repeated measures. There is limited published data supporting the test–retest reliability of accelerometers in TDC or adults. One study has previously explored test–retest reliability in adults under free-living conditions, with good-to-excellent correlation (ICC, 0.70–0.90) (25). The current study used a standardized protocol in a controlled environment using repeated measures, meaning the results assess HPA capacity rather than performance in a free-living environment. However, this was chosen to overcome methodological issues, which have been present in previous research of HPA measurement in children with CP. Previous systematic reviews of measures of physical activity in children with CP have appraised study quality with the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) criteria (27), which offer a rigorous and standardized tool to guide study appraisal. However, when the COSMIN criteria have been applied, previous studies investigating the validity of measures of physical activity ranged from fair to poor in quality (18). If the COSMIN criteria were applied to the current study, it would score excellent in quality; therefore, the results of this study can be interpreted with confidence. The agreement between repeated measures demonstrated in the current study was moderate to strong, with ICC values of

TABLE 3. Agreement between repeated measures for ActiGraph® axis 1 counts and the MDD in counts per minute of physical activity.

Task	Axis 1 Counts		SEM	MDD
	ICC	95% CI	(counts·5-s epoch^{-1})	(counts·min^{-1})
LW	0.80	0.76–0.83	27.8	926
MW	0.80	0.77–0.83	36.5	1214
VW	0.70	0.66–0.74	58.5	1945
STEP	0.66	0.60–0.72	64.3	2139
MVPA	0.80	0.77–0.83	42.5	1412

MVPA refers to MW, VW, and STEP combined.
CI, confidence intervals; N/A, not applicable.

TABLE 4. Performance variability in MVPA based on days of monitoring in children and adolescents with unilateral CP.

		Variability (Reliability Coefficient (95% Confidence Intervals))			Days to Achieve Reliability of		
	Number	2 d	3 d	4 d	0.7	0.8	0.9
Total	81	0.63 (0.44–0.76)	0.69 (0.56–0.79)	0.73 (0.61–0.82)	2.7	4.7	10.6
Children	58	0.57 (0.28–0.74)	0.63 (0.43–0.77)	0.73 (0.58–0.83)	3.5	6.0	13.6
Adolescents	23	0.72 (0.48–0.87)	0.74 (0.44–0.88)	0.78 (0.58–0.88)	1.8	3.1	7.0

0.66 for stepping tasks and up to 0.80 for standardized walking tasks. The higher ICC values for LW and MW may be due to external pacing by study personnel. Although children were verbally encouraged during the stepping task, there was no external pacing, meaning the actual speed and effort of the task may have varied between days depending on the motivation of the participant. This could also explain the lower ICC values for the VW standardized task compared to the slower walking speeds. Participants were verbally encouraged to walk more than 2.5 laps per 30 s for this task; however, they were not asked to slow down if they were exceeding this pace. However, walking and stepping speed between days was similar with ICC values above 0.86. Although some of the variability demonstrated may be due to differences in walking speeds, it may be that gait biomechanics in children with unilateral CP were variable during high-intensity tasks between days, contributing to a difference in recorded activity counts. Ankle foot orthotic use was consistent between days, as this is known to change walking patterns (4); however, although consistent and sturdy footwear was encouraged, in some instances, children wore different footwear between days. In addition, in many cases, the time of the standardized assessment varied between days. It may be that children were more or less fatigued, depending on the day's activities and that muscle tone associated with increased effort and walking biomechanics were different because of this during the vigorous-intensity tasks. This is important to consider when measuring physical activity performance in children with CP. In a community setting, these factors are likely to change between recording days and may influence the accuracy of the device. However, moderate-to-strong ICC values were recorded, and as such, the ActiGraph® and the analytical methods used within this study can be used with confidence to record HPA in the community.

Performance variability. The results from this study suggest that overall variability in MVPA is similar between children or adolescents with CP and their typically developing peers. Research on TDC has shown that 4 d of monitoring has produced reliability estimates between 0.75 and 0.78 (15). Our results are comparable, as the overall estimates of variability for 4 d of monitoring was 0.73 (0.61–0.82). However, when examining the differences between children and adolescents, the results from this study are conflicting with TDC. Previous research in TDC has indicated that with 3–4 d of monitoring, reliability estimates for adolescents ranged from 0.64–0.66 and increased to 0.77–0.79 for children (29). The results from this study suggest that children with unilateral CP demonstrate a wider variation in reliability estimates compared with adolescents (children, 0.57–0.73; adolescents, 0.72–0.78). These differences could be due to small subject numbers and an inequality between the number of children and adolescents in the current study. Given the larger number of children being monitored, a wider range of natural daily variation in children's MVPA would have resulted. Alternatively, this could reflect more consistent physical activity behaviors in adolescents with CP. Previous research has indicated that physical activity performance typically declines with age (29), so it may be that more a consistent sedentary behavior was demonstrated, resulting in less variability. Further research is required to confirm these results in adolescents with CP.

Limitations. There are some potential limitations to this study, which must be acknowledged. Accelerometers were worn for a maximum of 4 d, so it is unclear what the reliability would be for longer periods. However, acceptable reliability was found with 3 d of monitoring and did not improve greatly with 4 d. Therefore, it could be assumed that additional days would not improve the reliability significantly. In the current study, the agreement between repeated measurements has only been tested during walking and stepping tasks under controlled conditions. The standardized tasks used in the current study were chosen on the basis of the protocol by Clanchy et al. (6) where the validity of the ActiGraph® has been established against oxygen consumption. The validity during other tasks, such as running or jumping, or during a free-living situation has not been established in this population and requires further research. It is also important to note that the results only apply to independently ambulant children and adolescents with unilateral CP. The validity and reliability of accelerometers in individuals with different motor distributions or classified at different GMFCS levels, such as those who walk with walking aids or require physical assistance, have not been established. Walking patterns and energy expenditure levels are likely to be quite different between independently ambulant children and those with more severe motor impairments; therefore, it is important to determine the validity and reliability of HPA measurement instruments specific to each group.

CONCLUSIONS

Accelerometers have been previously shown to be valid and clinically useful tools for measuring physical activity in children and adolescents with CP (7,8,18). This study has demonstrated that at least 3 d of monitoring using the ActiGraph® GT3X+ triaxial accelerometer seems necessary to produce reliable estimates of MVPA performance in the

community. Accelerometers would seem an ideal tool to measure physical activity in the community and could be used to accurately record changes over time or after an intervention in independently ambulant children and adolescents with unilateral CP.

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The results of the present study do not constitute endorsement by the American College of Sports and Medicine.

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