Original Research Article

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Power, cardiorespiratory fitness and physical activity in young people with cerebral palsy

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Abstract

Objectives: Physical activity (PA) levels in young people with cerebral palsy (YPwCP) remain consistently low. Previous research suggests that fitness parameters such as muscular strength and cardiovascular capacity are interrelated with mobility and PA levels in YPwCP. This study aimed to (1) describe fitness parameters and PA levels in YPwCP, (2) explore associations between fitness parameters and PA, and (3) evaluate the reliability of accelerometer-based PA measurement.

Methods: A cross-sectional study was conducted with an embedded test–retest reliability assessment of accelerometer-measured PA over a one-month interval. Participants included 36 YPwCP (19 males, 17 females; mean age 15.5 ± 0.7 years), classified within GMFCS levels I–III. Cardiorespiratory endurance (VO_2max) was assessed using an incremental cycle ergometer test, and leg power was measured using the Five-Times Sit-to-Stand (5xSTS). PA was measured via self-report using the Physical Activity Questionnaire for Adolescents (PAQ-A) and via device-measured data using a wrist-worn accelerometer over seven consecutive days.

Results: We found low levels of PA. The 5xSTS completion time showed moderate to strong correlations with self-reported PA (ρ=−0.384, p≤0.01) and device-measured vigorous PA (ρ=−0.566, p≤0.01). VO_2max was positively but not significantly associated with total PA (ρ=0.173) and moderate-to-vigorous PA (ρ=0.115). Accelerometry demonstrated good reliability (ICC=0.796).

Conclusions: These findings suggest that accelerometer has good reliability in YPwCP but highlight low levels of PA measured by self-report and accelerometer. Higher lower-limb power, assessed by faster 5xSTS test, was associated with greater PA.

Keywords: cerebral palsy; physical activity; accelerometry

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Introduction

Young people with cerebral palsy (YPwCP) have different levels of disability and mobility limitations which affect participation in social and occupational activities [1]. Higher levels of physical activity (PA) are associated with a greater upper body and lower body strength and higher cardiorespiratory endurance, bone mineral density, and lower cardiovascular disease risk among young people in the general population. In YPwCP, physical disability is associated with lower PA and low activity levels are still reported alongside decreasing activity with increasing age [2–4]. In addition, the prevalence of cardiometabolic disease is higher and associated with diminished mobility and physical inactivity [5]. As such, monitoring and improving PA and fitness is especially important in YPwCP [4]. PA and leisure time training have been shown to improve fitness [2, 6], but research studies of high quality and rigor are needed.

Part of the challenge has been monitoring and measuring fitness and PA in YPwCP. Muscle power and cardiorespiratory endurance measures are useful as both diagnostic and prognostic health indicators, for both clinical use and clinical trials, however, to date there are limited data on the validity and reliability of PA measures for this group, limiting their use [7, 8]. Furthermore, there is limited description of fitness parameters and their interrelationship with mobility and PA in YPwCP. Methods used to quantify PA of individuals with disabilities include self-report, parental report, observation and accelerometery [9]. Accelerometer-based activity monitoring provides a device-measured, less burdensome alternative to self-report methods for assessing PA in YPwCP [10]. These devices provide real-time data on PA frequency, intensity, and duration with minimal participant burden, making them particularly useful in clinical and research settings [10].

Self-report measures in youth with CP are subject to recall bias both within the participant and proxy report and recall difficulty and thus may not be sufficiently valid or reliable, while accelerometer devices showed excellent reliability (ICC=0.94–0.975) [10]. Device-measured PA has been suggested to be a valid method for estimating the volume and intensity of both active and sedentary behaviour patterns in young people with and without disabilities [8]. However, there are some challenges in their use in people with disabilities whereby there is a dissociation between heart rate and device-measured activity affecting the estimation models. Individuals with movement disorders often exhibit atypical gait patterns and increased energy expenditure, leading to discrepancies between device-measured outputs and actual physiological effort [10]. Standard accelerometer algorithms, which are typically developed using data from individuals without physical impairments, may therefore underestimate or misclassify PA intensity in those with disabilities. This highlights the need for the development of tailored algorithms to improve measurement accuracy [11, 12].

A systematic review concluded that a combination of self-report and device-measured methods of monitoring PA is the best, as it provides a two dimensional view of PA levels in CP [13]. However, a different systematic review conducted in 2011, concluded that although device-measured methods provided valid data of PA patterns in CP, there was no evidence confirming their reliability over time [10]. Concurrent and longitudinal measures of reliability do not exist as do levels in people with varying disability; so in summary there is limited evidence and a call for more sound research on device-measured data on PA levels in YPwCP [12, 14].

Here we build on previous work, to explore power and cardiorespiratory endurance and device-measured PA with accelerometers, alongside mobility and self-reported participation in leisure activities of YPwCP [15–17]. The primary aim is to describe levels and estimate associations between PA and leg power and cardiorespiratory endurance, limitations in activities of daily living (ADL), and participation in PA. This study also estimates the test-retest reliability of PA measured via wrist-worn accelerometers and level of agreement with PA measured via self-report.

The summary of this article is presented in Figure 1.

Materials and methods

This is a cross-sectional analysis of data from a trial of YPwCP (ISRCTN84098935). The study received research governance and National Research Ethics System approvals (IRAS ID:251813; REC:18/SW/0200). The study is reported according to STROBE checklist for cross-sectional studies [18]. Data were obtained at the baseline assessment of a non-blinded, three-armed, randomised, crossover, exposure-response research study: "Standing up for Cerebral Palsy: Evaluation of a Standing Physical Activity Intervention" which explored the effects of interrupting prolonged sitting with brief MVPA exposures [19].

Recruitment

A sample of 36 young people aged 9–18 years, clinically diagnosed with CP, with Gross Motor Function Classification System (GMFCS) levels of I, II and III, were recruited between October 2018 and December 2019. Participants were recruited through Oxford University Hospitals NHS Foundation Trust, Oxford Health NHS Foundation Trust and John Chilton School at Northolt.

Inclusion and exclusion criteria

Young people between 9 and 18 years old, with a clinical diagnosis of CP and GMFCS level I, II or III were included in the study. Young people with type 1 and type 2 diabetes, uncontrolled seizures (epilepsy), surgery within the last 6 months, treatment of botulinum toxin within the last 6 weeks, or serial casting during the last 3 months (or planned), physical training contraindications, and those potential participants who were too cognitively impaired to participate in the trial, as determined by a medical consultant, were excluded. Young people who were known to have spinal problems or spinal instability that would prevent them from participating safely were excluded as well. Those on any form of steroids, anti-anxiety/depression drugs, birth

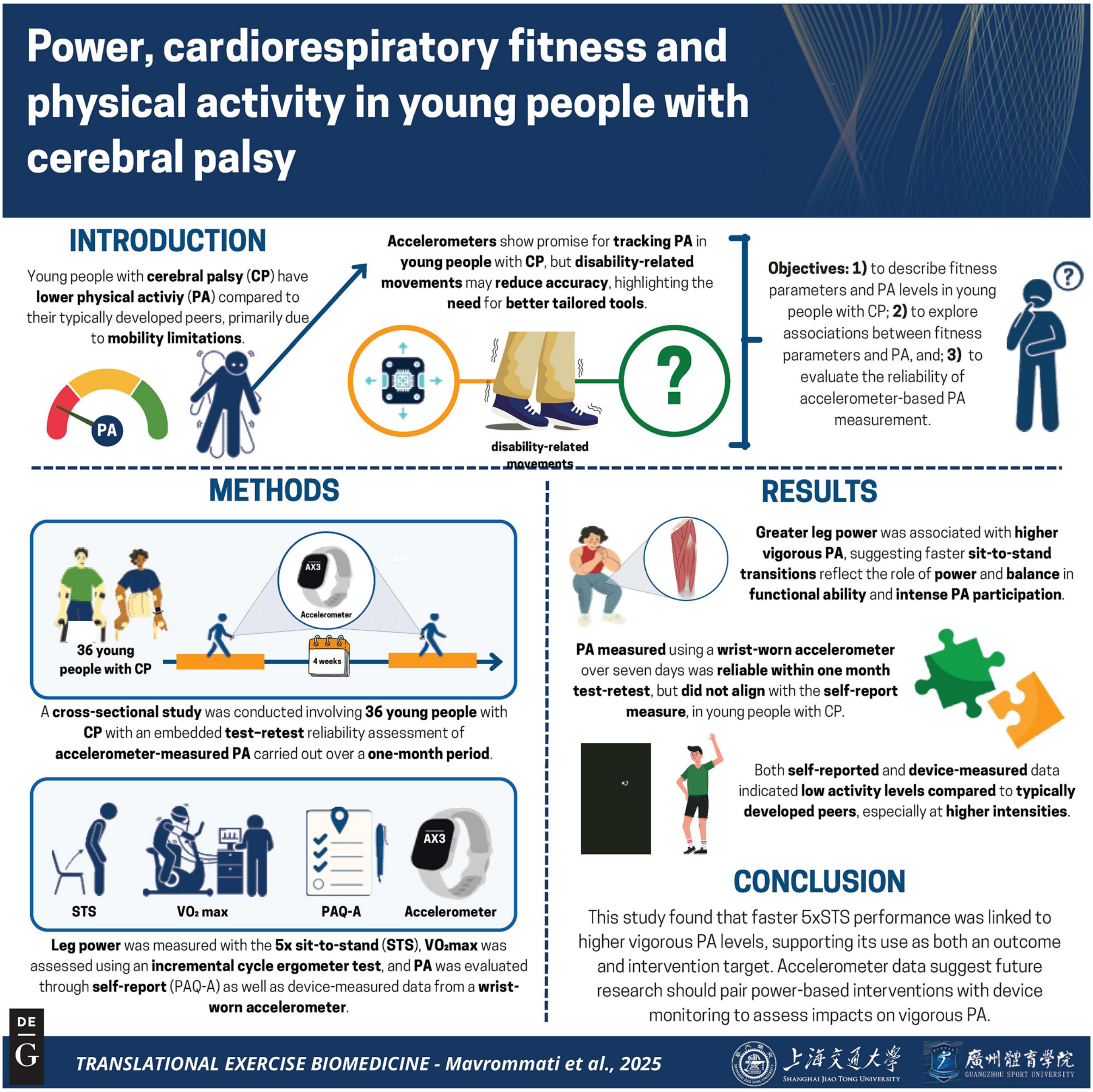

Figure 1: Graphical representation of this study. Key points: (1) This study bridges the gap between fitness assessment and health outcomes in YPwCP by linking leg power and cardiorespiratory endurance to PA levels, everyday function and PA participation. (2) We explored the relationships between PA, leg power, and cardiorespiratory endurance, while assessing the reliability of device-monitored PA. (3) We found that greater leg power is linked to higher levels of VPA in YPwCP, highlighting its potential health benefits if targeted in future interventions. Device-measured data were reliable over one month and may better capture PA; however, support strategies should be implemented to ensure adherence for this population. Figure created with BioRender.

control, beta-blockers, statin, Adrenaline, HIV or Hepatitis C medications, were also excluded.

Assessment

The study took place at Oxford Brookes University, Oxford, UK and the John Chilton School, Ealing, UK [19]. Procedures and equipment were standardised across sites and conducted by the same researchers. At baseline, information on participant demographics (age, height, weight), health history and condition severity were obtained. To establish the GMFCS level for each participant, the most recent GMFCS level reported by the direct care team was used. GMFCS levels I to III describe varying degrees of independent mobility in individuals with CP. While those at level I walk without limitations, individuals at level II also walk independently but face challenges with uneven terrain and long distances, whereas those at level III require assistive devices for walking and often use wheeled mobility for extended travel. For participants lacking direct care records of their GMFCS level, the GMFM-66 assessment was administered to determine their level.

GMFM-66

The Gross Motor Function Measure-66 (GMFM-66) is a standardised, performance-based tool used to assess changes in gross motor function in YPwCP, offering a unidimensional, interval-level score based on Rasch analysis [20]. While it correlates with the GMFCS, these tools serve different purposes. GMFM-66 quantifies specific motor task performance, whereas GMFCS reflects overall functional ability in daily life [21]. Although GMFM-66 scores typically decline with increasing GMFCS level, they are not interchangeable. They provide insights and are best used together in clinical and research settings [22].

Power

Muscle power data were collected from the 5 times Sit-to-Stand test (5xSTS). Each participant used a step with adjustable height and had the chance to try and stand up once and when they were ready; then proceeded with the five repetitions, as quickly as possible, with both elbows in flexion and crossed over the chest, with each hand touching the opposite side shoulder.

The 5xSTS has been used in YPwCP, particularly those with spastic diplegia, and has demonstrated strong reliability and validity [23]. Studies report excellent test-retest reliability (ICC=0.91–0.99) and significant correlations with established measures such as the Timed Up and Go test, Berg Balance Scale, and GMFM, supporting its convergent validity [23, 24]

Symptom limited incremental exercise test

VO_2max, or maximal oxygen uptake, is defined as the highest rate at which oxygen can be taken up and utilised during intense exercise, serving as a key indicator of aerobic capacity [25]. Endurance or aerobic capacity (cardiorespiratory fitness) has been reported as an important marker of health. Among young people endurance is associated with lower risk for cardiovascular problems and lower tendency to become obese [26]. VO_2max testing has been used in YPwCP as a means of assessing their aerobic capacity. Workload was progressed by 15–20 W from unloaded cycling each minute. This was based on the height of each participant [27]. When the participant reached volitional exhaustion or was unable to maintain a cadence of 60 revolutions per minute (RPM), despite verbal encouragement, the test was terminated. Pulmonary gas exchange including, oxygen uptake ($\dot{V}O_2$), carbon dioxide produced ($\dot{V}CO_2$) and volume of expired air per minute ($\dot{V}E$) were measured breath by breath using an online gas analyser (Cortex Metalyser 3B, Cortex, Leipzig, Germany). All participants wore a fitted facemask covering the nose and mouth connected to a low resistance volume transducer (Triple V, Hoechberg, Germany). Oxygen uptake ($\dot{V}O_2$) was recorded as the highest 30s of each stage, whereas $\dot{V}O_2$ was recorded as the highest 60s average before the termination of the test.

Child Health Utility- 9 Dimensions questionnaire

Child Health Utility– 9 Dimensions (CHU-9D) questionnaire is a paediatric, preference-based, generic measure that was developed exclusively with children [28]. The CHU-9D questionnaire consists of nine items and it is used to measure quality of life. It features nine dimensions: ***1*** Feeling worried, ***2*** feeling sad, ***3*** presence of pain, ***4*** feeling tired, ***5*** feeling annoyed, ***6*** facing problems with school work/homework (such as reading, writing, doing lessons), ***7*** having sleep problems, ***8*** problems with daily routine (things like eating, having a bath/shower, getting dressed) and ***9*** being able to join in activities (things like playing out with friends, doing sports, joining in things) [28]. Each dimension has five severity levels, level 1 being the least severe. Each of the nine dimensions can be analysed and reported both as a separate item and as part of the total questionnaire score. Although CHU-9D is used in order to collect information regarding the specific day of the questionnaire completion ("today"), for this analysis, we used these data as a reflection of an average day in the participant's life [29]. For the purpose of this analysis, we used the individual scores from two items to assess participation in activities of daily routine and with peers; ***8*** Daily routine (eating, having a bath/shower, getting dressed) and ***9***: Able to join in activities (playing out with your friends, doing sports, joining in things).

Physical Activity Questionnaire for Adolescents (PAQ-A)

The PAQ-A is a self-report outcome measure of duration, frequency, and intensity of PA [30]. It is a modified version of the PAQ-C which is for children and it was developed in order to assess levels of PA in high school students between 14 and 19 years old [30]. The PAQ-A has been used in YPwCP and shown acceptable validity and reliability, with studies reporting good test–retest reliability (ICC=0.90) and fair correlations with device-measured PA [31]. PAQ-A total score provides a composite measure of an adolescent's habitual PA over the past seven days, encompassing various daily contexts such as physical education classes, lunchtime, after school, evenings, and weekends [32]. The PAQ-A also captures the type of activity such as specific sports, leisure activities like dancing, playing with friends and walking for transport. It provides a total PA score recorded from eight items (Questions 1 to 9), each one scored on a five-point scale [30]. These questions assess PA across various daily contexts over the previous seven days, such as during physical education classes, at lunchtime, after school, evenings, and weekends. Question 10, which asks about activity levels during the week used to qualify or interpret the overall score but is not included in the total score calculation. For this study we use both the PAQ-total score and the score from Question 10. Specifically, Question 10 assesses the participant's general activity level during the past week. This item demonstrated a moderate correlation with device-measured PA (r=0.38 for Moderate to Vigorous PA (MVPA) and r=0.33 for total PA) indicating its utility in capturing perceived activity levels. For the purpose of assessing concurrent validity, we used the scores from Question 10.

Device-measured PA via wrist-worn accelerometers

Device-measured PA was used in order to record everyday PA for a seven-day period. Participants were given a triaxial accelerometer (AX3, Axivity Ltd., Melton Park, United Kingdom), to wear on their wrist, for seven consecutive days. The successful use of the AX3 accelerometer for providing an accurate detection of PA intensities, has been validated in large paediatric studies [33–35] including YPwCP [36, 37]. Data were collected over a seven-day period after each assessment.

To be considered valid, a recording had to include data from minimum 5 days; 4 weekdays and 1 weekend day. Periods corresponding to sleep and non-wear detected through algorithmic methods and manually verified were excluded from the dataset. Non-wear was defined as any continuous 15 min period during which the standard deviation and range of acceleration in 1 s epochs were below 0.018 g and 0.11 g, respectively. Data collection was conducted at a frequency of 100 Hz with a dynamic range of ±16 g, followed by calibration using a recognized method and signal processing with a fourth-order Butterworth bandpass filter (0.2–15 Hz). The principal PA metric, Bandpass-Filtered Euclidean Norm (BFEN), was derived from Euclidean Norm Minus One (ENMO) and aggregated into 1 s epochs. Validated BFEN thresholds were used to classify PA intensity: light (LPA) at or above 0.1 g, moderate (MPA) at or above 0.314 g, and vigorous (VPA) at or above 0.998 g. [38, 39]. Readings below 0.1 g were classified as sedentary time.

Reliability

We assessed the reliability of device-measured PA via wrist-worn accelerometer: the AX3 accelerometer (Axivity Ltd.). We used device-measured PA data from two different time points, one week following each of the first two study visits for 21 participants with valid recordings. LPA, MPA, VPA and MVPA data were recorded for seven days following the baseline visit, and again for 7 days following each participant's second study visit (1st intervention/exposure visit). In addition, concurrent validity between device-measured PA for seven days following the baseline visit and self-report PA, referring to the last seven days prior to the baseline visit, was assessed.

Analysis

Point estimates and variance, and frequency statistics are used to describe sample data. A Shapiro-Wilk's test (p>0.05) and a visual inspection of their histograms, normal Q-Q plots and box plots were used to explore normality with Spearman's correlation subsequently performed in order to determine the extent of the association between muscle power and cardiorespiratory endurance, ADL performance and PA levels.

In order to assess the reliability of device-measured PA, an Intraclass Correlation Coefficient (ICC), with data from two series of seven-day periods for each participant, was performed. An ICC, absolute agreement reliability analysis was completed to determine the reliability of the average measurement across the two tests (measurement 1 and measurement 2). In order to determine the concurrent validity between accelerometer-measured data seven days post baseline assessment and PAQ-A data 7 days prior to baseline, an ICC checking for consistency was conducted. As part of the ICC procedure an F-test determined whether the variance between test was significantly larger than the variance within tests. Data were analysed in SPSS v29. For ICC, values less than 0.5 indicate poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 demonstrate good reliability; and values greater than 0.9 show high reliability [40].

Results

Descriptives

Thirty-six YPwCP (19 male and 17 female), average age of 15.5 years were recruited between October 2018 and December 2019.

Table 1: Patient characteristics and outcomes.

Study outcome, n	Mean and SD
Age, y (n=36)	15.5 ± 0.7
Sex, M/F (n=36)	M=19/F=17
Height (cm) (n=36)	154.3 ± 13.9
Weight (kg) (n=36)	58.3 ± 11
GMFCS, I, II, III (n=34)	I=14, II=13, III=7
CHU-9D – participation (n=32)	1.5 ± 0.9
CHU-9D – ADL (n=34)	1.2 ± 0.5
CHU-9D – sleep (n=34)	1.3 ± 0.7
CHU-9D – tiredness (n=34)	2 ± 0.4
CHU-9D – pain (n=34)	1.2 ± 0.5
5xSTS (sec) (n=35)	9.9 ± 3.9
VO_2 max, mL/kg/min	35 ± 10.9
PA, PAQ-A (n=32)	2 ± 1
VPA, accelerometer (min) (n=21)	1.3 ± 1.7
MVPA, accelerometer (min) (n=21)	10.6 ± 7.3
MPA, accelerometer (min) (n=21)	9.4 ± 5.8
LPA, accelerometer (min) (n=21)	69.9 ± 29.7

Frequencies, means and standard deviations. M, male; F, female; GMFCS, gross motor function classification system; y, years (only descriptives – relationships are included in another table – participation, PA, power, card/ry endurance, pain, tiredness, sleep, ADL). CHU-9D, Child Health Utility Questionnaire – 9 Domains; 5xSTS, 5 times sit to stand; PA, physical activity; PAQ- A, PA Questionnaire – Adolescents; VPA, vigorous PA; MVPA, moderate to vigorous PA; MPA, moderate PA; LPA, light PA; SD, standard deviation.

Participant characteristics, fitness, wellbeing and PA

Table 1 shows the descriptive statistics of demographics, patient reported and clinical assessments outcomes of our cohort.

The cohort included 36 YPwCP (mean age 15.5 ± 0.7 years; 19 males, 17 females), with GMFCS levels I (n=14), II (n=13), and III (n=7). Participants had a mean VO_2max of 35.03 ± 10.93 mL/kg/min, completed the 5xSTS in 9.9 ± 3.95 s, and recorded a mean of 10.6 ± 7.3 min of daily MVPA, 9.4 ± 5.8 min of MPA, and 69.9 ± 29.7 min of LPA based on accelerometry (Table 1).

Correlations

Leg power, as measured by 5xSTS, produced the strongest correlations with PA, ADL and participation with the strongest correlation with VPA (p=−0.566) (Table 2). The strongest correlation with cardiorespiratory endurance (VO_2max) were with PAQ-A and MVPA, although did not reach significance.

Reliability

Test-retest data from the PA levels taken on two periods within a month are shown in Table 3. An ICC reliability analysis, checking for absolute agreement, indicates the reliability of the average of the two tests is moderate to good for LPA [0.796], MPA [0.783], VPA [0.783], MVPA [0.803], total PA [0.796]). The consistency agreement is reported in Table 4 showing low agreement but no significant difference between measures.

Test-retest reliability of accelerometer-derived physical activity measures showed strong agreement across all

Table 2: Correlations between measures.

Spearman's correlation ρ (rho) *p≤0.01 **p≤0.05	Age	GMFCS level	CHU-9D-ADL	CHU-9D-participation	PAQ_A_ total	PAQ_ last 7 days_Q10	LPA	MPA	VPA	MVPA
5xSTS	**0.514****	0.205	0.250	0.279	−0.323	**−0.384***	−0.039	−0.328	**−0.566***	−0.382
VO_2max	0.004	0.021	0.108	−0.042	0.173	−0.022	−0.069	0.084	0.031	0.115

Correlations between measures. PA, physical activity; PAQ- A, PA Questionnaire – Adolescents; VPA, vigorous PA; MVPA, moderate to vigorous PA; MPA, moderate PA; LPA, light PA; GMFCS, gross motor function classification system; CHU-9D, Child Health Utility Questionnaire– 9 Domains; 5xSTS, 5 times sit to stand. Age and 5xSTS (ρ=0.514, p≤0.05). This is a moderate positive correlation. As age increases, the time taken to complete the 5xSTS also increases. This suggests that older participants demonstrated lower leg power compared with younger participants. Self-reported physical activity and 5xSTS (ρ=−0.384, p≤0.01). This is a moderate negative correlation. Higher self-reported levels of physical activity are associated with faster Sit-to-Stand performance (shorter completion times). Participants who reported being more active performed better at 5xSTS. Device-measured vigorous physical activity and 5xSTS (ρ=−0.566, p≤0.01). This is a stronger negative correlation compared with self-reports. Participants with higher device-measured vigorous physical activity were faster in completing the 5xSTS.

Table 3: Test-retest reliability.

	Bias and LOA	ICC	95 % CI		F test with true value 0			
			LB	UB	Value	Df1	Df2	Sig.
LPA1 & LPA2	−2.7 −39.5: 34.1	0.796	0.565	0.912	8.597	20	20	<0.001
MPA1 & MPA2	−1.6 −8.9: 5.7	0.783	0.525	0.907	9.305	20	20	<0.001
VPA1 & VPA2	−0.5 −2.4: 1.4	0.783	0.499	0.909	9.821	20	20	<0.001
MVPA1 & MVPA2	−2.2 −10.5: 6.1	0.803	0.543	0.918	10.877	20	20	<0.001
Total PA1 & total PA2	−7 −54.8: 40.8	0.796	0.569	0.911	9.095	20	20	<0.001

Agreement on two seven-day periods. LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; ICC, intraclass correlation coefficient; CI, confidence intervals; LB, lower bound; UB, upper bound; LOA, limits of agreement.

Table 4: ICC between PAQ-A and accelerometry.

	ICC	95 % CI		F test with true value 0			
		LB	UB	Value	Df1	Df2	Sig.
PAQ_A total & LPA	0.14	−0.444	0.466	1.028	17	17	0.477
PAQ_A total & MPA	0.088	−0.383	0.522	1.192	17	17	0.361
PAQ_A total & VPA	0.215	−0.267	0.610	1.546	17	17	0.189
PAQ_A total & MVPA	0.069	−0.399	0.508	1.148	17	17	0.390
PAQ_A total & total PA	0.016	−0.456	0.481	1.032	17	17	0.475
PAQ_A_Q10 & LPA	0.028	−0.446	0.490	1.057	16	16	0.456
PAQ_A_Q10 & MPA	0.121	−0.369	0.557	1.274	16	16	0.317
PAQ_A_Q10 & VPA	0.239	−0.258	0.636	1.629	16	16	0.169
PAQ_A_Q10 & MVPA	0.095	−0.391	0.539	1.209	16	16	0.354
PAQ_A total & total PA	0.027	−0.461	0.503	1.056	15	15	0.459

Agreement between the two measures as described by ICC, LOA and ANOVA. PA, physical activity; PAQ- A, PA Questionnaire – Adolescents; VPA, vigorous PA; MVPA, moderate to vigorous PA; MPA, moderate PA; LPA, light PA.

intensity levels, with ICCs ranging from 0.783 to 0.803 (all $p<0.001$). The bias and limits of agreement (LOA) were small and clinically acceptable, indicating consistent measurement of LPA, MPA, VPA, and MVPA, as well as total PA over repeated assessments in young people with cerebral palsy.

Table 4 presents the association and difference between the two measures self-report and device-measured (PAQ_A and wrist worn accelerometer) taken on two seven-day periods, within a month.

The ICCs between self-reported and accelerometer-measured PA intensities (LPA, MPA, VPA, MVPA, and total PA) were low, ranging from 0.016 to 0.239, with all 95 % confidence intervals including zero and non-significant F-tests ($p>0.05$). These findings indicate poor agreement and limited reliability between self-reported and accelerometer-measured PA in this cohort of YPwCP.

Discussion

Our finding of higher leg power being associated with greater VPA suggests that the ability to perform sit-to-stand transitions quickly, may indicate that power and balance are linked to functional ability and participation on PA for YPwCP [41].

Leg power (5xSTS test)

Leg power is a key component of functional mobility in YPwCP, supporting activities such as walking, stair climbing, and rising from a chair, which are essential for independent participation in PA [17]. Although leg power correlates with age, its significant association with VPA suggests that those with greater lower limb strength, face less limitations in engaging in higher-intensity activities. This relationship can help researchers select clinically practical assessments that provide insights into real-world activity intensity and guide targeted interventions. Although particularly relevant in CP due to impaired motor function, the predictive utility of the 5xSTS has also been demonstrated in typically developing youth and other paediatric populations with disabilities, indicating its broader applicability [42]. YPwCP who demonstrate greater power in sit-to-stand movements, have previously been found to feel more empowered to participate in everyday physical activities [41], although we did not find this; possibly due to the relatively small numbers of participants across GMFCS levels in our study.

PA levels and fitness parameters

We found low levels of PA in the group in comparison to PA data from 339 typically developed children, aged 13–14 years, measured with the same methodology [43]. YPwCP present 30 % lower engagement in PA compared to their typically developed peers and were twice likely to engage in sedentary behaviour. Previous studies show that 75 % of YPwCP spend more time in sedentary activities compared to typically developed peers [2]. As previously observed, both PA and fitness parameters metrics were lower in older individuals [2, 44]. Promoting adherence to regular PA for YPwCP is becoming pivotal for cardiorespiratory fitness and the prevention of motor decline [45]. UK's Chief Medical Officers published the first ever PA guidelines for children and young people with disabilities in 2022 [46]. These guidelines recommend 120–180 min of moderate to vigorous aerobic exercise per week and strength, balance and motor skills training activities three times per week [46]. Considering our findings there is an urgent need to prioritise the promotion of PA among YPwCP in order to prevent health deterioration [2]. Previous studies show that regular PA has a positive effect on strength, gait speed and balance in CP, with benefits correlating to both frequency and duration, but not intensity of PA. In light of our findings, we recommend further research into the impact of more targeted, higher-intensity exercise interventions for this group, aiming to improve both leg power and overall exercise intensity.

Despite the established relationship between fitness measures and PA levels, the association of fitness measures to mobility and to participation in PA in this group of YPwCP, appears to be less robust. This suggests that fitness can be achieved across disability levels and may not be achieved in formal leisure activities [47]. Further research is needed to explore the direction of these relationships and the effect of targeted interventions. Given these findings, fitness parameters including leg power and cardiorespiratory endurance and PA levels, should be further assessed in YPwCP.

This study highlights the importance of leg power for supporting PA participation among YPwCP. Leg power plays an important role in enabling functional mobility and engagement in VPA and MVPA, which are often limited in YPwCP due to motor impairments and fatigue [15]. Evidence suggests that power training interventions can improve walking speed, functional strength, and activity participation in this population [48]. Given that PA participation is influenced not only by motivation and opportunity but also by underlying physical capacity, targeting lower limb power in interventions and exercise programmes is essential to reduce sedentary behaviour and promote health-enhancing PA [48].

Accelerometry reliability

Measures of PA, via wrist-worn accelerometer, over a seven-day period, were reliable within a month, but not comparable to self-report measures in YPwCP. We observed low levels of PA determined in self-reported and device-device measured metrics compared to data presented on typically developed young people at all intensities, and particularly at higher intensity levels. Our data support the use of accelerometer devices as a useful tool to accurately monitor and determine PA levels. Importantly we observed that leg power was strongly associated with VPA, whereas cardiorespiratory endurance was only weakly associated with PA. Taken together our findings add to current understanding and the need to measure PA using accelerometers in YPwCP when considering fitness outcomes.

This agrees with previous research supporting the use of accelerometers when measuring PA for YPwCP. Accelerometers provide device-measured, continuous data on movement intensity and duration, avoiding the biases and limitations of self-reported measures, which may be unreliable in this population due to cognitive or motor impairments [14]. Given the movement inefficiencies and atypical gait patterns common in CP, devices such as accelerometers offer a more accurate reflection of actual activity levels, which is critical when evaluating fitness outcomes, where traditional markers like heart rate or perceived exertion may be misleading [49].

Although device-measured PA data are valid, the feasibility of such devices which are wrist worn or/and ancle worn, as routine tools in research or clinical settings, for YPwCP, may be limited unless strategies to improve adherence are implemented. The fact that only 21 out of 36 participants provided valid data, highlights challenges with wear compliance and suggests that, despite its strengths, device-measured PA may not be practical for all YPwCP without targeted support.

It has been suggested that obtaining validated metrics in this population can be a challenge [9]. We were able to implement both questionnaires alongside device-measured methods. We confirmed that accelerometer-measured PA showed a weak association with self-report, and for the first time established that accelerometer-measured PA is reliable. This supports the use of device-measured assessment over a 7-day period alongside self-report, which capture contextual information about the types of activities performed and the environments in which they occur, providing a more comprehensive understanding of PA patterns. However, as self-reported data, questionnaires are subject to recall bias and inaccuracies, particularly in young people, who may struggle to accurately recall or estimate their PA [32]. For YPwCP, particularly those with cognitive impairments, completing a questionnaire accurately can be challenging. This agrees with previous research that assessed the reliability and validity of a modified PAQ-A and found acceptable internal consistency and test-retest reliability [32]. However, it also reported weak to moderate correlations with device-measured PA, indicating potential limitations in accurately capturing activity levels through self-report, especially in populations with physical disabilities [32].

Limitations

When evaluating the result of this study it should be considered that the cut points used to define the thresholds classifying PA intensity, the relatively small number of participants and less data for accelerometry and the large range of ages, can influence results. It is also important to consider that we did not attempt to control activity levels between our re-test measures. Whilst, this would have increased the variability due to individual activity patterns, affecting reliability results, they have ecological validity. It should also be considered that accelerometry may not have measured activities that individuals perceive or are arduous, such as activities against resistance that do not result in acceleration.

Conclusions

This study found that greater leg power, assessed by faster 5xSTS times, is associated with VPA among YPwCP. This suggests that leg power may be an important contributor that enables greater PA participation in YPwCP, and should be considered as both a functional outcome and potential intervention target in this population. Accelerometer-derived PA data appears reliable across one-month test-retest in this small cohort of YPwCP and may be more sensitive than self-report for capturing participation in PA, particularly more VPA. Future studies should combine power-focused interventions with device-measured PA to test the hypothesis that increasing leg power can boost participation in more intense PA in YPwCP.

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