

# Subjective Vs Objective Clinical Tools for Balance Assessment in Healthy Population

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## ABSTRACT

**Background:** The clinicians prefer subjective tools for balance assessment that are easily available and multiple researches have proved them reliable and valid for balance assessment. The force plate measures do the same postural analysis as we expect the other subjective tools to perform.

**Objectives:** To determine the correlation between subjective and objective standard tools of balance assessment in healthy population

**Material and method:** It was cross sectional observational study carried out at National institute of rehabilitation medicine (NIRM) Islamabad and Riphah international university Islamabad from January 2019 to June 2019. The sample size was calculated by using G power analysis graph, came out to be 64 for every age group. In this study non-probability purposive sampling technique was used. The inclusion criterion includes healthy individuals with 18-70 years of age (young (18-25 years), adult (25 -50 years), elderly (50-70 years) and both genders. Tools used in this research were BBS (Berg Balance Scale), POMA (The Performance-Oriented Mobility), TUG (Time Up and Go test), FRT (Functional Reach Test), Romberg test, SLS (Single Leg Stance), YBT (Y Balance Test) and Force plate.

**Results:** 192 total respondents were divided in equal distribution of 64 in three age groups of elderly, adults and young. In elderly group males were 49 and females were 15. In adult group males were 27 while females were 37. In young category total number of males were 27 while females were 37. Mean age and SD for elderly, adults and young were 57.3±5.51, 35.4±6.97 and 22.6±1.62 respectively. This study results were affirming the fact that force plate variables has significant correlations with subjective tools of balance. (YBT,  $r=0.3$  and SLS,  $r=0.8$ ).

**Conclusion:** This study concludes that force plate can replace or validate the subjective tools of balance that we use for different age groups. SLS (Single Leg Stance) is strongly and positively correlates with total AP sway on force plate, and shows strong negative correlation with AP standard deviation. YBT (Y-balance test) can also be validated or replaced for Total ML sway of force plate as it shows moderate correlation. On the other hand POMA, TUG, FRT shows weak and negative correlations with most of the force plate variables.

**Keywords:** BBS (berg balance scale), ML (mediolateral), SD (standard deviation), YBT (Y-balance test)

## INTRODUCTION

Assessment of balance is essential for majority of patients having physical therapy sessions to benefit them by establishing their accurate and optimal treatment plans, to increase the insight about risk of fall and advising patient required assistive devices according to their condition. Stability or control of posture depicts person's ability to keep an upright erect position while in a static and dynamic situation with or without any displacement.<sup>1, 2, 3</sup>

Functional and impairment grounded assessments are a significant element of rehabilitation training. Among the most frequently used measures for assessment of balance control in neuro-rehabilitation training includes different scales that based on performance observation. Yet, the overall score attained from those performance observing scales has inadequate ability to guide about specific problems related to each patient as it is easy for a patient to use compensatory strategies for achieving better scores on certain items<sup>4, 5</sup>.

According to biomechanics, the ability of a body to maintain its line of gravity within its base of support without any noticeable sway in posture is termed as balance. (6).

Impairment related to balance is usually associated with process of aging. Decrease in overall ability of visual, vestibular and somatosensory system systems with increasing age leads to decrease in balance control in elderly population which results in increased risk of falling among them. Adults past the age of 65 years are more prone to fall due to changes in their overall balance control system (4).

Since balance is a main predictor of recovery and plays vital role in so many of activities of daily living, it is frequently introduced into treatment regime by physiotherapists when dealing with elderly, those having neurological disorders, or to those determined it to be advantageous.(7)

A Balance exercise in patients with stroke has been augmented in the literature. Commonly used practices to help people with balance training includes standing or sitting practices using several progressions involving tilt board usage, reaching, changes in base of support, stair climbing exercises and varying the speed for gait training. Alternative method used to recover balance is perturbation training that involves an outside force given to an individual's center of mass to attempt it to change its base of support. The training type is determined by a qualified physiotherapist and will be subject to the severity and the nature of the stroke, recovery stage, and the extent of impairments post stroke (5).

Functional tests for assessment of balance targets the preservation of static and dynamic form of balance, while involving the change of center of mass or any form of perturbation or whether during clam stance. There are some standardized tests for the assessment of individual postural control and are widely used by various professional. Few of them are: Performance-Oriented Mobility Assessment (POMA), Romberg Test, Balance Efficacy scale, Functional Reach Test, Berg Balance Scale, Star Excursion Test, Timed Up and Go Test, Balance Evaluation Systems Test (BESTest), The Mini-Balance Evaluation Systems Test (Mini-BESTest)<sup>8-12</sup>

In order to reduce the struggle of interest, force plates are now being in use for assessing an individual balance in standing and upright erect posture. These force plates and other similar force measurement tools or instruments are used to evaluate forces that are generated externally. Various force plates are designed to measure ground reaction forces (GRF) externally in three planes simultaneously i.e. posterior-anterior, vertical and lateral-medial because of this three planar information, such force plates provide a comprehensive guide about individual interaction with the group<sup>2</sup>.

Due to current technological developments, a rising trend for assessment of balance has touch the new heights and using different methods for it, for instance, the observing of center of pressure (CoP), length of a path for a particular duration and the resultant of vector reaction of center of mass in accordance with the ground. Force plate is now being termed as "gold-standard" for laboratory grade measurement of center of pressure. There are various posturography systems available these days that utilizes patent software to measure CoP while performing different tasks.

With the help of these assessment options, it is quite an easy now to measure balance abnormalities. These systems uses sensory input test and evaluate the limitations of stability test by monitoring the subject's reaction time, velocity and ankle joint's range of motion.<sup>17</sup>

During the last 5 years, research has led us toward portable and comparatively low-priced devices which are efficient for the measurement of CoP with accuracy. There are many low-cost and customized force plates that are being incorporated into innovative dynamics so to produce a rising field for both assessments for clinical purposes and research that will help people throughout the globe, in Pakistan the availability of medical resources and procedures must be ensured, in developing countries there are less resources, low health literacy and awareness about disease.<sup>18,24,25,26,27,28,29,30</sup>

## MATERIAL AND METHODS

It was cross sectional observational study carried out at National institute of rehabilitation medicine (NIRM) Islamabad and Riphah international university Islamabad from January 2019 to June 2019 after getting approval from ethical review committee of Riphah College of Rehabilitation Sciences (RIPHAH/RCRS/REC/Letter-00504). The sample size was calculated by using G power analysis graph, came out to be 64 for every age group. In this study non-probability purposive sampling technique was used. The inclusion criterion includes healthy individuals with 18-70 years of age (young (18-25 years), adult (25 -50 years), elderly (50-70 years) and both genders. Any ailment causing individual to be physically dependent, uncontrolled diabetes, systemic hypertension, unfit cardiopulmonary status, stroke or paralysis of any etiology, neurological diseases, vestibular impairment, uncorrected visual impairment, orthopedic alterations like amputation / fracture, spinal deformities, foot, ankle, knee, hip complaints (major/ specific) in past 6 months, inability to stand without aids, poor scores in MMSE (less than 18) and those on drugs like antidepressants, anticonvulsants, sedatives or tranquillizer were excluded out of the study. Subjective and objective tools that are included in this study are as following;

**Berg Balance Scale:** Its psychometric properties have been very much surveyed, and the scale has demonstrated to be a legitimate and dependable proportion of equalization. The Berg Balance Scale has a high relative unwavering quality with between rater dependability assessed at 0.97 (95% CI 0.96 to 0.98) and intrarater dependability evaluated at 0.98 (95% CI 0.97 to 0.99).

**POMA test:** The Performance-Oriented Mobility Assessment (POMA) scale was created by Tinetti et al and first distributed in 1986. It is a generally utilized basic apparatus for surveying parity and portability in more seasoned individuals. The benefit of the POMA scale is its incorporation of both parity and walk parts (9). The Tinetti test has been suggested and generally utilized in the older to survey versatility, equalization and walk, and anticipate falls. Various forms can be found. An orderly writing inquiry recognized 37 productions on the Tinetti test and falls (13)

**Timed up and Go Test (TUG):** The Timed up and Go test (TUG) is a fundamental assessment of useful portability and measures the time expected to ascend from a seat, walk 3 m, pivot and come back to a situated position. Intratester and intertester dependability (ICC) have been accounted for as high, in old populaces, from .92-.99. The affectability and explicitness have been accounted for to be 87%.The TUG test has been utilized broadly in geriatric medication so as to assess walk and parity execution (14).

**Functional reach test:** Standing balance is basic for the protected and compelling execution of regular exercises. The Functional Reach Test (FRT), first depicted in the mid-1990s, is one of numerous trial of standing offset utilized with more established grown-ups and grown-ups with different pathologies and ailments. It has been consolidated, with adjustment, into a few equalization test batteries. There is proof for its dependability and its simultaneous prescient and known gathering's legitimacy among more established grown-ups (15)

**Romberg test:** The Romberg test is a suitable instrument to analyze tactile ataxia, a walk aggravation brought about by anomalous proprioception including data about the area of the joints. It is additionally demonstrated to be delicate and precise methods for estimating the level of disequilibrium brought about by focal vertigo, fringe vertigo and head trauma (16)

**Single leg stance test:** The One-Legged Stance Test (OLST) is a straightforward, simple and successful strategy to screen for equalization weaknesses in the youthful and more seasoned grown-up populace. To play out the test, the patient is told to remain on one leg without help of the furthest points or propping of the un-weighted leg against the position leg. The patient starts the test with the eyes open, rehearsing on more than one occasion on each side with his look fixed straight ahead (17)

**Y Balance Test:** The Y Balance Test (YBT) is an apparatus used to test an individual's hazard for damage. It very well may be utilized for both the upper quarter and lower quarter. The YBT for the lower quarter (LQYBT) has been altogether investigated as its convention depends on research done on the Star Excursion Balance Test. The Star Excursion Balance Test showed solid outcomes on its capacity to foresee LE damage in secondary school b-ball players, and the LQYBT has distinguished competitors at expanded hazard for damage (15)

**Force plate:** Force platforms or force plates are measuring instruments that measure the ground reaction forces generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Most common areas of application are medicine and sports. Force plates are known as an excellent teaching aid to demonstrate the kinematics and dynamics of motion and commonly used in biomechanics laboratories to measure ground forces involved in the motion of human. It is consisting of a metal plate with sensors attached to give an electrical output proportional to the force on the plate (18)

Every patient was asked to perform standard tests discussed above in detail as tools for balance and scores will be measured. After subjective assessment, objective assessment was done on force plate and data was calculated.

**Data analysis procedure:** Every patient was asked to perform standard tests discussed in detail as tools for balance and scores were be calculated. After subjective assessment, objective assessment was done on force plate and data was measured. For data analysis procedure, collected data was analyzed by using SPSS 21 (Statistical package for social sciences) software. In SPSS 21 software we entered all the data for each age group with their respective subjective tests data scores. Mean and standard deviation for each category was calculated. The normality of data was analyzed by using Shapiro Wilk test. Results showed that values for each variable was less than 0.05 which suggested data was not normally distributed so non-parametric tests were applied for data analysis. P value of normality for Berg balance, POMA, TUG, SLS in adults, SLS in young, Romberg's test with eyes open and closes were less than 0.01 that suggested data was skewed. Similarly, Normality value for functional reach test was 0.002 and Y-balance test came up with the value Of 0.007. Both values were less than 0.05 suggesting data was non-normally distributed. Above mentioned tests were subjective tools we used in our study, the only objective tool we used in this study was force plate, and we included six variables of force plate that included Medio-lateral mean with normality value of 0.004, Medio-lateral standard deviation with p value of 0.002, total Medio-lateral sway with p value of 0.014, antero-posterior mean with normality value of

0.003, Antero-posterior standard deviation with p value of 0.007, and total antero-posterior sway which has normality value of 0.138. Spearman's correlation coefficient was used to analyze the data with significance level of 5%. By the definition, spearman's correlation coefficient analysis was used to know the strength between each subjective test with force plate variables. We used correlation analysis to know the closeness of the relationship of variables used in our study. Strength of relation can be understood by the fact that if the value of correlation is 0.5 or above it indicates strong relation between the two variables.

**RESULTS**

A total of 192 subjects were included in the study. Subjects were divided in three age groups of elderly (50-70years) adults (25-50years) and young (18-25 years). Gender distribution of the study suggested that of 192 total respondents, we divided them in equal distribution of 64 in three age groups of elderly, adults and young. In elderly group males were 49(77%) and females were 15(23%). In adult group males were 27(42.2%) while females were 37(57.8%). In young category total number of males were 27(42.2%) while females were 37(57.8%) (Figure 1).

Study showed that mean and standard deviation for subjective tools of balance for elderly group was: BBS 50.56 ±4.96, POMA 23.66 ±2.93, FRT 12.61±2.59, TUG 13.70±3.42. Similarly, for adult group mean and standard deviation was 29.56±3.27 for SLS and 107.64±10.27 for Y-balance test. For young group SLS showed mean and standard deviation of 27.09±1.62 while for Romberg's test (eyes open) were 29.17±1.67 and mean and standard deviation values for Romberg's test (eyes close) were 12.98±1.7. (Table 1)

BBS correlation with force plate variables showed r and p value of 0.26 and 0.04 respectively, that showed berg balance mildly correlates with Medio-lateral mean of force plate. R and p values for Medio-lateral standard deviation were 0.08 and 0.53, for total Medio-lateral sway R and p values were 0.14 and 0.25 respectively. R value for antero posterior mean was -0.07 that shows inverse relation between these two components while p value was 0.56 which is insignificant. R and p values for antero-posterior standard deviation were 0.16 and 0.19 respectively. Total antero-posterior sway and berg balance showed no correlation and values were 0.06 and 0.59 for correlation coefficient and significance. (Table 2)

When POMA was correlated with force plate variables, it showed significance only with Medio-lateral standard deviation with significant value of 0.05 and R value of 0.24. While rest of force plate variables did not show any significance with POMA. R and p values for Medio-lateral mean were 0.20 and 0.11, they were mildly correlated. Total Medio-lateral sway showed no significance with R and p values of 0.06 and 0.63 respectively. Antero-posterior mean, antero-posterior standard deviation and total antero-posterior sway did not show any correlation with POMA and showed no significance. (Table 3)

When we correlated TUG with force plate variables it showed inverse relation between antero-posterior mean and total antero-posterior sway with R values of -0.08 and -0.014 respectively but p values for both were non-significant. There was no significance found between rest of the variables and TUG with p values >0.05. (Table 4)

FRT and force plate variables showed some interesting results. Medio-lateral mean and FRT showed mild correlation with R value of 0.24 while p value was significant (0.05). Antero-posterior standard deviation showed inverse or indirect relation with FRT with r value of -0.04 and p value of 0.72. R value for total Medio-lateral sway and FRT was 0.15 that shows a weak correlation. Rest of the variables did not show any correlation with FRT and p values were insignificant (>0.05). (Table 5)

Correlation between SLS and force plate variables showed negative or inverse correlation between Medio-lateral mean and antero-posterior standard deviation and SLS with r value of -

0.016 and -0.11 respectively. Medio-lateral standard deviation, total Medio-lateral sway and antero-posterior mean showed weak correlation with FRT with r values of 0.11, 0.16 and 0.13 respectively. Total antero-posterior sway did not show any correlation with FRT and p value was insignificant (>0.05). (Table 6)

Y-balance test and force plate variables correlation showed that Medio-lateral standard deviation, antero-posterior mean and total antero posterior sway are negatively correlated with r values of -0.11, -0.16 and -0.06 respectively. Total Medio-lateral sway showed moderate correlation with YBT with significant p value of 0.01. Remaining variables did not show any correlation with YBT and their p values were also insignificant. (Table 7)

SLS was correlated with force plate variables in adults and results showed that Medio-lateral mean, antero-posterior mean and antero-posterior standard deviation were in inverse relations with SLS with r values being -1.16, -0.03 and -0.85 respectively. While Medio-lateral standard deviation showed weak correlation with SLS and r value was 0.17. (Table 8)

In young we correlated Romberg's test with eyes open and eyes closed with force plate variables. With eyes open we saw that Medio-lateral mean and total Medio-lateral sway are inversely correlated and r value was -0.08 and -0.11 respectively. Total antero-posterior sway showed weak correlation with Romberg's eyes open condition with r value of 0.10. P values for all the variables of force plate were insignificant in this group (>0.05). (Table 9)

With eyes closed condition we saw that Medio-lateral mean, total Medio-lateral sway, antero-posterior standard deviation and total antero-posterior sway were inversely correlated and their r values were -0.22, -0.12, -0.16 and -0.01 respectively. P values for all force plate variables and Romberg's eyes close condition were insignificant (>0.05). (Table 10)

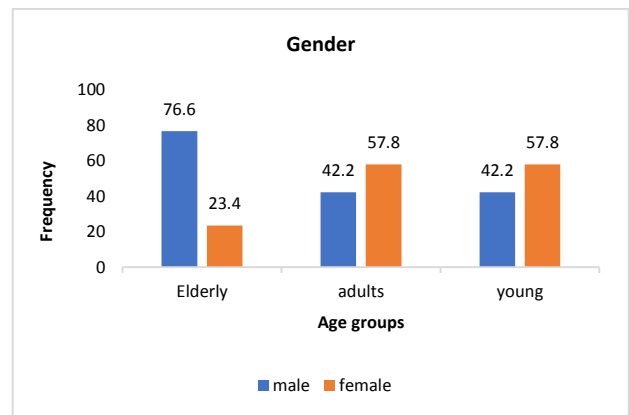


Figure 1: Graph showing gender distribution of participants

Table 1: Mean and SD of subjective tools

Subjective tools	Mean ± SD
Berg balance scale	50.56±4.96
Performance oriented motor assessment	23.66±2.93
Time up and go	13.70±3.42
Functional reach test	12.61±2.59
Single leg stance in adults	29.56±3.27
Y-balance test	107.64±10.27
Single leg stance in young	27.09±3.327
Romberg's with eyes open	29.17±1.68
Romberg's with eyes closed	12.98±1.76

Table 2: Correlation of berg balance test with force plate variables.

Berg balance test	r value	p value
Medio-lateral mean	0.259	0.04*
Medio-lateral standard deviation	0.080	0.528
Total Medio-lateral sway	0.146	0.250
Antero-posterior mean	-0.074	0.560
Antero-posterior standard deviation	0.162	0.197
Total antero-posterior sway	0.067	0.598

Table 3: Correlation of POMA with force plate variables

POMA	R value	p value
Medio-lateral mean	0.20	0.11
Medio-lateral SD	0.24	0.05*
Total Medio-lateral sway	0.06	0.63
Anterio-posterior mean	0.11	0.4
Anterio-posterior SD	0.1	0.43
Total anterio-posterior sway	-0.09	0.50

Table 4: Correlation of TUG with force plate variables

Time up and go	R value	p value
Medio-lateral mean	0.03	0.76
Medio-lateral SD	0.06	0.64
Total Medio-lateral sway	0.05	0.68
Anterio-posterior mean	-0.08	0.95
Anterio-posterior SD	0.11	0.36
Total anterio-posterior sway	-0.14	0.26

Table 5: Correlation of FRT with force plate variables

Functional reach tests	R value	p value
Medio-lateral mean	0.24	0.05*
Medio-lateral SD	0.02	0.82
Total Medio-lateral sway	0.15	0.21
Anterio-posterior mean	0.07	0.56
Anterio-posterior SD	-0.04	0.72
Total anterio-posterior sway	0.08	0.49

Table 6: Correlation of SLS with force plate variable

Variable Single leg stance	R value	p value
Medio-lateral mean	-0.016	0.89
Medio-lateral SD	0.11	0.38
Total Medio-lateral sway	0.16	0.18
Anterio-posterior mean	0.13	0.27
Anterio-posterior SD	-0.11	0.35
Total anterio-posterior sway	0.01	0.91

Table 7: Correlation of YBT with force plate variables

Y-balance test	R value	p value
Medio-lateral mean	0.08	0.49
Medio-lateral SD	-0.11	0.36
Total Medio-lateral sway	0.30	0.01*
Anterio-posterior mean	-0.16	0.20
Anterio-posterior SD	0.01	0.89
Total anterio-posterior sway	-0.06	0.59

Table 8: Correlation of SLS with force plate variables

Single leg stance	R value	p value
Medio-lateral mean	-1.16	0.20
Medio-lateral SD	0.17	0.17
Total Medio-lateral sway	0.01	0.93
Anterio-posterior mean	-0.03	0.81
Anterio-posterior SD	-0.85	0.50
Total anterio-posterior sway	0.98	0.44

Table 9: Correlation of Romberg's EO with force plate variables

Romberg's test with eyes open	R value	p value
Medio-lateral mean	0.08	0.52
Medio-lateral SD	0.09	0.46
Total Medio-lateral sway	-0.11	0.39
Anterio-posterior mean	0.06	0.62
Anterio-posterior SD	0.02	0.88
Total anterio-posterior sway	0.10	0.43

Table 10: Correlation of Romberg's EC with force plate variables

Romberg's test with eyes close	R value	p value
Medio-lateral mean in	-0.22	0.09
Medio-lateral SD	0.02	0.58
Total Medio-lateral sway	-0.12	0.35
Anterio-posterior mean	0.01	0.94
Anterio-posterior SD	-0.16	0.21
Total anterio-posterior sway	-0.01	0.94

**DISCUSSION**

The above explained results are affirming the fact that force plate variables have significant correlations with subjective tools of balance. If we start with the berg balance scale, this scale has been widely used in elderly static and dynamic balance assessment and has been proved most reliable and valid tool. We have studied six variables of force plate and we have assessed them for each individual and correlated with subjective tools of

balance. Results have shown that BBS scale was weakly correlated with ML mean with r value of 0.259 and showed p value of 0.04 which is less than significant p value (>0.05) Previous studies also show that there was moderate positive correlation between force place variables and subjective balance test.

In 2015 a study was conducted in Italy on mobility and balance evaluation, and they estimated the fall risks, which symbolize vital fundamentals for supporting a healthy aging process. In their study they examined the association between two close variables in community based elderly adults. They used the short physical performance battery as clinical-based test, and the laboratory-based assessments were acknowledged by means of output measures which they obtained with the Wii balance board. They observed poor correlation between clinical scores and laboratory measures for standing balance and sit to stand measures. These findings may appear to support the probability of using the Wii Balance Board for the assessment of balance and sit-to-stand abilities in elderly people. They concluded that health professionals also can use force plate with the clinical test for obtaining more useful information for their analysis (19)

Another study was conducted by Degani and Leonard in 2017 studied the effects of early stages of aging on postural sway by using traditional and latest postural indices from different domains. Eleven healthy young adults and fourteen healthy non-faller older adults were included in the study and they were asked to perform two postural tasks:(a) functional limits of stability and (b) untroubled bipedal stance for 120 s. Postural sway from temporal, spatial, frequency and structural domains were extracted from the body's center of pressure (COP) signals and its Incoherent and Wobbly components. Study results exposed a conservation of functional limits of upright stability in elderly complemented by faster, larger, and shakier body sway in both Medio-lateral and anterio-posterior directions; increased irregularity of body sway pattern in time in both directions; increased Medio-lateral sway frequency; and increased variability, velocity, area, and jerkiness of both tedious and wobbly components of the COP shift in the anterio-posterior direction (p < 0.02) (20)

In 2017 Troester observed the inter-test (between tests) and inter-trial (within test) reliability of single-leg landing measures and single-leg balance test performed in professional rugby union players using commercially available software (SpartaMARS, Menlo Park, USA) on a force plate. Twenty-four players participated in the study– re-test measures on two occasions, first being on the first training day (7 days apart) of two respective pre-season weeks following 48h rest and similar weekly training loads. Two 20s single- leg balance trials were performed with eyes closed condition on a force plate. Three single-leg landing trials were performed by jumping off two feet and landing on one foot in the middle of a force plate 1m from the starting position. Single-leg balance results proved acceptable inter-trial reliability (ICC = 0.60-0.81, CV = 11-13%) for anterio-posterior sway velocity, sway velocity, and Medio-lateral sway velocity variables. Acceptable inter-test reliability (ICC = 0.61-0.89, CV= 7-13%) was evident for all variables except Medio-lateral sway velocity on the dominant leg (ICC = 0.41, CV = 15%). Single-leg landing results only showed inter-trial reliability which is acceptable for force-based measures of relative peak landing force and impulse (ICC = 0.54-0.72, CV = 9-15%). Inter-test results indicated improved reliability through the averaging of three trials with force-based measures again demonstrating acceptable reliability (ICC = 0.58-0.71, CV = 7- 14%). Of the variables studied here, total sway velocity and relative landing impulse are the most reliable measures of single-leg balance and landing performance, respectively. In professional rugby union these measures should be considered for monitoring potential changes in postural control (21)

In 2016 Li Z and Liyang conducted a studied to evaluate the validity and reliability of center of pressure-based parameters for balance assessment. Two hundred and forty older adults were included in the study and they were evaluated by using the Berg Balance Scale and force platform at 1-week intervals. The Pearson

correlation coefficient and intra-class correlation coefficient were used to test validity and reliability respectively. Results showed that the Berg Balance Scale was moderate to good ( $r = -0.62$  to  $-0.88$ ) and the reliability of the 12 selected center of pressure measures was satisfactory (intra-class correlation coefficient =  $0.75-0.99$ ) and the validity between the parameters. Center of pressure-based parameters are valid and reliable measures in older adults.

In adolescents and young adults the Balance Error Scoring System (BESS) is a commonly used test. Portability and affordability of newer force plates has led to instrumentation of many clinical balance tests including the BESS. Regardless of the higher precision of force plate measures compared with clinical scoring, it is unclear if the instrumented BESS demonstrate concurrent validity and reliability when compared with the original BESS. The purpose of this study was to examine the reliability and concurrent validity of instrumented BESS testing using a commercially available force plate system. Thirty-six participants were included in the initial testing day (17 male/19 female,  $M = 15.9$  years,  $SD = 1.5$  years). The test-retest sample consisted of 26 participants who accomplished the same testing procedure after 1 week. For all testing sessions, participants performed the BESS while standing on a portable force plate system. Number of errors and sway velocity were acquired. Concurrent validity was established through correlation analysis examining the relationship between the original and the instrumented BESS scores. Reliability was established using Intraclass Correlation Coefficient (ICC) computed for the instrumented and the original BESS. Study results showed a significant moderate relationship exists between the total scores of the original and the instrumented BESS ( $r_s = 0.54$ ,  $p = 0.001$ ). Regardless of a range of reliability scores for the different conditions in the instrumented BESS ( $ICC_{3,1} = 0.19-0.61$ ) and the clinically scored BESS ( $ICC_{3,1} = 0.13-0.71$ ), the reliability score for the total test score was the same for the instrumented and the clinical test ( $ICC_{3,1} = 0.74$ ).

Although the instrumented BESS may appear to demonstrate concurrent validity against the original BESS, instrumentation did not improve its reliability. Future research should examine if the instrumented BESS demonstrates validity against laboratory level force plates and if it is able to overcome the ceiling effect reported for the clinical BESS test. (22)

The functional reach test (FRT) is widely used for assessing dynamic balance stability in elderly and pathological subjects. Force platforms (FPs) represent a fundamental part of the instrumented FRT experimental setup due to the central role of center-of-pressure (COP) displacement in FRT analysis. Recently, the Nintendo Wii balance board (NBB) has been suggested as a low-cost and reliable device for ground reaction force and COP measurement in poorly dynamic motor tasks. Therefore, this paper aimed to compare NBB-COP data with those obtained from a laboratory-grade platform during FRT. Data from 48 healthy subjects were simultaneously acquired from both devices. FP-COP and NBB-COP trajectories showed a remarkable correlation in both directions ( $r > 0.990$ ) and low root-mean square error values ( $1.14 \pm 0.88$  mm and  $0.55 \pm 0.28$  mm for anterior-posterior and medial-lateral direction). Fixed biases between COP-based parameters did not exceed 2% of the FP outcomes with high consistency throughout the present measurement range (ICC consistency always  $>0.950$ ). Only the COP mean velocity exhibited a tendency toward proportional errors, which can be adjusted by a calibration of NBB data. Findings of this paper confirmed the NBB validity for COP measurement in a widely used motor task as the functional reach, supporting the feasibility of NBB in research scenarios (23)

Our study has a limitation that only selective force plate variables were discussed and sample was collected from only two clinical settings due to limited time duration. We recommend future researchers to study force plate variables at large spectrum for exploring correlation at advance level.

## CONCLUSION

Results of this study conclude that force plate can replace or validate the subjective tools of balance that we use for different age groups. After all the above detailed discussion we have concluded that SLS is strongly and positively correlates with total AP sway on force plate, and shows strong negative correlation with AP standard deviation. YBT can also be validated or replaced for Total ML sway of force plate as it shows moderate correlation. On the other hand, POMA, TUG, FRT shows weak and negative correlations with most of the force plate variables.

**Conflict of interest:** The authors declare no conflict of interest in this study

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