Reliability and Validity of The Brief-Balance Evaluation Systems Test (Brief-BESTest) in Children with Cerebral palsy

ความเชื่อถือได้และความตรงของการใช้แบบประเมิน The Brief-Balance Evaluation Systems Test (Brief-BESTest) ในเด็กสมองพิการ

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ABSTRACT

Background: Poor balance is one of the problems in children with cerebral palsy (CP) that it causes difficulties with functional tasks involved in activities of daily living.

Objective: To study the reliability and validity of the Brief-Balance Evaluation Systems Test (Brief-BESTest) to determine balance and gross motor function in children with CP.

Methods: This study was a descriptive cross-sectional study designed by convenience sampling from the Regional Special Education Center in the South of Thailand. Children with CP classified by GMFCS-E&R level I-III aged 5–15 years. Participants were evaluated by Brief-BESTest, Pediatric Balance Scale (PBS) and Gross Motor Function Measurement (GMFM-88: Dimension D&E). At the first assessment, they were recorded with videotape during the test to repeated assessment after a two-week interval for intra-rater and inter-rater reliability by four raters. For concurrent and convergent validity, the Spearman's correlation (ρ) was used to analyze the correlation between Brief-BESTest and PBS to assess balance and correlation between Brief-BESTest and GMFM-88 (Dimension D&E) for gross motor function.

Results: Sixteen children with CP, aged 7.69±0.69 years old were recruited. Brief-BESTest had high intra-rater ($ICC_{3,1}$=0.99) and inter-rater reliability ($ICC_{2,4}$=0.95) and also showed the significant correlation with PBS (ρ=0.93, p-value<0.05) and GMFM-88 (Dimension D&E) (ρ=0.86, p-value<0.05).

Conclusion: Brief-BESTest has good reliability and validity in assessing balance and also reveals a gross motor function for children with CP. Brief-BESTest is easily and quickly test along with can distinguish each item of postural control.

Keywords: Balance, Cerebral palsy, Gross motor function, Brief-BESTest, Reliability

บทคัดย่อ

ที่มาและความสำคัญ: เด็กสมองพิการมีปัญหาด้านการควบคุมการทรงตัวหรือการรักษาสมดุลของร่างกาย นับเป็นสาเหตุหนึ่งที่ส่งผลให้มีความยากลำบากในการเคลื่อนไหวหรือการทำกิจวัตรประจำวัน

วัตถุประสงค์: เพื่อศึกษาความเชื่อถือได้และความตรงของการใช้แบบประเมินการทรงตัว Brief-Balance Evaluation Systems Test (Brief-BESTest) และการเคลื่อนไหวของกล้ามเนื้อมัดใหญ่ในเด็กสมองพิการ

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วิธีการวิจัย: รูปแบบของการศึกษานี้เป็นการพรรณนาแบบภาคตัดขวาง มีการสุ่มตามความสะดวกจากศูนย์การศึกษาพิเศษในเขตภาคใต้ในการคัดอาสาสมัครเข้าร่วมงานวิจัย โดยเป็นเด็กสมองพิการที่มีระดับความสามารถในการเคลื่อนไหวจำแนกด้วยระบบ GMFCS-E&R I-III อายุ 5-15 ปี อาสาสมัครได้รับการประเมินการทรงตัวด้วย Brief-BESTest และ Pediatric Balance Scale (PBS) และประเมินการเคลื่อนไหวของกล้ามเนื้อมัดใหญ่ด้วย Gross Motor Function Measurement (GMFM-88: Dimension D&E) ผู้วิจัยบันทึกวิดีโอเทปในการประเมินครั้งแรกและประเมินซ้ำจากภาพวิดีทัศน์หลังจากครั้งแรก 2 สัปดาห์ เพื่อวิเคราะห์ความเชื่อถือได้ภายในและระหว่างบุคคล โดยมีผู้ประเมินทั้งหมด 4 คน สำหรับการหาค่าความตรง (Concurrent และ Convergent validity) ใช้สถิติ Spearman Correlation (ρ) วิเคราะห์ความสัมพันธ์ของการประเมินการทรงตัวระหว่าง Brief-BESTest กับ PBS และระหว่างการประเมินการทรงตัวโดยใช้ Brief-BESTest กับการประเมินการเคลื่อนไหวของกล้ามเนื้อมัดใหญ่โดยใช้ GMFM-88 (Dimension D&E)

ผลการวิจัย: เด็กสมองพิการจำนวน 16 คน อายุเฉลี่ย 7.69+0.69 ปี ที่เข้าร่วมงานวิจัยครั้งนี้ ค่าความเชื่อถือได้ของการใช้ Brief-BESTest อยู่ในระดับสูงทั้งภายในบุคคล ($ICC_{3,1}$=0.99) และระหว่างบุคคล ($ICC_{2,4}$=0.95) และ Brief-BESTest มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับ PBS (ρ=0.93, p-value<0.05) และ GMFM-88 (Dimension D & E) (ρ=0.86, p-value<0.05)

สรุปผล: Brief-BESTest มีความเชื่อถือได้และความตรง เหมาะสมสำหรับการประเมินการทรงตัวและสะท้อนถึงความสามารถในการเคลื่อนไหวของกล้ามเนื้อมัดใหญ่ในเด็กสมองพิการได้ อีกทั้งการประเมินด้วย Brief-BESTest สามารถทำได้ง่าย รวดเร็ว และยังสามารถจำแนกถึงองค์ประกอบของการทรงตัวได้

คำสำคัญ: การทรงตัว เด็กสมองพิการ การทำงานของกล้ามเนื้อมัดใหญ่ Brief-BESTest ความเชื่อถือได้

Introduction

In the present, children with cerebral palsy (CP) are increasing throughout in Thailand.[1, 2, 3] According to the definition of CP, describes a group of permanent CP is a group of the development disorder of movement and posture that results in permanent disorder and leads to activity limitation. The main cause is a non-progressive disorder that occurred in the developing fetal or infant brain. CP often accompanied by disturbances of sensation, perception, cognition, communication, and behavior by epilepsy, and secondary musculoskeletal problems.[4] The deficits of motor and sensory systems involve abnormal muscle tone, poor coordination, and impaired postural control.[4] The static and dynamic balance, which involves the ability to recover from instability and anticipatory of children with CP are poorer than the typically developing children.[5,6] Poor balance leads to difficulties in performing everyday tasks as balance skills are a part of gross motor abilities.[4] Gross Motor Function Measure (GMFM) is widely used for assessing the motor function in children with CP.[7] The GMFM consists of 88 items grouped into five dimensions: (A) supine/ rolling, (B) sitting, (C) crawling/ kneeling, (D) standing and (E) walking/ running/ jumping which has many items in each dimension including static and dynamic balance as a component. [8] Kembhavi et al. (2002) reported that the dimensions D and E of the GMFM-88 were the best reflections about the

construct of balance as a component of overall gross motor function.[9]

There are many tools for assessing the static and dynamic balance of children with CP such as Time-one leg standing,[10] Functional Reach Test (FRT),[10] Timed Up and Go (TUG),[11] Five-times-sit-to-stand test,[12] Berg Balance Scale (BBS),[13] and Pediatric Balance Scale (PBS).[13] Gan and colleagues (2008) found that TUG, BBS and FRT were very strongly correlated with GMFM-88 (ρ=0.72-0.97).[14] Yi and colleagues (2012) also found strong correlations between PBS, GMFM-88, and GMFM-66.[15] In addition, Pediatric Balance Scale (PBS) is a modified version of the BBS including changes of (1) the ordering of items, and (2) reducing testing time in some items.[13] PBS is a reliable and valid balance test[16] and commonly used for examining children with CP.[13,16] It consists of 14 items similar to activities of daily living. The items are scored on 5 points (0, 1, 2, 3 or 4) with zero is an inability to perform the activity without assistance and four-point are the ability to perform the task with complete independence. Therefore the total score of PBS is 56 points.[17]

From the previous studies, Brief-Balance Evaluation Systems Test (Brief-BESTest) was used to assess for balance in individuals with different conditions, as well as multiple sclerosis,[18] chronic stroke,[19] and Parkinson's disease.[20] The Brief-BESTest is adapted from Balance Evaluation Systems Test (BESTest), that designed to assess a basic of elements of postural control in standing and walking such as (1) Biomechanical constraints, (2) Stability limitation, (3) Transitions-Anticipatory postural adjustment, (4) Reactive postural response, (5) Sensory orientation, and (6) Stability in gait. The higher scores can indicate the better of balance.[18] Brief-BESTest is a simple test, takes less time to administrate, and can represent each component of postural control.

However, the reliability and validity of using Brief-BESTest have not been evaluated in children. Therefore, it is essential to establish its reliability and validity before the Brief-BESTest can be used in typically children, especially children with CP. In addition, BESTest and Mini-Balance Evaluation Systems Test (Mini-BESTest) has been used to evaluate balance in typically developing children.[21] Although PBS is one of the popular tools to assess balance in children with CP and indicate 4-basic components of postural control which represent less than Brief-BESTest, PBS lacks the assessment of gait ability. GMFM-88 also reflects gross motor function in children with CP which balance is essential in the performance of activity daily living. Hence, the purposes of the study were to study (1) the reliability of Brief-BESTest and (2) the validity (Concurrent and convergent) of Brief-BESTest in children with CP.

Methods

This study was a descriptive cross-sectional study recruiting convenience participants from the Regional Special Education Center in the South of Thailand. Sixteen children with CP were recruited based on the following inclusion criteria: a diagnosis of CP, a functional classification of levels I, II or III of the Gross Motor Function Classification System-Expanded and Revised (GMFCS-E&R), aged between 5 to 15

years old, independent walking with or without gait aid, no impairment of visual and hearing which disturbed walking or participating in the study, and received consent from parents or caregiver to participate in this study. Ethical approval was obtained from the Human Research Ethics Committees of The University of Walailak (WUEC-18-013-01).

Brief-BESTest is the main measure of interest to assess balance in children with CP in this study. It consists of 8 items similar to activities of daily living. Each item is scored on a 3-point score, yielding a maximal possible score of 24. The higher score indicates better balance performance.[20] The items of Brief-BESTest are as follows: (1) Hip/ Trunk Lateral Strength, (2) Functional Reach Forward, (3) Stand on One Leg-Right, (4) Stand on One Leg-Left, (5) Compensatory Stepping-Lateral Right, (6) Compensatory Stepping-Lateral Left, (7) Stance With Eyes Closed on Foam Surface, and (8) Timed "Up & Go" Test. The test is performed with the participants clothed and making use of his/ her gait assistance device.[17]

Accordingly, the other commonly used balance measurement tool for children with CP, namely, the Pediatric Balance Scale (PBS), was also included. PBS contains 14 items.[22] Each item is scored on 4-point. The maximum score is 56 points with higher scores indicating better postural control.[23] Subsequently, gross motor function was assessed by Gross Motor Function Measurement (GMFM-88), consisting of 88 items grouped into 5 dimensions: (A) supine/ rolling (17 items), (B) sitting (20 items), (C) crawling/ kneeling (14 items), (D) standing (13 items), and (E) walking/ running/ jumping (24 items). However, this study used only D and E dimensions that are capable of ambulatory children with CP. It is scored by observation of a participant's performance on each item which is scored on a 4-point.[7] This study used a total score, which is obtained by adding the scores for 2 dimensions and dividing by 2 (Dimension D&E). Each dimension contributes equally to the total score (range 0-100 percent) which higher scores indicate better motor function.[7]

After the basic information of participants were recorded. The tests were performed in the following sequence of Brief-BESTest, PBS and GMFM-88 by 4 raters, respectively. During testing of the Brief-BESTest, the motor performance of all participants was recorded by videotape at the first assessment and the records were used for repeated assessments with a 2-week interval for intra-rater and inter-rater reliabilities. The intra-class correlation coefficient (ICC) was used for analyzing the intra-rater ($ICC_{3,1}$) and inter-rater reliability ($ICC_{2,4}$) of the Brief-BESTest total scores. The concurrent validity was analysed by the Spearman correlation coefficient (ρ) to evaluate correlations between the Brief-BESTest and PBS. The relationships between the results of Brief-BESTest and GMFM-88 (Dimension D&E) were also evaluated with Spearman correlation coefficient (ρ) to indicate convergent validity. All analyses were performed with SPSS version 17.0 statistic software. The significance level was set at p-value $\leq$ 0.05. Descriptive analysis (mean ± standard deviation) was carried out to describe

the performance on Brief-BESTest, PBS, GMFM-88 (Dimension D&E) test for children with CP of various GMFCS-E&R levels.

Results

Participants

A total of 16 children with CP who met the inclusion criteria were recruited from three Regional Special Education Centers in the South of Thailand including Trang province (n=3), Phuket province (n=4) and Nakhon Sri Thammarat province (n=9). They were aged from 5 years to 15 years old (mean 7.69 years). Of these, 2 participants were on asthma medication with the continuous onset of symptoms, and one participant received surgery to release right Achilles tendon for 1.3 years ago (Table 1). All participants received conventional physical therapy at least once a month. Table 2 demonstrates descriptive data of the 3 measures, Brief-BESTest, PBS, and GMFM-88 (Dimension D&E) in children with different GMFCS-E&R levels. It showed that children with CP at GMFCS-E&R level I are the best scores of all measurements followed by level II, III, respectively. Similarly, a higher score indicates better performance.

Reliability of Brief-BESTest

For intra-rater reliability of Brief-BESTest demonstrated excellent reliability ($ICC_{3,1}$=0.985; 95%CI = 0.958-0.995) (Table 3). Inter-rater reliability of 4-rater were also showed excellent reliability ($ICC_{2,4}$ =0.951, 95%CI=0.896-0.981) (Table 4). Moreover, all items of Brief-BESTest showed good to excellent intra-rater ($ICC_{3,1}$=0.722-0.991) and inter-rater reliability ($ICC_{2,4}$ =0.388-0.951) except the item-4: Stand on One Leg-Left showed low inter-rater reliability ($ICC_{2,4}$ =0.388).

Table1 Characteristic's participants

Characteristics (n=16)	Number; n, (%)
Gender	
Male (n, %)	10 (62.5%)
Female (n, %)	6 (37.5%)
Age (mean±SD)	7.69±0.688
GMFCS-E&R level*	
level I (n, %)	3 (18.75%)
level II (n, %)	7 (43.75%)
level III (n, %)	6 (37.5%)
Types of cerebral palsy	
Spastic diplegia (n, %)	3 (18.75%)
Spastic quadriplegia (n, %)	3 (18.75%)
Spastic hemiplegia (n, %)	5 (31.25%)
Ataxia (n, %)	4 (25%)
Dyskinesia (n, %)	1 (6.25%)
Gait aids	
None (n, %)	10 (62.5%)
Anterior walker (n, %)	4 (25%)
Posterior walker (n, %)	1 (6.25%)
Crutches (n, %)	1 (6.25%)

Note: *GMFCS-E&R level, Gross Motor Function Classification Expanded & Revised level

Concurrent and convergent validity

The relationship between Brief-BESTest and PBS was very strong (ρ=0.933, p-value< 0.001), which reveals the good concurrent validity between the Brief-BESTest and the PBS. Brief-BESTest was strongly correlated with GMFM-88

(Dimension D&E) (ρ=0.858, p-value<0.001), which shows good convergent validity. In addition, each item of Brief-BESTest showed low to high correlation with PBS and GMFM-88 (Dimension D&E). The strongest correlation particularly was Item 2: Functional Reach Forward (Table 5).

Table 2 Mean for Functional Balance Tests and Clinical Measures by Different GMFCS-E&R Level

GMFCS-E&R (n=16)	Brief-BESTest (Score) (Mean ± SD)	PBS (Score) (Mean ± SD)	GMFM-88 (%) (Mean ± SD)		
			Total	Dimension D	Dimension E
Level I-III (n=16)	8.44±1.408	27.25±3.953	49.78±23.56	55.28±5.81	44.26±6.85
- Level I (n=3)	13.67±2.404	45.33±3.667	72.72±10.82	65.80±15.12	79.62±4.41
- Level II (n=7)	11.29±1.128	33.29±4.116	61.71±14.53	68.86±5.60	54.55±5.64
- Level III (n=6)	2.50±1.118	11.17±2.386	24.38±8.75	34.18±6.12	14.57±1.17

Note: GMFCS-E&R Level; Gross Motor Function Classification Expanded & Revised level, Pediatric balance scale (PBS), Gross Motor Function Measure-88 (GMFM-88)

Table 3 Intra-rater reliability of Brief-BESTest (n=16)

Reliability of Brief-BESTest	Intra-rater reliability ($ICC_{3,1}$)	95 %CI
Total	0.985	0.958-0.995
– Item 1: Hip/Trunk Lateral Strength	0.810	0.455-0.933
– Item 2: Functional Reach Forward	0.959	0.883-0.986
– Item 3: Stand on One Leg-Right	0.722	0.203-0.903
– Item 4: Stand on One Leg-Left	0.742	0.261-0.910
– Item 5: Compensatory Stepping-Lateral Right	0.991	0.973-0.997
– Item 6: Compensatory Stepping-Lateral Left	0.991	0.973-0.997
– Item 7: Stance With Eyes Closed on Foam Surface	0.951	0.973-0.997
– Item 8: Timed “Up & Go” Test	0.989	0.967-0.996

Table 4 Inter-rater reliability of Brief-BESTest (n=16)

Reliability of Brief-BESTest	Inter-rater reliability ($ICC_{2,4}$)	95 %CI
Total	0.951	0.896-0.981
– Item 1: Hip/Trunk Lateral Strength	0.842	0.661-0.938
– Item 2: Functional Reach Forward	0.995	0.990-0.998
– Item 3: Stand on One Leg-Right	0.812	0.598-0.927
– Item 4: Stand on One Leg-Left	0.388	-0.311-0.761
– Item 5: Compensatory Stepping-Lateral Right	0.900	0.786-0.961
– Item 6: Compensatory Stepping-Lateral Left	0.866	0.713-0.948
– Item 7: Stance With Eyes Closed on Foam Surface	0.917	0.823-0.968
– Item 8: Timed “Up & Go” Test	0.896	0.777-0.959

Table 5: Correlation between Brief-BESTest, PBS and GMFM-88 (Dimension D&E).

Breif-BESTest	PBS (p-value)	GMFM-88 (Dimension D&E) (p-value)
Total	0.933[a](<0.001*)	0.858[a](<0.001*)
- Item 1: Hip/Trunk Lateral Strength	0.688[a](0.003*)	0.484[a](0.057)
- Item 2: Functional Reach Forward	0.808[a](<0.001*)	0.783[a](<0.001*)
- Item 3: Stand on One Leg-Right	0.525[a](0.037*)	0.570[a](0.021*)
- Item 4: Stand on One Leg-Left	0.298[a](0.262)	0.350[a](0.183)
- Item 5: Compensatory Stepping-Lateral Right	0.791[a](<0.001*)	0.701[a](0.002*)
- Item 6: Compensatory Stepping-Lateral Left	0.791[a](<0.001*)	0.701[a](0.002*)
- Item 7: Stance with Eyes Closed on Foam Surface	0.591[a](0.016*)	0.517[a](0.040*)
- Item 8: Timed “Up & Go” Test	0.750[a](0.001*)	0.753[a](0.001*)

Note: [a] Statistical analysis was performed using the Spearman’s correlation (ρ), *Significant p-value $\leq$ 0.05

Discussion

Reliability of Brief-BESTest

This study was the first study to examine the reliability of Brief-BESTest in children with CP who were classified as the GMFCS-E&R level I-III. Results showed good intra-rater and inter-rater reliabilities, which were in line with those results in adults with neurological conditions with and without a neurological diagnosis such as Parkinson disease, multiple sclerosis, and peripheral neuropathy. The previous study showed that the Brief-BESTest exhibited excellent

inter-rater reliability in with and without a neurological diagnosis (ICC=0.994).[18] In addition, Haung and colleagues (2017) used Brief-BESTest to determine the balance in chronic stroke subjects and also showed excellent intra-rater and inter-rater reliability (ICC=0.972 and 0.974, respectively).[19]

In our analysis of item 4, Stand on One Leg-Left in Brief-BESTest, showed fair inter-rater reliability ($ICC_{2,4}$=0.288). As this result, the raters were unclear score rating between 0-point (unstable) and 1-point (stand 2–10 seconds), including most of the participants had weakness on the left side. However, it was judged somewhat subjectively and may vary among different raters that caused the correlation less than other items. Our results were consistent with the previous study. Accordingly, for the reliability, it showed very excellent reliability regardless of the extent of their clinical experience.

Concurrent validity (The relationship between Brief-BESTest and PBS)

Our result showed a strong correlation between the Brief-BESTest and the PBS (ρ=0.933, p-value< 0.001). Accordingly, the previous study of Huang and colleagues (2017) showed a strong relationship in chronic stroke subjects (r_s=0.872, p-value<0.001).[19] This result reveals that Brief-BESTest can evaluate the ability of functional balance in children with CP. Therefore, Table 2 showed a higher score of Brief-BESTest, which indicates excellent balance performance as well as PBS. Both tests examine four elements of postural control as follows: Biomechanical constraints, Stability limitation, Transitions-Anticipatory postural adjustment, and Sensory orientation. Nevertheless, Brief-BESTest can reflect some components of postural control more than PBS, such as stability in gait: get up and go test.

Notably, this study showed the strongest relationship between item 2: Functional Reach Forward of Brief-BESTest and PBS (ρ=0.808, p-value<0.001) . Functional reach forward reflects the ability to control movement and balance when weight shifting in forwarding of the standing position. The result is the same way of the previous study that showed a strong correlation between BBS and Functional Reach Test (FRT) in children with CP (ρ= 0.840; p-value=0.01).[14] The weakly correlation is item 4: Stand on one leg-left of Brief-BESTest with PBS (ρ=0.298, p-value=0.262). Static stability control may be related to the leg-muscles strength[10] or the dominant leg.[19] Brief-BESTest evaluates both legs that are different from the PBS. PBS only assesses in the dominant leg.

Moreover, some participants in this study are spastic hemiplegia diplegia and quadriplegia that are a partial weakness on the left side. Therefore, the relationship between this item between Brief-BESTest and PBS is weak. However, all of the above reflects Brief-BESTest can be used to assess balance similarly to PBS and can discriminate postural control abilities in children with CP.

Convergent validity (The relationship between Brief-BESTest and GMFM-88 (Dimension D&E))

The Brief-BESTest was strongly correlated with the GMFM-88 (Dimension D&E)

(ρ=0.858, p-value<0.001), which reflects good convergent validity. It indicated that children with CP who have a good balance could do better daily activities. When determining the relationship in each item of Brief-BESTest and GMFM-88 (Dimension D&E), this study found that the items 2 showed the strongest correlation: Functional Reach Forward of Brief-BESTest (ρ=0.783, p-value<0.001). It reflected that the control stability of balance was related to the gross motor skills in daily activities.[14] On the other hand, items 4: Stand on one leg-left of Brief-BESTest showed a non-significantly weak correlation (ρ=0.350, p-value=0.183). It probably resulted from the different detail of total time to rate score on single leg standings between Brief-BESTest (if they took time less than 20 seconds, they were rated in 3-score) and GMFM-88 (if they took time less than 10 seconds, they were rated in 3-score). Skills and strength of the leg muscles might be concerned when considered the postural control of balance in children with CP.[10] This study demonstrated a high correlation between total score of Brief-BESTest and GMFM-88 (Dimension D&E) which indicated activities in GMFM-88 (standing, walking and jumping) were using balance.

This study had some limitations such as the age range of participants who were recruited according to inclusion criteria, which were quite narrow. Although Brief-BESTest is a short question to assess, it is appropriate for children who understand and follow an order. Moreover, it has not been studied in older children or adults with CP which may be different postural control from younger CP. Therefore, further study should be distributed participants in age-range groups and larger sample sizes that will be required to further investigate the optimal cut-off score of the Brief-BESTEST for discriminating the different severity levels of GMFCS-E&R in children with CP.

Conclusion

This was the first study to assess functional balance using Brief-BESTest for children with CP. Brief-BESTest is simple and had good reliability and validity and could be a useful tool in assessing the functional balance performance, which reflected gross motor function in children with CP.

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