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Comparison of the Pediatric Balance Scale and Fullerton Advanced Balance Scale for Predicting Falls in Children With Cerebral Palsy

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Abstract

Background: The Pediatric Balance Scale (PBS) and the Fullerton Advanced Balance (FAB) scale were used to assess balance function in patients with balance problem. These multidimensional clinical balance scales provide information about potential risk factors for falls.

Objects: The purpose of this study was to investigate and compare the predictive properties of the PBS and FAB scales relative to fall risk in children with cerebral palsy (CP) using a receiver operating characteristic analysis.

Methods: In total, 49 children with CP (boy=21, girl=28) who were diagnosed with level 1 or 2 according to the Gross Motor Function Classification System participated in this study. The PBS and FAB were performed, and verified cut-off score, sensitivity, specificity, and the area of under the curve (AUC).

Results: In this study, the PBS scale was as a predictive measure of fall risk, but the FAB was not significant in children with CP. A cut-off score of 45.5 points provided optimal sensitivity of .90 and specificity of .69 on the PBS, and a cut-off score of 21.5 points provided optimal sensitivity of .90 and specificity of .62 on the FAB. Both scales showed moderately accurate of AUC with .79 and .76, respectively.

Conclusion: The PBS is a useful screening tool for predicting fall risk in children with cerebral palsy, and those who score 45.5 or lower indicate a high risk for falls and are in need of balance intervention.

Key Words: Cerebral palsy, Fullerton advanced balance scale; Pediatric balance scale; Receiver operating characteristics.

Introduction

Cerebral palsy (CP) is a permanent neurological disorder resulting from damage to brain regions that control posture, movement, and balance, following abnormal development (prenatal) or injury to the developing brain (perinatal) (Rosenbaum et al, 2007). Neuromuscular deficits observed in children with CP include impaired motor control, disturbances of sensation, perception, cognition, and musculoskeletal problems (Rosenbaum et al, 2007; Shumway-Cook et al, 2003). In addition, lack of balance control and impaired movement and postural control disturb a child's right reaction, therefore increasing the risk of falling. Consequently, children with CP suffer from functional limitations and altered daily life activities (Franjoine et al, 2003; van der Heide et al, 2004).

Indeed, falls are the leading cause of functional disability in patient with neurological disorders. Fall-related injuries such as fractures, muscle injury and traumatic brain injury hinder independent activity and alter quality of life (Fortinsky et al, 2008; Legters, 2002). However, falls may be prevented if the risk factors, such as balance dysfunction, are diagnosed through early assessment and treatment plans designed to decrease the risk of falling are followed (Hernandez and Rose, 2008; Tinetti et al, 1994). For this purpose, a reliable and valid assessment is needed to evaluate balance dysfunction and to identify the risk of falling. The validation of such

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assessment is additionally important to evaluate improvement in balance following treatment and to predict the prognosis of patients in clinical settings (Franjoine et al, 2003; Hernandez and Rose, 2008).

Clinical balance scales are effective assessment tools to evaluate various dimensions of postural control, such as static or dynamic postural control as well as feedforward and feedback postural control (Schlenstedt et al, 2016). Particularly, multidimensional clinical balance scales have the advantage of providing a detailed description of symptoms and information about potential risk factors for falls that could be used to justify and plan the treatment (Li et al, 2012; Smania et al, 2010).

For a long time, the Pediatric Balance Scale (PBS), a modified version of the Berg Balance Scale (BBS), has been reliably used to assess balance in children with CP, delayed development, and other neurological disorders (Darr et al, 2015; Verbecque et al, 2015). Specifically, the PBS allows evaluation of balance dysfunction in a time dependent manner, including changes with age and treatment (Darr et al, 2015; Franjoine et al, 2003). Because PBS is easy to use and requires minimal equipment, it has been widely applied and therefore, translated into at least nine different languages (Darr et al, 2015). However, the PBS has several limitations. First, it does not include items that assess dysfunction of the multiple sensory systems such as the visual and vestibular systems associated with balance function during gait. Second, it is not suitable for assessing balance in a higher functioning children aged over 6 years due to a ceiling effect (Franjoine et al, 2003; Franjoine et al, 2010).

Recently, the Fullerton Advanced Balance (FAB) scale has been validated and compared with the existing balance assessment tools, such as BBS, to assess postural control in patients with neurological disorders (Schlenstedt et al, 2016). The FAB scale is a performance-based measure that was developed to identify the subtle changes in balance and comprehensively approach the multiple dimensions of balance (Rose et al, 2006). It includes items that are specifically designed to assess the balance abilities in higher functioning individuals and to assess the multiple dimensions of balance including both static and dynamic environments, and reactive postural control (Boulgarides et al, 2003; Brauer et al, 2000).

Sensitivity and specificity are the main measures used for evaluation of test accuracy in the diagnostic test with dichotomous outcome evaluation (Swets, 1979). Generally, sensitivity is the proportion of correctly classified cases among all of those that are truly positive, and specificity is the proportion of correctly classified cases among all of those that are truly negative (Eng, 2005). The sensitivity and specificity vary across the different threshold, and the sensitivity is inversely related with specificity. The plot of sensitivity versus (1-specificity) is called a receiver operating characteristic (ROC) curve. The area under the ROC curve (AUC), has been considered an effective measure of accuracy with meaningful interpretations. This curve plays a central role in evaluating diagnostic ability of tests to discriminate the true state of subjects, finding the optimal cut off values, and comparing two alternative diagnostic tasks when each task is performed on the same subject (Hajian-Tilaki, 2013; Hanley and McNeil, 1982).

Several studies have been conducted to assess balance function, and the reliability and validity of the Korean version of PBS (KPBS) has been verified (Ko et al, 2008; Lim, 2016). However, to date, no studies that verify the prospective use of KPBS to assess falls have been conducted. Although, the FAB is able to predict recurrent fallers from non-recurrent fallers with a sensitivity and specificity in healthy older adults, it remains unclear whether this scale is appropriate to predict falls in children with CP (Hernandez and Rose, 2008; Schlenstedt et al, 2016).

The purpose of the this study was to investigate and compare the predictive properties of PBS and FAB scales relative to fall risk in children with CP.

Methods

Participants

Forty-nine children (boy=21, girl=28) with CP participated in this study. All participants met the inclusion criteria of being clinically diagnosed with level 1 or 2 according to the Gross Motor Function Classification System. In this system, level 1 indicates that the child is able to climb stairs without the use of a railing, and level 2 indicates that the child is able to walk with physical assistance or use handheld mobility devices (Rosenbaum et al, 2002). Children were excluded from the study if they met any of the following criteria: (1) a history of any orthopedic injuries within the previous three months, (2) any medical conditions that resulted in activity restriction, and (3) a history of any uncontrolled seizures within the previous six months. The general characteristics of the participants are presented in Table 1.

Procedures

Prior to initiation of the study, parents or guardians of all participants were sufficiently informed regarding the research purposes and procedures. They agreed to the publishing of their study data, and signed informed consent forms. All participants completed a general characteristics questionnaire documenting their medical history, sex, age, and fall frequency. The participants were assessed randomly to evaluate their balance ability using the PBS and FAB scales. Any criterion that was duplicated between the PBS and FAB scales was performed only once, and scored on each scale to minimize learning effect and fatigue. Fall history was recorded by asking the participants how often they had fallen during the last six months, and two or more falls were regarded as a positive fall history (Shumway-Cook et al, 2000). A fall was defined as any event that led to an unplanned, unexpected contact with a supporting surface. Falls resulting from unavoidable environmental hazards, such as a chair collapsing, were excluded (Shumway-Cook et al, 1997; Shumway-Cook et al, 2000).

Instruments

The PBS was developed as a modified version of the BBS to identify balance dysfunction in school-age children with motor deficits. It consists of 14 items; sitting to standing (item 1), standing to sitting (item 2), transfers (item 3), standing unsupported (item 4), sitting unsupported (item 5), standing with eyes closed (item 6), standing with feet together (item 7), standing with one foot in front (item 8), standing on one foot (item 9), turning 360 degrees (item 10), turning to look behind (item 11), retrieving object from floor (item 12), placing alternate foot on stool (item 13), reaching forward with

Table 1. Demographic characteristics of the participants (N=49)

Parameters	Fallers (n_1=24)	Non-fallers (n_2=25)	Total
Boy	8	13	21
Girl	16	12	28
Hemiplegia	7	19	26
Diplegia	17	6	23
Age (year)	11.4±3.5[a]	11.4±2.5	11.4±2.9
Fall frequency	3.6±2.2	.8±.4	2.2±2.0
Total PBS[b] score	39.8±7.8	50.5±2.9	45.2±7.9
Total FAB[c] score	17.3±9.0	29.3±5.3	23.4±9.5

[a]mean±standard deviation, [b]pediatric balance scale, [c]Fullerton advanced balance scale.

outstretched arm (item 14). In PBS, the concept of functional balance is defined that the ability of a child to gain and maintain upright posture control during childhood activities of daily living, school, and play. Each item is scored on a 5-point scale (range 0~4) with specific qualitative and quantitative scoring criteria. The total score can range from 0 to 56, and a lower score indicates greater balance disability. The PBS has a high test-retest reliability [Intra-class correlation coefficient (ICC)=.998] and inter-rater reliability (ICC=.997) (Darr et al, 2015; Franjoine et al, 2003).

The FAB, multi-item balance assessment tool, was initially developed to assess postural control in higher functioning individuals. It consisted of 10 items; standing with feet together and eyes closed (item 1), reaching forward to retrieve an object (item 2), turning in a circle (item 3), stepping up and over a bench (item 4), tandem walking (item 5), standing on one leg (item 6), standing on foam with eyes closed (item 7), jumping for distance (item 8), walking with head turns (item 9), and recovering from an unexpected loss of balance (item 10). Each item is scored on a 5-point Likert scale (range 0~4), with 0 indicating that the person is unable to perform and 4 indicating the highest performance level. The total score ranges from 0 to 40, a score 25 or lower indicates a high risk of falling. The FAB scale has also a high test-retest reliability (r=.96), and inter-rater reliability (r=.91~.95). Moreover, it correlates with the BBS (r=.75, p<.001) (Hernandez and Rose, 2008; Klein et al, 2011; Rose et al, 2006).

Statistical analysis

For statistical analysis, SPSS ver 18.0 (SPSS Inc., Chicago, IL, USA) was used. Two statistical measures were used to examine the fall risk predictive properties of the PBS and FAB scales. First, a binary logistic regression analysis was performed on the basis of the total PBS and FAB scores, to investigate a predictive model for fall risk. Second, an ROC analysis was conducted for each balance scale to determine the cut-off score that provides the optimal level of sensitivity and specificity.

Results

Predicted probability of falling as a function of the PBS and FAB scale

The results of the binary regression analysis showed that a test of the full model was significantly reliable (N=49, χ^2=34.88, p<.001), and indicated the total PBS score was predictive of fall risk. The Hosmer-Lemeshow test, which is used to formally evaluate the goodness-of-fit for logistic regression models, was not statistically significant (p=.99), indicating that the assessed model was good. The overall prediction success rate was 79.6% (Table 2). The total PBS was significant as a predictive variable for evaluating fall risk (p<.05) while the total FAB score was not (Table 3).

Predictive values for the PBS and FAB scales

The PBS and FAB scales showed comparable accuracy identifying fallers with two or more falls versus non-fallers, with an AUC of .79 and .76, respectively (Figure 1). In the PBS, a cut-off score of 45.5 points provided optimal sensitivity of .90 and

Table 2. Frequencies of test outcome for faller and non-faller

Observed	Predicted		
	Faller	Non-faller	Percentage correct (%)
Faller	20	5	80.0
Non-faller	5	19	79.2
Overall percentage			79.6

Table 3. Predicted probability of falling as a function of total PBS and FAB scores

	B	S.E	Wald	df	p	Exp (B)
Total PBS[a] score	.59	.25	5.65	1	.02*	1.79
Total FAB[b] score	-.56	.11	.27	1	.61	.95
Constant	-26.02	9.76	7.10	1	<.001	.00

[a]pediatric balance scale, [b]Fullerton advanced balance scale, *p<.05.

Table 4. Predictive values for the PBS and FAB scales

Test	AUC[a]	Cut-off score	Sensitivity	Specificity
PBS[b]	.79	≤45.5/56	.90	.69
FAB[c]	.76	≤21.5/40	.90	.62

[a]area under the curve, [b]pediatric balance scale, [c]Fullerton advanced balance scale.

specificity of .69. In the FAB scale, a cut-off score of 21.5 points provided optimal sensitivity of 0.90 and specificity of .62 (Table 4).

Discussion

The objective of the present study was to investigate the predictive properties of PBS and FAB relative to faller status in children with CP. For that, an ROC analysis was used to decide whether total PBS and FAB cut-off scores produced the optimal level of sensitivity and specificity. The basic assumption of ROC analysis is that a diagnostic variable is utilized to discriminate between two mutually exclusive states of tested participants. The diagnostic sensitivity and specificity are a function of the selected cut-off value. An ROC analysis assesses the diagnostic performance of the system in terms of sensitivity and (1-specificity) for each possible cut-off value of the test (Greiner et al, 2000). The AUC is a summary statistic of diagnostic accuracy. Swets (1988) proposed the arbitrary guideline to distinguish between non-informative (AUC<.5), less accurate (.5<AUC<.7), moderately accurate (.7<AUC<.9), highly accurate (.9<AUC<1) and perfect tests (AUC=1).

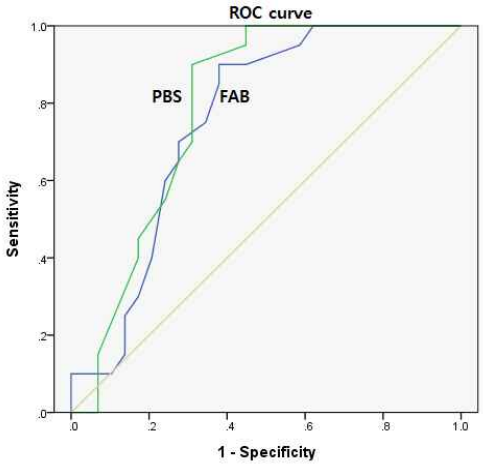

Figure 1. ROC curve of the PBS and FAB (ROC: receiver operating characteristic, PBS: pediatric balance scale, FAB: Fullerton advanced balance scale).

The binary logistic regression analysis indicated that the PBS is a predictive measure of faller status in children with CP. Specifically, whenever the total PBS score increase by one point, the probability of children with CP who were classified as a non-falling group increased 1.79. The AUC value of .79 and the optimal cut-off score of 45.5-points of the PBS provides optimal sensitivity and specificity on the PBS, with a good level of sensitivity (90%) but poor level of specificity (67%). This is in contrast with a previous study reporting a cut-off score from 23.3-points (age of 2 years 4 months) to 54.6-point (age of 13 years 7 months) in typically developing children (Franjoine et al, 2010). The higher PBS cut-off score may be because the participants in the

previous study comprised developing children with higher levels of functioning than in this study. Indeed, PBS values with a cut-off score of 45.5 points, higher than the mean of the total PBS score (45.2±7.9) indicate that the participants of this study were comprised of children with CP with lower level of balance ability.

The FAB scale was developed in order to (1) provide a functional balance measure that is less prone to the ceiling effect when assessing higher functioning individuals and (2) measure multiple dimensions of balance ability (Hernandez and Rose, 2008). Therefore, the FAB scale consists of more challenging items than many other clinical tools and is consequently more sensitive to subtle changes in balance functions (Hernandez and Rose, 2008; Klein et al, 2011; Rose et al, 2006).

Our present study shows that the FAB is not a significant predictive measure of fall risk in children with CP. However, the AUC value of .76 and the optimal cut-off score of 21.5 points provide optimal sensitivity and specificity on the FAB, with a good level sensitivity (90%) but poor level of specificity (62%). A previous study reported a cut-off score 27 points and poor sensitivity (67%) and specificity (58%) in Parkinson's patients (Schlenstedt et al, 2016), as well as a cut-off score 25 points and moderate sensitivity (74.6%) and poor specificity (52.6%) in older adults (Hernandez and Rose, 2008). The average of total FAB score (23.4±9.5) in this study was lower than the 25-points that indicate a high risk of falling. Since the participants of our present study are school age children with CP with a lower level of balance ability, their ability to perform the more difficult items included in the FAB is limited. Despite the fact that the PBS and FAB scale shows lower specificity, it is more important that they both demonstrate high sensitivity versus specificity.

This study has several limitations. First, the small sample size of our participants, the children with CP, cannot be considered as representative for the whole population with balance disability. This may limit the validity of generalizing our results to the entire population of children with balance disabilities. Second, this study was performed following a retrospective research design, whereby study participants provided information about the frequency of falls experienced in the previous 6 months, relying on a good memory recall. Further studies are needed that the use of prospective research design in which fall incidence occurrences are monitored in order to increase the reliability of the reports.

Conclusion

This study was conducted to investigate the validity of PBS and FAB as predictive measure of fall risk in children with CP. The present results suggest that PBS is a reliable predictive measure of faller status, demonstrating high sensitivity and moderate accurate of AUC value, in children with CP. In contrast, the FAB is not a significant predictive measure of fall risk, although it does show high sensitivity and moderately accurate of AUC value. Therefore, these scales are useful screening tools for identifying subtle changes in balance ability as well as a outcome measures for confirming the change after intervention.

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