Psychometric properties of the Obstacles and Curb tests and their discriminative ability across functional levels in ambulatory children with spastic cerebral palsy

Article *in* International journal of rehabilitation research. Internationale Zeitschrift fur Rehabilitationsforschung. Revue internationale de recherches de readaptation · April 2023

DOI: 10.1097/MRR.0000000000000575

CITATIONS
0

READS
8

6 authors, including:

Maha Fahad
King Saud University
4 PUBLICATIONS **4** CITATIONS
SEE PROFILE

Banan Almass
Majmaah University
3 PUBLICATIONS **26** CITATIONS
SEE PROFILE

Afaf Shaheen
Cairo University
32 PUBLICATIONS **318** CITATIONS
SEE PROFILE

Samiah Alqabbani
Princess Nora bint Abdul Rahman University
10 PUBLICATIONS **93** CITATIONS
SEE PROFILE

Psychometric properties of the Obstacles and Curb tests and their discriminative ability across functional levels in ambulatory children with spastic cerebral palsy

Maha F. Algabbani[a], Banan A. Almass[a,b], Afaf A. M. Shaheen[a,c], Adel Alhusaini[a], Muneera M. Almurdi[a] and SamiahAlqabbani [d]

The Obstacles and Curb tests are timed walking assessments that have emerged from the Spinal Cord Injury Functional Ambulation Profile and have been modified for children; however, their psychometric properties have not been adequately investigated. The aim of this research was to examine the psychometric properties of the Obstacles and Curb tests for children with cerebral palsy (CP). This cross-sectional study included 68 children aged 6–12 years; there were 34 children with CP and 34 age- and sex-matched typically developing children. Validity was examined by correlation with the 10-m Walk Test (10-MWT), Modified Time Up and Go test (mTUG), and Pediatric Balance Scale (PBS). Differences in the Obstacle and Curb test scores were calculated between children with CP and typically developing children and within different Gross Motor Function Classification System (GMFCS) levels. Children with CP completed the tests twice within a 30-min interval in the same session. The tests showed significant strong to very strong correlations with the 10-MWT, mTUG, and PBS. The within-session reliability was excellent, typically developing children were significantly faster than children with CP with high sensitivity and specificity, and the time differed significantly within the GMFCS level. Thus, the Obstacles and Curb tests can be considered valid, reliable, and sensitive walking tests for ambulatory children with CP. *International Journal of Rehabilitation Research* XXX: XXXX–XXXX Copyright © 2023 The Author(s). Published by Wolters Kluwer Health, Inc.

International Journal of Rehabilitation Research XXX, **XXX**:XXXX–XXXX

Keywords: cerebral palsy, children, Curb test, Gross Motor Functional Classification System, Obstacles test, timed walking tests

[a]Department of Health Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, [b]Department of Physical Therapy, College of Applied Medical Sciences, Majmaah University, Al-Majmaah, Saudi Arabia, [c]Basic Sciences Department, Faculty of Physical Therapy, Cairo University, Cairo, Egypt and [d]Department of Rehabilitation Sciences, College of Health and Rehabilitation Sciences, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia

Correspondence to Samiah F. Alqabbani, PT, DSc, P.O. Box 84428, Riyadh 11433, Saudi Arabia
Tel: +966118240370; e-mail: sfalqabbani@pnu.edu.sa

Received 10 February 2023 **Accepted** 6 March 2023.

Introduction

Cerebral palsy (CP) is an umbrella term for a non-progressive motor disorder resulting from damage to the developing brain that affects movement and posture and causes functional activity limitation and participation restrictions [1]. It is the most common physical disability among children [2]. With the presence of CP, children are usually challenged with walking activities as a part of everyday life [3,4].

Many children with CP and their parents prioritize walking above all other activities [5] because it is a means of independence and participation in other physical, recreational, and social activities [6]. In general, children with CP find it more difficult to walk on uneven surfaces and curving paths [7,8]. The specific limitation in mobility for children with CP depends on the type of CP and the severity of the condition. The Gross Motor Functional Classification System (GMFCS) is a five-level classification tool used to indicate motor function in children with CP. It rates a child's motor function from the least severe (Level I) to the most severe (Level V) [9]. Children with classifications of I, II, or III are considered ambulatory children [10].

Walking is a complex task when being evaluated; it requires tools that measure different aspects of walking, such as gait speed, dynamic balance, and stepping ability. Timed walking tests play a large role in examining the walking ability of children with CP. Currently, timed walking tests, such as the 10-m Walk Test (10-MWT) and Modified Time Up and Go test (mTUG), are important assessments of walking for children with CP [11,12]. Although these measures provide information regarding walking speed and general walking function, they assess walking over level ground only. In contrast, the Standardized Walking Obstacle Course test [13] examines differences in functional ambulation performance among children in relation to environmental demands and obstructions. It involves walking through a standardized obstacle pathway that is long and curved; however,

this test is suitable for children walking without the need for hand-held mobility devices [14]. Balance can be measured independently or as a component of the walking assessment. The Pediatric Balance Scale (PBS) is the most widely used tool to assess balance in children with CP [15,16].

For ambulatory children with CP, there is a need for walking tests that are suitable for ambulatory children at different GMFCS levels, challenge individuals with higher walking abilities, and reflect on walking in the community [17,18].

Kane *et al.* [19] modified two tasks of the Spinal Cord Injury Functional Ambulation Profile for adults: walking-above-and-around obstacles (modified to the Obstacle test) and a curb/step task (modified to the Curb test). The modified tests are feasible for children with CP [20]. A turn around a trash can to return to the start pathway in the walking-above-and-around-obstacles task was substituted with a straight pathway and the addition of two lines (1 m after the start line and 1 m before the end line) to indicate the actual time duration without considering the time taken for acceleration and deceleration (before and after the two lines). The height and length of the two obstacles were adjusted to each child's leg height and to the use of a walking aid. For the Curb test (similar to the Obstacles test), two lines were added to the pathway to allow for acceleration and deceleration independent of the actual timed measured; in addition, the child was allowed to get on and off the wooden platform (i.e. the curb) by either stepping or crawling [20].

The Obstacles and Curb tests assess walking in challenging environments and provide a clearer overall picture of the walking ability of children with CP; they provide visible measures for children with CP, whether they use assistive devices or not. Moreover, they conceded the difficulty for the children in initiating the movement by allowing a period of acceleration (and also deceleration) separate from the actual time measurement. Moreover, the height of the obstacles is modified for each child to eliminate a bias regarding the child's height in performing the tests. These aspects make these tests unique when compared to other timed walking tests. Normative values of both tests were established for typically developing Saudi children aged 6–11 years old, allowing for appropriate quantifications for Obstacles and Curb walking scores [21]; however, the psychometric properties of the Obstacles and Curb tests have not been investigated adequately in children with CP. Kane *et al.* [19] conducted a preliminary assessment of the tests on a group of 16 ambulatory children with CP or spina bifida and 16 age- and sex-matched typically developing children. They found that both tests were valid when performed at a fast speed; the tests' scores correlated strongly to very strongly with 10-MWT and TUG (*rho* = 0.86–.90, $P < 0.001$). The scores of the children with CP or spina bifida differed significantly from the scores of typically developing children ($P < 0.001$). Both tests showed high within-session test–retest reliability (ICC = 0.94–.95).

In clinical settings, to increase the feasibility, useability, and appropriateness of the Obstacles and Curb tests to measure functional ability and observe changes before and after treatment, further studies are required. This research needs to test the psychometric properties of the tests on a larger sample of patients with CP with different motor function levels.

Therefore, the aim of this study was to assess the psychometric properties of the tests in ambulatory children with CP, including concurrent and convergent validity, sensitivity and specificity, discriminative validity, within-session test-retest reliability, and the minimal detectable change (MDC_{95}) of the test's completion times for each functional level in both tests.

We hypothesized that the scores of the Obstacles and Curb tests would strongly correlate (> 0.6) with 10-MWT, mTUG, and PBS (at an α level of 0.01). We expected that both tests would distinguish children with CP from typically developing children and would distinguish between different GMFCS levels. Moreover, we hypothesized that both tests would have excellent within-session reliability, low measurement error, and acceptable MDC. Finally, we predicted that the tests would have moderate accuracy with an area under the curve (AUC) of 0.70 or higher.

Materials and methods

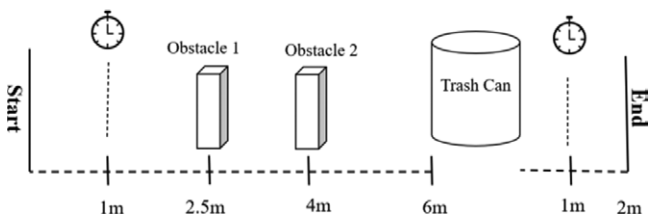
Study design and setting

In this cross-sectional, psychometric testing study, a convenience sample of children with CP was recruited from the pediatric rehabilitation departments of Sultan bin Abdulaziz Humanitarian City in Riyadh, Saudi Arabia. Additionally, a group of typically developing children was recruited through flyer distribution in five recreational centers in Riyadh, Saudi Arabia. The recruitment of children took place from November 2020 to February 2021.

Participants

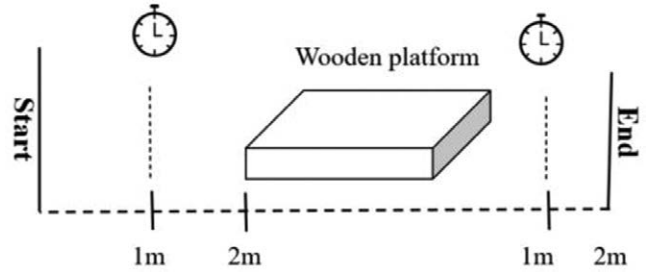
The children with CP were able to participate in the study if they met the following criteria: diagnosed with spastic CP; aged between 6 and 12 years; GMFCS Levels I, II, or III; able to walk for 14 m with or without walking aids; and able to cooperate and follow instructions. Children who had orthopedic surgery within the past 6 months or botulinum toxin type A injections within the past three months were excluded. Typically developing children were included if they were able to be age- and sex-matched with a child with CP, born full-term, and had no trauma or medical issues that affected their walking or balance ability [20].

Fig. 1



Obstacle test. The length of the walking pathway is 8.56 m (marked by two bold lines). Timing starts at 1 m after the start line and is stopped 1 m before the end line (marked by intercepted lines). Two obstacles (0.5 m in length or 0.25 m for children with assistive devices) are placed 2.5 m and 4 m from the start line. A trash can (56 cm in width and 69.5 cm in height) is placed 6 m from the start line [20].

Fig. 2



Curb test. The start and end lines are marked by bold lines at 2 m before and 2 m after the wooden platform (0.21 m × 0.81 m × 1.22 m). Timing starts 1 m after the start line and is stopped 1 m before the end line (interrupted lines) [20].

The sample size was estimated using a web-based sample size calculator for reliability studies considering two repetitions of the tests [22] with a minimum acceptable reliability of 0.7, an expected reliability of 0.9 [20], a significance level of 0.05; a power of 0.80, and a 20% dropout rate. On the basis of this calculation, 68 children (34 children with CP and 34 typically developing children) were considered an adequate sample for this study. The children with CP were subdivided into three subgroups according to their GMFCS level ($n_{GMFCS\ I}$ = 12, $n_{GMFCS\ II}$ = 12, and $n_{GMFCS\ III}$ = 10). According to this subdivision, the typically developing children were matched.

Instruments

Gross motor functional classification system

In the GMFCS classification system, children with CP are categorized into five levels based on their ability to self-initiate movement. The focus is primarily on walking, climbing stairs, and using assistive technology, such as walking aids or wheeled mobility devices. The GMFCS levels are as follows:

Level IChild can walk indoors and outdoors; run and jump with limited speed, balance, and coordination; and can climb stairs.

Level IIChild can walk in most settings but with difficulty on uneven surfaces and may need assistive technology for long distances. They can climb stairs with a railing.

Level IIIChild can walk with hand-held mobility devices in most indoor settings and use wheeled mobility for long distances. The child can climb stairs with railing with supervision or physical assistance.

Level IVIn most settings, the child requires physical assistance or powered mobility to move around.

Level VAll settings require the child to be transported in a manual wheelchair [9].

Obstacles test

The Obstacles test is a walking assessment that involves stepping over two different in-height obstacles (Styrofoam). Depending on the child's leg length, the first one is at a height of 10–20%, and the second one is 20–25% of leg length. The child then walks around one trash can (56 cm in width and 69.5 cm in height) within a pathway 8.5 m in length (see Fig. 1). The child stands at the start line and, when instructed, walks at a fast speed (without running), stepping over two obstacles, goes around the trash can from either the right or left side, and then walks until the end line without touching the obstacles or trash can. If so, the child does not stop and continues walking until the end line. If the child does touch an obstacle, either with their body or an assistive device, a 10% time penalty is added to the scoring time. A child can use a walking aid, but no physical assistance from another individual is allowed.

Curb test

The Curb test involves stepping onto and off a wooden platform (i.e. the curb) (see Fig. 2). The child is instructed to stand behind the start line, then walk fast (without running) in a straight line toward the wooden platform, step onto it, and then step down to the ground to cross the end line. If the child cannot step up, crawling onto and off the step is allowed; in this case, the examiner can move a walking aid (if one is used by the child) to the other side of the platform.

Ten-m walking test

The 10-MWT is a performance measure that indicates walking ability and gait speed [17]. It is a valid and reliable tool for children with CP [5,12,23]. The test requires the use of a stopwatch and a 14-m path marked at 2 m and 12 m. Time is measured for the 10 intermediate meters.

Modified Time Up and Go test

The mTUG is a test used to assess functional mobility and dynamic balance in 4–12-year-old children [24,25]. It has good validity and reliability in children with CP [26–30]. To administer this test, a stable chair with a

back and no armrests are used. The test requires a chair that maintains 90° (more or less 10°) of the knee and hip flexion with feet flat on the ground. Near the child's feet, a start line is set on the floor, and a photo is hung on the wall three meters away from the start line for the child to touch and walk back to the chair to sit down [27,29].

Pediatric Balance Scale

The PBS is a valid tool used for assessing balance in children from ages 5 to 15 years [31]. It consists of 14 items that measure balance. Each item is scored from 0 to 4. The scores for all items are added to generate a total score. It is a valid and reliable tool for children with CP [15,16,31–34]

Time is measured in seconds; less time required to complete a test shows better performance for the Obstacle test, Curb test, 10-MWT, and mTUG test. For PBS, a higher total score shows better balance ability.

Demographic characteristics

Demographic data were collected at baseline. The weight of the children was measured in kilograms using a digital weight scale. The height of typically developing children and children with CP with no skeletal deformities was measured from standing against a tape measure secured to a wall [35]. For those with major skeletal deformities, such as scoliosis, kyphosis, or flexion deformities in the lower limbs [36], height was estimated using segmental measuring through the knee height equation, where height (cm) = [2.69 × knee height (cm)] + 24.2 [37]. Knee height was measured with the knee and ankle flexed to 90° from the heel to the anterior surface of the thigh over the femoral condyle; this measurement has been shown to be accurate (95% CI, 0.90–0.98) [37] in measuring height for children with CP [38]. A tape measure was also used to measure the height of the lower limbs of all children to customize the obstacle heights in the Obstacles test.

Procedure

The Obstacles and Curbs test setups and instructions were given to the children following the protocol suggested by Kane *et al* [20]. The tests were conducted in one session by the same assessor. They were completed in the following order: 10-MWT, mTUG, Obstacles test, Curb test, and PBS to ensure consistency in the collected data, with a rest period of 3–5 min between the tests to minimize participant fatigue. The Obstacle and Curb tests were repeated after a 30-min interval (retest) to evaluate within-session test–retest reliability [12,20,39]. A separate data collection form was used for each test to minimize potential scoring bias from knowledge of prior results.

Statistical analysis

IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, New York, USA) was used for the data analysis. The data were examined regarding normality using the Shapiro–Wilk test. Data were summarized as means and SD for bell-shaped data and as quartiles [first, second (median), and third] for skewed data. Frequencies and percentages were used to describe the categorical variables.

Concurrent (criterion) and convergent validity

The validity of the Obstacle and Curb tests was examined by correlating the test scores with the scores of 10-MWT and mTUG for concurrent validity and with PBS scores for convergent validity. The Pearson correlation coefficient (r) or Spearman's ranked correlation (rho) was used according to the data distribution. At a 0.01 level of significance, the correlation values were interpreted as follows: 0.00–0.19, very weak; 0.20–0.39, weak; 0.40–0.59, moderate; 0.60–0.79, strong; and 0.80–1, very strong correlation [40].

Sensitivity, specificity, and cutoff point

The receiver-operating characteristic (ROC) curve was used to test the sensitivity and specificity and to establish the optimal cutoff points for the tests. The AUC quantifies the accuracy of the tests to discriminate the performance between the children with CP and the typically developing children. The AUC was interpreted as follows: <0.50, no discrimination; 0.5–0.7, poor discrimination; 0.7–0.8, acceptable discrimination; 0.8–0.9, excellent discrimination, and >0.9 outstanding discrimination [41].

Discriminative validity

Discriminative validity was assessed in terms of the differences between children with CP and typically developing children using a paired-sample t-test [$\alpha = 0.05$, 95% confidence interval (CI)] or Wilcoxon matched-pairs tests ($\alpha = 0.05$) according to data distribution. The ability of tests to discriminate among diverse GMFCS levels was also investigated using a one-way analysis of variance (ANOVA) and Tukey's honest significant test (HSD) post hoc test analysis if needed. The effect size was interpreted as follows: 0.2 = small, 0.5 = medium, and 0.8 = large (based on [42]).

Within-session test-retest reliability

Within-session test-retest reliability was analyzed using a two-way random-effects intra-class correlation coefficient model with a single rater ($ICC_{2,1}$) and absolute agreement. Correlations were considered significant at the 0.01 level, with an acceptable value ranging from 0.70 to 0.95 [43]. Moreover, the correlation coefficients r were used to detect test-retest reliability.

Table 1 Participants' characteristics

	Children with CP				Typically developing children
	GMFCS I (*N* = 12)	GMFCS II (*N* = 12)	GMFCS III (*N* = 10)	Total (*N* = 34)	Total (*N* = 34)
Age (years)	9.6	8.1	9.2	8.9	8.9
Mean (SD)	(1.9)	(1.6)	(1.8)	(1.8)	(1.8)
Height (cm)	126.1	12.9	122.6	123.2	128.2
Mean (SD)	(11)	(5.2)	(7.6)	(8.4)	(13.1)
Weight (kg)	24.9	24.8	25.7	25.1	30.2
Mean (SD)	(7.9)	(5.7)	(6.1)	(6.5)	(9.4)
Sex					
Boy, *N* (%)	6 (35)	4 (23)	7 (41)	17 (50)	17 (50)
Girl, *N* (%)	6 (35)	8 (47)	3 (17)	17 (50)	17 (50)
Diagnosis					
Diplegia, *N* (%)	9 (75)	5 (41)	5 (50)	19 (55)	
Quadriplegia, *N* (%)	0	1 (8)	5 (50)	6 (17)	
Hemiplegia, *N* (%)	3 (25)	6 (50)	0	9 (26)	

Data presented as mean (SD), except for sex and CP diagnosis as frequency and percentage.
CP, cerebral palsy; GMFCS, Gross Motor Function Classification.

Minimum detectable change

Absolute reliability was estimated for each GMFCS level using minimum detectible change with a 95% CI (MDC_{95}). The MDC_{95} was calculated on the basis of the standard error (SE) of measurement (SEM) using the formula: $MDC = SEM \times 1.96 \times \sqrt{2}$. Furthermore, the MDC% was defined as (MDC/mean) × 100%, where mean represents the mean value for the retest assessment. SEM was calculated using the formula: $SEM = SD_{\text{at baseline}} \times \sqrt{(1 - ICC)}$, where SD is the SD at baseline. Values for ICC greater than 0.90 indicate excellent reliability, between 0.75 and 0.90 indicate good reliability, between 0.50 and 0.75 indicate moderate reliability, and lower than 0.50 indicate poor reliability [44].

Results

None of the data were found to differ statistically significantly from normal distribution except for the scores on the Curb test, combining all the GMFCS levels ($P < 0.001$).

Participant characteristics

In general, 44 children with CP were invited to participate in this study; 10 children were excluded because they did not meet the study criteria (seven were diagnosed with ataxic CP, and three were not cooperative). The analysis was conducted with 68 participants: 34 children with CP [mean age 8.9 (1.8) years, height 123.2 (8.3) cm, and weight 25.1 (6.4) kg] and 34 age- and sex-matched typically developing children [mean age 8.9 (1.8) years, height 128.2 (13.1) cm, and weight 30.2 (9.4) kg]. The participant's characteristics are presented in Table 1.

Concurrent and convergent validity

The analysis of concurrent validity revealed statistically positive very strong correlations between the Obstacles test and both 10-MWT ($r = 0.84, P < 0.001$) and mTUG ($r = 0.90, P < 0.001$) and between the Curb test and mTUG ($rho = 0.93, P < 0.001$). A positive strong correlation was found between the Curb test and 10-MWT ($rho = 0.79, P < 0.001$). Moreover, the convergent validity analysis revealed that there was a statistically negative very strong correlation between PBS and both the Obstacles test ($r = -0.86, P < 0.001$) and Curb test ($rho = -0.92, P < 0.001$).

Sensitivity, specificity, and cutoff point

AUC values of 0.95 (SE = 0.03) and 0.96 (SE = 0.02) were obtained after constructing the ROC curve for the Obstacles and Curb test scores, respectively (see Fig. 3). These values indicate outstanding discriminative ability and accuracy. The cutoff time for the Obstacles test was determined to be 6.2 s (sensitivity, 97%; specificity, 91%; AUC = 0.95; $P < 0.001$), and for the Curb test, it was determined to be 4.1 s (sensitivity, 97.1%; specificity, 91.2%; AUC = 0.96; $P < 0.001$).

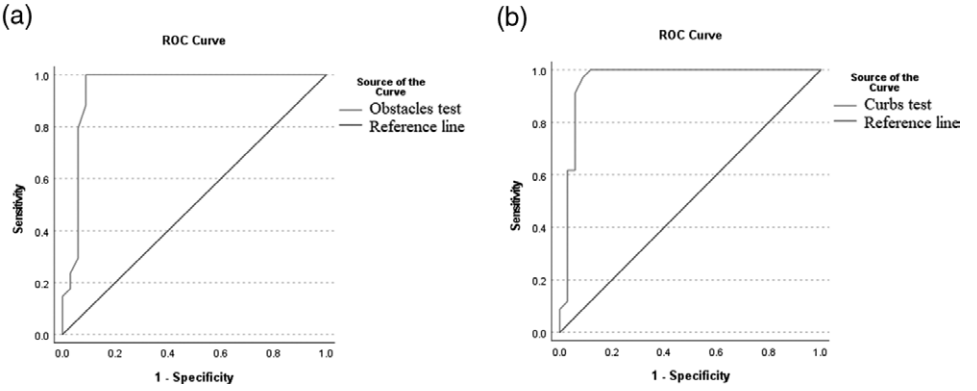
Discriminative validity of Obstacles and Curb test scores between children with CP and typically developing children.

The mean scores of the Obstacle test were 5.24 (0.58) and 13.72 (5.25) for typically developing children and children with CP, respectively. The medians and quartiles for the Curb test were 2.9 (2.6, 3.43) and 13.5 (5.78, 36.60) for typically developing children and children with CP, respectively. Overall, the typically developing children were significantly faster than the children with CP [Obstacles: $t(33) = -9.70, P < 0.001$; Curb: $Z = -5.04, P < 0.001$]. Moreover, the typically developing children in the age- and sex-matched group were faster than the children with CP at each GMFCS level (see Fig. 4 and Table 2).

Discriminative validity of Obstacles and curb tests scores within Gross Motor Function Classification System level

A one-way ANOVA revealed a significant difference in Obstacle test scores [$F_{(2,31)} = 105.24, P < 0.001$] between participants at GMFCS Level I (mean = 7.94, SD = 2.06),

Fig. 3



Receiver-operator characteristics (ROCs) curves of (a) the Obstacles test, and (b) the Curb test.

Level II (mean = 14.33, SD = 2.22), and Level III (mean = 19.94, SD = 1.33). Similarly, the analysis of Curb test scores in relation to GMFCS indicated a significant difference [$F_{(2,31)}$ = 524.98, P < 0.001] between participants at GMFCS Level I (mean = 5.26, SD = 2.06), Level II (mean = 13.40, SD = 2.03), and Level III (mean = 40.51, SD = 3.69).

The post-hoc analysis with Tukey's HSD test found that the mean values of the Obstacle test and Curb test differed significantly among the three GMFICS levels (P < 0.001), with large effect sizes (see Table 3).

Within-session test-retest reliability

Test-retest reliabilities were high; the intra-class correlation for Obstacle and Curb tests showed excellent correlations: $ICC_{2,1}$ = 0.98 (95% CI, 0.97–.99) and $ICC_{2.1}$ = 0.99 (95% CI, 0.97–.99), respectively. For both tests, the test and retest scores were strongly correlated (Obstacle test, r = 0.98; Curb test, *rho* = 0.95).

Minimal detectable change in the test's completion times for each Gross Motor Function Classification System level

As a result of the significant differences between the times among the three levels, the ICC, SEM, and MDC_{95} were investigated for each GMFCS level separately (see Table 4).

Discussion

The current study investigated the psychometric properties of the Obstacles and Curb tests on children with spastic CP. The results showed that both tests have acceptable psychometric properties, expanding the results initiated by Kane *et al* [20]. Both tests were valid (strong to very strong correlations with 10-MWT, mTUG, and PBS); able to discriminate between children with CP and typically developing children; and had high within-session reliability. In addition, this study adds to the previous knowledge that both tests show high sensitivity and specificity (>90%), providing cutoff points to discriminate children with CP from typically developing children. Moreover, the scores of both tests significantly differed within GMFCS levels. These psychometric properties were tested on a larger sample, as recommended by Kane *et al*.

The results of the current study showed that the Obstacles and Curb tests were valid for children with CP at GMFCS Levels I–III when performed at a fast speed. In this study, the tests were performed at a fast speed [20]. According to Kane, Lanovaz, Bisaro, Oates, and Musselman [20], the tests were more valid, with greater reliability when performed at fast speed. Testing walking abilities at a fast speed agrees with studies on other timed walking tests, such as the 10-MWT and mTUG [11,12].

The Obstacles and Curb test scores showed an ability to discriminate between children with CP and an age- and sex-matched group of typically developing children, and these results were in line with Kane *et al*.'s study [20]; in it, test scores were significantly lower for typically developing children when compared to children with CP, and that was expected as a result of the postural and movement impairment in the latter group [1]. A decrease in balance is a major result of motor impairments associated with CP. Balance and endurance are the greatest factors limiting walking abilities in children with CP [4].

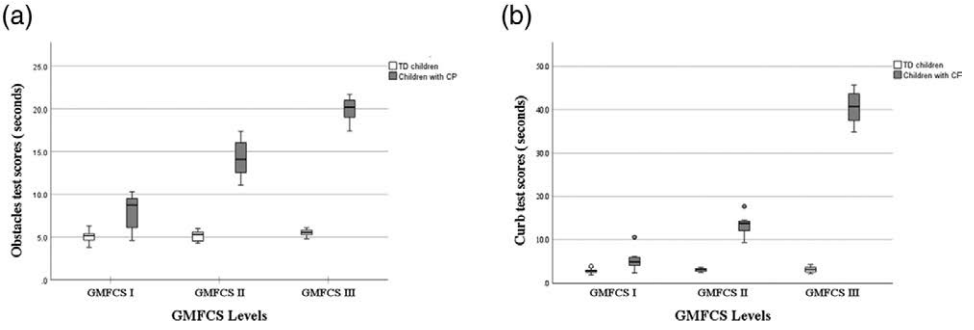
Completed times for the Obstacles and Curb tests differentiated well between children with CP and typically developing children with high sensitivity and specificity (>90%), meaning more than a 90% probability of correctly identifying the differences between children with and without CP. The sensitivity of the test provides us with an overview of a child's problems with walking when exceeding the cutoff point time. To the authors' knowledge, no previous studies have estimated the cutoff point

for timed walking tests regarding identifying children with or without CP.

Similar to other timed walking tests, those with lower GMFCS levels required more time to complete the Obstacles and Curb tests, with significant differences between the three-classification levels; this indicates that both tests could distinguish among the different GMFCS levels of the children with CP. This could be due to the higher impairments associated with the degree of disability, which decreased gait quality [4]. These results were in line with the 10-MWT in showing an ability to differentiate children with various GMFCS levels [45]. In contrast, the TUG test was not able to differentiate between high ambulatory children with CP classification I and II; this is probably the result of the less challenging nature of mTUG compared to the Obstacles and Curb tests [46]. In addition, the current results were similar to previous studies that assessed the balance of children with CP; for example, Yi *et al* [32]. concluded that PBS has the ability to distinguish among the three GMFCS levels after finding significant differences among them ($P < 0.05$).

In line with Kane *et al*.'s [20] study from 2016, the results of the current study showed that the Obstacles and Curb tests were reliable assessments with high ICCs; Kane *et al*. found high within-session test-retest reliabilities of the Obstacles test (ICC = 0.94) and Curb test (ICC = 0.95), though their participants were children with CP and spina bifida. Similar results were found with other walking tests for children with CP; mTUG and 10-MWT were highly reliable within the session: ICC = 0.99 and 0.95, respectively [12,24].

Fig. 4



Comparison of Obstacles and Curb test scores for different Gross Motor Function Classification System (GMFCS) levels. Distributions are depicted using boxplots; thick line denotes median, box denotes interquartile range, and circles denote outliers.

Table 2 Comparison of Obstacles and Curb test scores for different Gross Motor Function Classification System (GMFCS) Levels I ($n = 12$), II ($n = 12$), and III ($n = 10$) with age- and sex-matched group of typically developing children

Tests	GMFCS level	Children with CP Mean (SD)	Typically developing children Mean (SD)	Independent sample test			
				T	df	*P* value	Effect size
Obstacle test							
	Level I	7.94 (2.06)	5.08 (0.67)	−4.20	11	<0.001	2.36
	Level II	14.33 (2.22)	5.16 (0.17)	−15.99	11	<0.001	1.99
	Level III	19.94 (1.33)	5.53 (0.38)	−33.29	9	<0.001	1.37
Curb test	Level I	5.26 (2.06)	2.84 (0.53)	−4.06	11	<0.001	2.02
	Level II	13.40 (2.03)	3.05 (0.36)	−17.03	11	<0.001	2.11
	Level III	40.51 (3.69)	3.15 (0.70)	−27.97	9	<0.001	4.22

CP, cerebral palsy; GMFCS, Gross Motor Function Classification System.

Table 3 Comparison of Obstacle test and Curb test scores by Gross Motor Function Classification System level

	GMFCS level	Mean differences	SE	*P* value	95% CI		Effect size
					Lower	Upper	
Obstacles test				<0.001			
	Level I vs. II	−6.39	0.79		−8.34	−4.44	2.14
	Level I vs. III	−12.00	0.83		−14.05	−9.96	1.77
	Level II vs. III	−5.61	0.83		−7.66	−3.57	1.87
Curb test	Level I vs. II	−8.19	1.07		−10.84	−5.55	2.06
	Level I vs. III	−35.30	1.13		−38.08	−32.53	2.91
	Level II vs. III	−27.11	1.13		−29.88	−24.34	2.90

Post-hoc significance level $P < .05$.
GMFCS, Gross Motor Function Classification System; SE, standard error; CI, confidence interval.

Table 4 Interclass correlation coefficient, SE of measurement for repeated measures, and minimal detectable change scores at 95% confidence intervals for Obstacle and Curb tests

Test	GMFCS level	Test	Retest	$ICC_{2,1}$ (95% CI)	SEM	MDC_{95}(%)
Obstacles Test	I	7.94	7.66	0.97	0.94	0.99
Mean (SD)		(2.06)	(2.64)	(0.91–0.99)		(12.47)
	II	14.33	14.13	.90	0.70	1.94
		(2.22)	(1.42)	(0.66–0.97)		(13.73)
	III	19.94	19.53	0.63	0.81	2.24
		(1.33)	(1.43)	(0.45–0.91)		(11.47)
Curb Test	I	5.26	4.85	0.98	0.29	0.81
Mean (SD)		(2.06)	(1.84)	(0.87–0.99)		(16.63)
	II	13.40	12.68	0.91	0.61	1.69
		(2.03)	(1.99)	(0.58–0.98)		(13.30)
	III	40.51	39.75	0.90	1.16	3.23
		(3.69)	(2.43)	(0.62–0.98)		(8.13)

CI, confidence interval; GMFCS, Gross Motor Function Classification; ICC, interclass correlation coefficient; MDC, minimum detectable change.

In the current study, the time separating the test and retest (30 min) was longer than that of Kane *et al*.'s study (15 min) to ensure that the rest time was appropriate and that fatigue was not present to bias the test scores. Similarly, re-applying the test on the same day was in agreement with the practices of previous studies concerning mTUG test-retest reliability [47,48].

On the basis of our results, if a change between the repeated tests exceeded the MDC_{95} of both tests, the examiner can be 95% confident that the differences are not due to measurement errors or variabilities among participants. As a result of the nature of the heterogeneity of the children with CP, the MDC_{95} was investigated for each GMFCS level separately. It appeared that the absolute reliability among the GMFCS levels increased when the functional disability increased. Examiners can identify changes beyond those expected from measurement error and individual variability using the SEM and MDC_{95} values for each test. This information will help in monitoring performance changes over time and assessing the effectiveness of exercise interventions in children with CP. The current study was the first to establish the MDC of the Obstacles and Curb tests.

Limitations and recommendations

The participants were drawn from a convenience sample, and the number of participants in each GMFCS level was relatively small. Therefore, more research with a larger sample should be conducted. Other psychometric properties, such as inter-rater reliability, should be established. It is advised to investigate the psychometric characteristics of these tests in relation to other pediatric diseases, such as spina bifida.

Conclusion

On the basis of the empirical evidence, we conclude that the Obstacles and Curbs tests have adequate psychometric properties for children with CP aged 6–12 years at GMFCS Levels I, II, and III. They are suitable for children with or without walking aids. Both tests had the ability to discriminate between children with CP and typically developing children and between different GMFCS levels (I–III). Both tests offer the capability of testing walking abilities on uneven surfaces.

Acknowledgements

We would like to express our gratitude to the families and children who participated in this study. Conceptualization: M.F.A., B.A.A., and A.A.M.S. Methodology: M.F.A., B.A.A. and A.A.M.S. Formal analysis: M.F.A. and A.A.M.S. Investigation: M.F.A., B.A.A., and A.A.M.S. Resources: A.A., M.M.A., and S.F.A. Data curation: B.A.A. Writing – original draft preparation: M.F.A., B.A.A., and A.A.M.S. Writing – review & editing: M.F.A., B.A.A., A.A.M.S., A.A., M.M.A., and S.F.A. Visualization: A.A., M.M.A., and S.F.A. Supervision: M.F.A. Project administration: B.A.A. The study was approved by the research ethics committees of the College of Medicine, King Saud University (Reference Number 20/0802/IRB) and Sultan Bin Abdulaziz Humanitarian City (Reference Number 34-2020-IRB). Permission from the children recreational centers was obtained. Prior to participation, written informed consent was obtained from a parent/legal guardian, and verbal or written assent from the children. The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of the research participants.

Conflicts of interest

There are no conflicts of interest.

References

1 Papavasiliou A, Ben-Pazi H, Mastroyianni S, Ortibus E. Editorial: cerebral palsy: new developments. *Front Neurol* 2021; **12**:1378–1381.
2 Aravamuthan B, Fehlings D, Shetty S, Fahey M, Gilbert L, Tilton A, *et al*. Variability in cerebral palsy diagnosis. *Pediatrics* 2021; **147**:e2020010066.
3 WHO. *International classification of functioning, disability, and health: children & youth version: ICF-CY*. World Health Organization; 2007.
4 Nelson J, Boyer E. Perceived limitations of walking in individuals with cerebral palsy. *Phys Ther* 2021; **101**:1–9.

5 Graser J, Letsch C, Van Hedel H. Reliability of timed walking tests and temporo-spatial gait parameters in youths with neurological gait disorders. *BMC Neurol* 2016; **16**:1–12.
6 Begnoche D, Chiarello L, Palisano R, Gracely E, McCoy S, Orlin M. Predictors of independent walking in young children with cerebral palsy. *Phys Ther* 2016; **96**:183–192.
7 Malone A, Kiernan D, French H, Saunders V, O'Brien T. Do children with cerebral palsy change their gait when walking over uneven ground? *Gait Posture* 2015; **41**:716–721.
8 Malone A, Kiernan D, French H, Saunders V, O'Brien T. Obstacle crossing during gait in children with cerebral palsy: cross-sectional study with kinematic analysis of dynamic balance and trunk control. *Phys Ther* 2016; **96**:1208–1215.
9 McDowell B. The gross motor function classification system-expanded and revised. *Dev Med Child Neurol* 2008; **50**:725.
10 Narayanan UG. Management of children with ambulatory cerebral palsy: an evidence-based review. *J Pediatr Orthop* 2012; **32**:S172–S181.
11 Pawłowski M, Gąsior J, Bonikowski M, Marek D. The use of selected walk tests for gait assessment in children and adolescents with cerebral palsy. *Child Neurol* 2015; **24**:13–17.
12 Chrysagis N, Skordilis E, Koutsouki D. Validity and clinical utility of functional assessments in children with cerebral palsy. *Arch Phys Med Rehabil* 2014; **95**:369–374.
13 Held S, Kott K, Young B. Standardized Walking Obstacle Course (SWOC): reliability and validity of a new functional measurement tool for children. *Pediatr Phys Ther* 2006; **18**:23–30.
14 Kott KM, Held SL, Giles EF, Franjoine MR. Predictors of standardized walking obstacle course outcome measures in children with and without developmental disabilities. *Pediatr Phys Ther* 2011; **23**:365–373.
15 Duarte N, Grecco L, Franco R, Zanon N, Oliveira C. Correlation between pediatric balance scale and functional test in children with cerebral palsy. *J Phys Ther Sci* 2014; **26**:849–853.
16 Chen C, Shen I, Chen C, Wu C, Liu W, Chung C. Validity, responsiveness, minimal detectable change, and minimal clinically important change of pediatric balance scale in children with cerebral palsy. *Res Dev Disabil* 2013; **34**:916–922.
17 Ammann-Reiffer C, Bastiaenen C, De Bie R, van Hedel H. Measurement properties of gait-related outcomes in youth with neuromuscular diagnoses: a systematic review. *Phys Ther* 2014; **94**:1067–1082.
18 Balasubramanian C, Clark D, Fox E. Walking adaptability after a stroke and its assessment in clinical settings. *Stroke Res Treat* 2014; **2014**:1–21.
19 Musselman K, Brunton K, Lam T, Yang J. Spinal cord injury functional ambulation profile: a new measure of walking ability. *Neurorehabil Neural Repair* 2011; **25**:285–293.
20 Kane K, Lanovaz J, Bisaro D, Oates A, Musselman K. Preliminary study of novel, timed walking tests for children with spina bifida or cerebral palsy. *SAGE Open Med* 2016; **4**:1–8.
21 Almass BA, Algabbani MF, Shaheen AA, Alqabbani S. Normative normative reference values for obstacles test and curb test and their correlation with demographic characteristics: a cross-sectional study in Saudi children. *Int J Rehabil Res* 2022; **10**:1097.
22 Arifin W. A web-based sample size calculator for reliability studies. *Educ Med J* 2018; **10**:67–76.
23 Thompson P, Beath T, Bell J, Jacobson G, Phair T, Salbach N, *et al*. Test-retest reliability of the 10-metre fast walk test and 6-minute walk test in ambulatory school-aged children with cerebral palsy. *Dev Med Child Neurol* 2008; **50**:370–376.
24 Dhote S, Khatri P, Ganvir S. Reliability of 'modified timed up and go' test in children with cerebral palsy. *J Pediatr Neurosci* 2012; **7**:96–100.
25 Al-Toaimi NS, Shaheen AAM, Algabbani MF, Gawad RFM. Reference values for the modified timed up and go test in Saudi children aged 4–12 years old in Riyadh City: cross-sectional study. *Ann Med* 2021; **53**:1905–1913.
26 Carey H, Martin K, Combs-Miller S, Heathcock J. Reliability and responsiveness of the timed up and go test in children with cerebral palsy. *Pediatr Phys Ther* 2016; **28**:401–408.
27 Nicolini-Panisson R, Donadio M. Normative values for the timed 'up and go' test in children and adolescents and validation for individuals with Down syndrome. *Dev Med Child Neurol* 2014; **56**:490–497.
28 Gan S, Tung L, Tang Y, Wang C. Psychometric properties of functional balance assessment in children with cerebral palsy. *Neurorehabil Neural Repair* 2008; **22**:745–753.
29 Williams E, Carroll S, Reddihough D, Phillips B, Galea M. Investigation of the timed 'up & go' test in children. *Dev Med Child Neurol* 2005; **47**:518–524.
30 Zaino C, Marchese V, Westcott S. Timed up and down stairs test: preliminary reliability and validity of a new measure of functional mobility. *Pediatr Phys Ther* 2004; **16**:90–98.
31 Franjoine M, Gunther J, Taylor M. Pediatric balance scale: a modified version of the berg balance scale for the school-age child with mild to moderate motor impairment. *Pediatr Phys Ther* 2003; **15**:114–128.
32 Yi S, Hwang J, Kim S, Kwon J. Validity of pediatric balance scales in children with spastic cerebral palsy. *Neuropediatrics* 2012; **43**:307–313.
33 Her J, Woo J, Ko J. Reliability of the pediatric balance scale in the assessment of the children with cerebral palsy. *J Phys Ther Sci* 2012; **24**:301–305.
34 Ko J, Kim G. Test-retest, inter-rater, and intra-rater reliability of a pediatric balance scale in children with cerebral palsy. *J Korean Soc Phys Ther* 2010; **22**:43–48.
35 Louer A, Simon D, Switkowski K, Rifas-Shiman S, Gillman M, Oken E. Assessment of child anthropometry in a large epidemiologic study. *J Vis Exp* 2017:e54895.
36 Araujo L, Silva L. Anthropometric assessment of patients with cerebral palsy: which curves are more appropriate? *J Pediatr (Rio J)* 2013; **89**:307–314.
37 Stevenson R. Use of segmental measures to estimate stature in children with cerebral palsy. *Arch Pediatr Adolesc Med* 1995; **149**:658.
38 Lamounier J, Marteletto N, Calixto C, Andrade M, Tibúrcio J. Stature estimate of children with cerebral palsy through segmental measures: a systematic review. *Rev Paul Pediatr* 2020; **38**:e2018185.
39 Hastad DN, Lacy AC. *Measurement and evaluation in physical education and exercise science*. Gorsuch Scarisbrick; 1994.
40 Shah A. Correlation vs. regression: a review. *Int J Social Impact* 2020; **5**:151–162.
41 Unal I. Defining an optimal cut-point value in ROC analysis: an alternative approach. *Comput Math Methods Med* 2017; **2017**:1–14.
42 Cohen J. *Statistical power analysis for the behavioral sciences*. Elsevier Science; 2013.
43 Mukaka MM. A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J* 2012; **24**:69–71.
44 Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 2016; **15**:155–163.
45 Gilbertson TJ, Bjornson KF, McDonald C, Hafner BJ. Clinical gait measures for ambulatory children with cerebral palsy: a review. *J Prosthet Orthot* 2016; **28**:2–12.
46 Niiler TA. Assessing dynamic balance in children with cerebral palsy. *Cerebral Palsy* 2020:695–726.
47 Lans C, Cider A, Nylander E, Brudin L. Test-retest reliability of six-minute walk tests over a one-year period in patients with chronic heart failure. *Clin Physiol Funct Imaging* 2020; **40**:284–289.
48 Mesquita R, Janssen D, Wouters E, Schols J, Pitta F, Spruit M. Within-day test-retest reliability of the timed up & go test in patients with advanced chronic organ failure. *Arch Phys Med Rehabil* 2013; **94**:2131–2138.