ARTICLE

A Retrospective Analysis of Post-Stroke Berg Balance Scale Scores: How Should Normal and At-Risk Scores Be Interpreted?

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ABSTRACT

Purpose: The Berg Balance Scale (BBS) is a performance-based measure of standing balance commonly used by clinicians working with individuals post-stroke. Performance on the BBS can be influenced by compensatory strategies, but measures derived from two force plates can isolate compensatory strategies and thus better indicate balance impairment. This study examined BBS scores that reflect "normal" and disordered balance with respect to dual force-plate measures of standing balance in individuals post-stroke. ***Methods:*** BBS and force-plate measures were extracted from 75 patient charts. Individuals were classified by BBS score with respect to (1) age-matched normative values and (2) values that suggested increased risk of falls. Multiple analysis of variance was used to examine the effect of group assignment on force-plate measures of standing balance. ***Results:*** Individuals with BBS scores within and below normative values did not differ in force-plate measures. Individuals with BBS scores below the falls risk cutoff loaded their affected leg less than individuals with BBS scores above the cutoff. There were no other differences in force-plate measures between these two groups. ***Conclusions:*** BBS scores indicating either normal or disordered balance function are not necessarily associated with normal or disordered quiet standing-balance control measured by two force plates. This finding suggests that the BBS may reflect a capacity for compensation rather than any underlying impairments.

Key Words: balance; Berg Balance Scale; force-plate measures; stroke.

RÉSUMÉ

Objectif : l'échelle de Berg est un outil de mesure de l'équilibre debout fréquemment utilisé par les cliniciens traitant des personnes ayant subi un AVC. Des stratégies compensatoires peuvent influencer le score Berg, même si les mesures obtenues de deux plateformes de force peuvent isoler les stratégies compensatoires et ainsi mieux détecter les troubles d'équilibre. L'objectif de cette étude était d'examiner les scores Berg indiquant un équilibre « normal » et un trouble d'équilibre parallèlement aux doubles mesures des plateformes de l'équilibre debout de personnes ayant subi un AVC. ***Méthodologie :*** on a extrait le score Berg et les mesures des plateformes de 75 dossiers médicaux de patients. On a classé les personnes selon leur score Berg en tenant compte (1) des valeurs normatives appariées selon l'âge et (2) des valeurs suggérant un risque accru de chutes. On a réalisé une analyse de variance multivariée pour examiner l'effet de la répartition des groupes sur les mesures de l'équilibre debout obtenues à l'aide des plateformes. ***Résultats :*** les personnes ayant obtenu un score Berg égal ou inférieur aux valeurs normatives n'ont pas obtenu de mesures différentes sur les plateformes. Les personnes ayant obtenu un score Berg sous le seuil de risque de chute mettaient moins de charge sur la jambe touchée que les personnes ayant obtenu un score Berg au-dessus du seuil. Il n'y avait aucune autre différence dans les mesures des plateformes entre ces deux groupes. ***Conclusions :*** les scores Berg indiquant un équilibre normal ou un trouble d'équilibre ne sont pas nécessairement associés à un équilibre debout normal ou à un trouble d'équilibre debout tel que mesuré par deux plateformes de force. Ce constat suggère que l'échelle de Berg reflète la capacité de compensation plutôt que le trouble sous-jacent.

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Contributors: All authors designed the study; or collected, analyzed, or interpreted the data; and drafted or critically revised the article and approved the final draft.

Competing Interests: None declared. This study was supported by the Heart and Stroke Foundation Canadian Partnership for Stroke Recovery, the Canadian Institutes of Health Research (MAT-91865), and the Toronto Rehabilitation Institute. Equipment and space were funded with grants from the Canada Foundation for Innovation, the Ontario Innovation Trust, and Ontario's Ministry of Research and Innovation. Kara K. Patterson was supported by a Focus on Stroke personnel award from the Heart and Stroke Foundation and the Canadian Stroke Network. Elizabeth Inness is supported by the Canadian Institutes of Health Research. Avril Mansfield holds a New Investigator Award from the Canadian Institutes of Health Research (MSH-141983).

Acknowledgements: The views in this article are those of the grantees and do not necessarily reflect those of the funding agencies.

Physiotherapy Canada **2017; 69(2);142–149; doi:10.3138/ptc.2015-73**

Individuals with stroke fall more often and are more likely to sustain a hip fracture and lose independent mobility than the general population of elderly adults;[1,2] thus, improved balance is a priority during stroke rehabilitation. It is recommended that treatment be tailored to individuals' needs, guided by a comprehensive assessment to identify their specific impairments (i.e., problems in body function and structure).[3–5] In a survey of physiotherapists, more than 90% agreed that balance assessment is important, and they reported regularly using at least one standardized assessment in their clinical practice.[4,6] Among physiotherapists practising in the field of neurology, the Berg Balance Scale (BBS) is the most commonly used standardized balance assessment.[6]

The BBS is a performance-based measure consisting of 14 items and a maximum score of 56. Originally developed to assess balance in older adults,[7] it was subsequently adopted as a falls-risk prediction tool for older adults (although studies have differed in the recommended cutoff score for falls risk).[8,9] A review of BBS psychometric properties in the stroke population found moderate to excellent reliability and good validity.[10] The BBS is sensitive to change, and admission scores can predict length of hospital stay and discharge destination.[11,12] More than 90% of neurological physiotherapists report that the BBS is useful for guiding treatment planning for balance impairments, although these plans may also be guided by the physiotherapists' observations of patients' performance rather than the BBS score alone.[4,13] Clinical interpretation of BBS scores can be informed by referring to published cutoff thresholds, which identify individuals post-stroke who are at risk of falls as well as age- and gender-specific normative values.[14,15]

Despite its apparent clinical utility, however, the BBS has some limitations that may complicate the interpretation of scores and hence restrict its use to guide treatment planning for individuals with balance impairments post-stroke. First, the BBS has both floor and ceiling effects,[11] and its interrater reliability is lower when assessing individuals post-stroke who score in the mid-range of the scale.[16] Second, the BBS may be a poor predictor of falls post-stroke.[17] Finally, some individuals post-stroke can improve their BBS scores without any concomitant improvement in physiological measures of standing balance.[18,19] Thus, individuals may achieve "good" BBS performance by applying compensatory strategies without recovering from the stroke-related impairments underlying their poor balance.[18] Thus, individuals who achieve a BBS score greater than the age- and gender-matched normal value may still not have normal balance. These complications in interpreting BBS scores may limit the use of the measure in stroke rehabilitation because the ability to identify and distinguish primary impairments from compensatory strategies is essential when a physiotherapist is tailoring post-stroke balance interventions to individuals' needs.[20]

Another approach to assessing balance impairment post-stroke is using instrumented methods such as force plates.[21] However, as with the BBS, certain force-plate measures may reflect a combination of impairments and compensatory strategies. One compensatory strategy is to rely on the non-paretic (non-affected) limb while the paretic limb behaves like a fixed strut instead of actively contributing to standing-balance control.[22] A measure of centre of pressure (COP) displacement, under both feet combined, cannot reveal such compensatory strategies,[23,24] but using two force plates (one under each foot) allows a physiotherapist to calculate measures that tease out compensatory strategies and thus better indicate balance impairment.

Examples of such measures are (1) loading the paretic limb as the individual naturally adopts it during quiet stance, (2) loading the paretic limb to the maximum during a forced condition to reveal the person's capacity to load that limb, and (3) creating an index of COP displacement under each limb to reveal its individual contribution to standing-balance control.[23] The BBS is associated with COP displacement under both feet combined in the mediolateral (ML) and anterior posterior (AP) directions in elderly individuals.[25,26] To the best of our knowledge, the relationship between the BBS and measures of standing balance taken using two force plates has not been explored. These dual force-plate measures can provide insight into how post-stroke BBS scores should be interpreted.

The overall study objective was to investigate the interpretation of BBS scores that reflect normal balance and those that reflect risk of falling post-stroke. Thus, our research questions were as follows: (1) Do BBS scores equal to or greater than normal values reflect standing balance similar to that of healthy adults and (2) do BBS scores greater than the cutoff score for risk of falls reflect standing balance that is not related to risk of falls? To meet the study objective, we examined the BBS and force-plate measures of standing balance among individuals with stroke classified with respect to (1) normal balance, based on published BBS scores for healthy older adults,[15] and (2) risk of falls, defined as BBS scores below a published cutoff score for falls risk (BBS score < 49).[14] A greater understanding of the relationship between BBS scores that reflect, on one hand, normal and disordered balance and, on the other, force-plate measures that distinguish compensatory strategies from underlying impairment may help in interpretation of BBS results and improve treatment planning.

METHODS

We reviewed the charts of 75 individuals with stroke who had been admitted to a rehabilitation hospital from October 2009 to September 2011. One of four physiotherapists at an on-site clinic that integrates technological (e.g., force plates, pressure-sensitive mat) with clinical (e.g., the BBS) assessments of gait and balance conducts a standardized assessment at admission to and discharge from in-patient rehabilitation.[27] The assessment is considered part of routine care, and the results are entered into the patient's care record. The testing procedures have been described in detail elsewhere.[23]

Inclusion criteria for reviewing the charts were (1) the patient could stand independently for 30 seconds without a mobility aid and (2) the BBS and quiet standing-balance assessment were completed within 1 day of each other. Exclusion criteria were (1) the patient had previous lower limb orthopaedic surgeries, prosthetics, or ankle–foot orthoses and (2) he or she had a history of other neurological conditions that influence balance (e.g., Parkinson's disease). A convenience sample of 13 healthy older adults (inclusion criteria: aged 50–85 y, no history of vertigo or dizziness, normal BBS scores for age and gender[15]) was recruited, and they completed a modified version of the quiet standing-balance assessment, administered by two evaluators (not those in the on-site clinic).

This study was approved by the institution's research ethics board. The convenience sample of healthy older adults provided informed written consent. The ethics board granted a waiver of patient consent for the retrospective chart review of individuals with stroke.

Data extraction

We extracted demographic information (i.e., age, gender, date of stroke, and affected side) and values for the BBS and quiet standing-balance assessment from the patients' charts. We also extracted values for the Chedoke-McMaster Stroke Assessment (CMSA) leg and foot scores,[28] which were used as a measure of motor impairment. We analyzed the foot and leg scores separately.

Quiet standing-balance assessment procedure

Quiet standing balance was measured using two force plates. Individuals stood with one foot on each force plate in a standardized position (heels 17 cm apart, 14° between the long axes of the feet).[29] A standardized position was used because foot placement can influence measures of COP.[30] The foot position recommended by McIlroy and Maki[29] represents the central tendency of the preferred stance measured in 262 adults, and it allows for a compromise between the need for standardization and the need to simulate a naturally adopted stance. Three-dimensional forces and moments under each limb were sampled at 256 hertz under two conditions: (1) standing with eyes open (STANDEO) for 30 seconds, an estimate of an individual's natural tendency to bear weight on the paretic limb, and (2) standing with eyes open while bearing as much weight as possible on the paretic limb for up to 20 seconds (LOAD), an estimate of an individual's capacity to bear weight on the paretic limb. Because individuals' tolerance for LOAD is generally less than that for STANDEO, it is sampled for a shorter time.

The LOAD condition was not completed by the healthy older adults because every individual in this group could maintain single-limb stance (i.e., 100% body weight) without difficulty (perfect score on BBS item 14, single-limb stance). A trial ended if a participant needed to take a step or required assistance from the supervising physiotherapist to prevent a fall. Data were filtered using a 10-hertz low-pass zero-phase-lag Butterworth filter before processing. AP and ML COP were calculated under each foot separately and under both feet combined.

Data analysis

Measures of quiet standing balance for individuals post-stroke

We calculated the following measures using the force-plate data collected during the STANDEO and LOAD conditions.

Percentage of body weight borne on the paretic limb: We expressed the amount of weight borne on the paretic limb during the STANDEO condition as a percentage of body weight, averaged over the trial (%BWSTAND).

Maximum percentage of body weight borne on the paretic limb: We expressed the amount of weight borne on the paretic limb during the LOAD condition as a percentage of body weight, averaged over the trial (%BWLOAD).

Duration of LOAD condition: We recorded the amount of time the individual was able to tolerate the LOAD condition in seconds (DURATION).

COP displacement: We calculated the root mean square (RMS) of the COP displacement in the AP (RMS-AP) and ML (RMS-ML) directions under both the paretic and the non-paretic limbs and the total displacement under both limbs combined.

Symmetry of COP: We calculated an index of non-paretic and paretic RMS-AP values (AP index) using the following equation:

$$AP\ index = \frac{non\ paretic\ RMS - AP}{(non\ paretic\ RMS - AP + pareticRMS - AP)}.$$

Therefore, the AP index is a between-limb comparison of the contributions made to standing balance by the paretic and non-paretic limbs. AP index values range from 0 to 1.0, and a value of 0.5 indicates equal contribution from the paretic and non-paretic limbs.[23]

Measures of quiet standing balance for healthy older adults

For the healthy group, we calculated %BWSTAND, RMS-AP, RMS-ML, and AP index. The limb that bore less weight during the STANDEO condition was designated as the paretic limb for the %BWSTAND and AP index calculations. We did not calculate DURATION and %BWLOAD for the members of this group because they did not complete testing in the LOAD condition. We calculated group mean values for each force-plate measure. We also calculated the 95% CI for each mean value, which was used in further analyses of the stroke group data.

To meet the study objective, we subsequently analyzed the BBS score and force-plate measures from two perspectives: normal balance and risk of falls. We classified the sample of individuals with stroke ($n = 75$) in two ways on the basis of two sets of criteria, one relating to normal balance and a second relating to risk of falls. Thus, we classified the same 75 individuals in both ways.

Classification of post-stroke individuals according to BBS score

Normal balance: We compared the BBS score for each post-stroke individual with the published lower 95% CI boundary of the mean BBS score from a group of healthy adults of similar age and gender (lower CI boundary for the BBS in men and women aged 60–69 y = 55 and 54, respectively; in men and women aged 70–79 y = 52; in men and women aged 80–90 y = 51 and 49, respectively).[15] This divided the study sample into two groups: those with a normal BBS score (BBSNORM) and those with a BBS score below the normal range (BBSBELOW).

Risk of falls: We defined disordered balance as a BBS score below the published cutoff score (BBS score ≤ 49); this indicates a risk of falls in individuals with stroke.[14] Thus, we divided the study sample into two groups: BBSRISK (BBS score ≤ 49) and BBSNORISK (BBS score > 49).

Classification of post-stroke individuals according to force-plate measures of quiet standing

Normal balance: We classified participants as being within or outside the 95% CIs, obtained from the convenience sample of healthy older adults (mean age 65.6 y, range 55–79 y), for %BWSTAND (95% CI: 44.6%, 48.6%), total RMS-AP (95% CI: 3.9 mm, 6.8 mm), total RMS-ML (95% CI: 1.8 mm, 2.8 mm), and AP index (95% CI: 0.4, 0.6).

Risk of falls: We also classified participants as being above or below a cutoff for RMS-ML, which has been shown to predict falls in a group of older adults.[25] For the cutoff value, we used the threshold RMS-ML with the best sensitivity and specificity for predicting falls risk in individuals 6 months after being discharged from in-patient rehabilitation (3.5 mm) (A. Mansfield, unpublished data).[31]

Statistical analysis

All calculations and statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC).

Comparisons of BBSNORM with BBSBELOW and of BBSRISK with BBSNORISK

We tested all variables of interest for normality using the Shapiro-Wilk test and rank-transformed variables that were not normally distributed. We calculated group means and standard deviations for demographic variables, BBS scores, CMSA leg and foot scores, and force-plate measures for the entire study sample and for the BBSNORM, BBSBELOW, BBSRISK, and BBSNORISK groups. We checked the normal and risk-of-fall comparison groups for similarity in age, time since stroke, length of stay, and CMSA leg and foot scores using unpaired *t*-tests. We corrected multiple comparisons using the Holm method, and the initial adjusted level of significance was 0.01. We checked differences in gender using Fisher's exact test. We calculated Cohen's d when significant differences were found.

Normal balance: To answer the first research question ("Do BBS scores equal to or greater than normal values reflect standing balance similar to that of healthy adults?"), we compared the BBSNORM and BBSBELOW groups on standing balance, assessed by force plates, in two ways. First, we investigated an effect of group assignment (i.e., BBSNORM and BBSBELOW) on %BWSTAND, %BWLOAD, DURATION, RMS-AP, RMS-ML, and AP index using multivariate analysis of variance (MANOVA). In the case of a significant result using MANOVA, we investigated differences between the two groups in individual force-plate measures using one-way analysis of variance (ANOVA) and calculated Cohen's d. We corrected multiple comparisons using the Holm method,[32] and the initial adjusted level of significance was 0.008. Second, we further investigated differences in standing balance between BBSNORM and BBSBELOW using Fisher's exact tests to compare the proportions of individuals within and outside the healthy-older-adult 95% CIs in individual force-plate measures (%BWSTAND, RMS-AP, RMS-ML, AP index). We corrected multiple comparisons using the Holm method,[32] and the initial adjusted level of significance was 0.01.

Risk of falls: To answer the second research question ("Do BBS scores greater than the cutoff score for risk of falls reflect standing balance that is not related to risk of falls?"), we compared the BBSRISK and BBSNORISK groups on standing balance, assessed by force plates, in two ways. First, we investigated an effect-of-group assignment (BBSRISK and BBSNORISK) on %BWSTAND, %BWLOAD, DURATION, RMS-AP, RMS-ML, and AP index using MANOVA. In the case of a significant result using MANOVA, we investigated differences in individual force-plate measures between the two groups using ANOVA and calculated Cohen's d. We used the Holm method to correct for multiple comparisons, and the initial adjusted level of significance was 0.008.[32] Second, we further investigated differences in standing balance by comparing the proportion of individuals with an RMS-ML value below the cutoff for falls risk in the BBSRISK and BBSNORISK groups using Fisher's exact test.

RESULTS

Of the total number of individuals in the database ($N = 324$), 75 individuals met the inclusion criteria and were included in the analyses. The number of post-stroke individuals with missing data for variables of interest was as follows: CMSA leg and foot, $n = 8$, and %BWLOAD and DURATION, $n = 3$.

Table 1 Classification of Individuals with Stroke by BBS Score

Group	BBSNORISK	BBSRISK	Total
BBSBELOW	14	40	54
BBSNORM	21	0	21
Total	35	40	75

BBS = Berg Balance Scale; BBSNORISK = BBS score > 49; BBSRISK = BBS score ≤ 49; BBSBELOW = BBS score < normative value; BBSNORM = BBS score ≥ normative value.

Classification of post-stroke individuals according to BBS score

The classification of all 75 individuals post-stroke by BBS score with respect to normative values (BBSNORM, BBSBELOW) and the falls-risk cutoff (BBSRISK, BBSNORISK) is summarized in Table 1. The mean (SD) for demographics, CMSA scores, BBS scores, and force-plate measures for the entire study group and the four BBS groups are summarized in Table 2.

Normal balance: comparison of BBSNORM group with BBSBELOW group

The BBSNORM and BBSBELOW groups were not significantly different on gender, $p = 0.07$; age, $t(73) = 1.08$, $p = 0.29$; length of stay, $t(73) = 1.71$, $p = 0.09$; or time post-stroke, $t(73) = 0.93$, $p = 0.35$. The BBSNORM group had higher CMSA leg scores than the BBSBELOW group, $t(65) = -3.05$, $p = 0.003$, $d = 0.80$, but CMSA foot scores were not significantly different, $t(65) = -1.46$, $p = 0.15$.

MANOVA for the effect of group (BBSNORM vs. BBSBELOW) on the six force-plate measures was not significant, $F(65, 6) = 1.96$, $p = 0.09$. There were also no significant differences in the proportion of individuals within the normative CIs for %BWSTAND, RMS-AP, RMS-ML, or AP index (see Table 3).

Risk of falls: comparison of BBSNORISK group with BBSRISK group

The BBSNORISK group was younger than the BBSRISK group, $t(73) = -2.90$, $p = 0.005$, $d = 0.67$, but the groups were not significantly different in time post-stroke, $t(73) = -1.46$, $p = 0.15$, or gender, $p = 0.64$. The BBSNORISK group had significantly shorter lengths of stay in hospital, $t(73) = -3.77$, $p = 0.0003$, $d = 0.98$, and it had higher CMSA leg scores, $t(65) = 4.23$, $p < 0.001$, $d = 0.99$, and foot scores, $t(65) = 3.90$, $p < 0.001$, $d = 0.92$, than the BBSRISK group.

MANOVA for the effect of group (BBSRISK vs. BBSNORISK) on the six force-plate measures was significant, $F(65, 6) = 3.44$, $p = 0.005$. ANOVA on individual

Table 2 Groups' Mean (SD) Values for Demographic, Clinical, and Balance Measures

	Whole group		BBSNORM		BBSBELOW		BBSNORISK		BBSRISK	
Measure	Mean (SD) or no.	95% CI	Mean (SD) or no.	95% CI	Mean (SD) or no.	95% CI	Mean (SD) or no.	95% CI	Mean (SD) or no.	95% CI
Age, y*	70.2 (10.5)	67.8, 72.6	68.1 (10.6)	63.3, 73.0	71.0 (10.4)	68.2, 73.9	66.7 (9.3)	63.5, 69.8	73.4 (10.6)	70.0, 76.7
Gender (female/male)	31/44	–	5/16	–	26/28	–	13/22	–	18/22	–
Time post-stroke, d	20.1 (18.7)	15.8, 24.4	17.0 (11.7)	11.6, 22.3	21.4 (20.7)	15.7, 27.0	17.1 (12.5)	12.8, 21.4	22.8 (22.6)	15.6, 30.0
Affected side (right/left)	45/30	–	15/6	–	30/24	–	22/13	–	23/17	–
Length of stay, d*	33.3 (11.5)	30.6, 35.9	28.8 (7.5)	25.3, 32.2	35.0 (12.3)	31.7, 38.4	27.9 (6.9)	25.6, 30.3	38.0 (12.7)	33.9, 42.0
BBS	45.7 (9.3)	43.5, 47.8	54.3 (1.8)	53.5, 55.1	42.3 (9.0)	39.9, 44.8	53.1 (2.1)	52.4, 53.9	39.2 (8.3)	36.5, 41.8
CMSA leg (0–7)*†	4.9 (1.0)	4.7, 5.2	5.5 (0.9)	5.0, 5.9	4.7 (1.0)	4.4, 5.0	5.4 (0.9)	5.1, 5.8	4.5 (0.9)	4.2, 4.8
CMSA foot (0–7)*	4.7 (1.0)	4.4, 4.9	4.9 (0.9)	4.5, 5.4	4.5 (1.0)	4.3, 4.8	5.1 (0.8)	4.8, 5.4	4.3 (0.9)	4.0, 4.6
RMS-AP, mm	5.9 (2.7)	5.3, 6.6	5.4 (2.0)	4.6, 6.3	6.1 (2.9)	5.3, 6.9	5.6 (2.0)	4.9, 6.3	6.2 (3.2)	5.2, 7.3
RMS-ML, mm	4.1 (2.4)	3.5, 4.6	3.4 (2.1)	2.4, 4.4	4.4 (2.4)	3.7, 5.0	3.5 (1.9)	2.8, 4.1	4.6 (2.6)	3.8, 5.5
%BWSTAND	47.9 (9.3)	45.8, 50.0	46.7 (7.5)	43.3, 50.2	48.4 (9.9)	45.7, 51.1	49.2 (8.4)	46.3, 52.1	46.7 (10.0)	43.6, 50.0
%BWLOAD*	74.6 (14.3)	71.2, 77.9	79.5 (13.6)	73.2, 85.9	72.6 (14.2)	68.7, 76.6	78.5 (16.2)	72.7, 84.2	71.3 (11.7)	67.5, 75.1
Duration, s	13.0 (3.7)	12.2, 13.9	13.9 (1.4)	13.3, 14.6	12.7 (4.2)	11.5, 13.8	13.4 (2.8)	12.4, 14.4	12.7 (4.3)	11.3, 14.1
AP index	0.6 (0.1)	0.5, 0.6	0.5 (0.1)	0.5, 0.6	0.6 (0.1)	0.5, 0.6	0.6 (0.1)	0.5, 0.6	0.6 (0.1)	0.5, 0.6

*Significant difference for BBSNORISK and BBSRISK groups.
†Significant difference for BBSNORM and BBSBELOW.
BBS = Berg Balance Scale; BBSNORM = BBS score ≥ normative value; BBSBELOW = BBS score < normative value; BBSNORISK = BBS score > 49; BBSRISK = BBS score ≤ 49; CMSA = Chedoke-McMaster Stroke Assessment; RMS-AP = root mean square of the centre of pressure displacement in the anterior–posterior direction; RMS-ML = root mean square of the centre of pressure displacement in the mediolateral direction; %BWSTAND = percentage of body weight borne on the paretic leg; %BWLOAD = maximum percentage of body weight borne on the paretic leg; AP index = index of RMS-AP values of the paretic and non-paretic limbs.

Table 3 Counts and Percentages of Individuals Post-Stroke with Normal and Below-Normal BBS Values within and outside the 95% CI for Healthy Older Adults

Measure	BBSNORM, no. (%) $n = 21$	BBSBELOW, no. (%) $n = 54$	*p*-value
%BWSTAND			0.76
Within	4 (19)	13 (24)	
Outside	17 (81)	41 (76)	
RMS-AP			0.61
Within	11 (52)	24 (44)	
Outside	10 (45)	30 (56)	
RMS-ML			0.56
Within	7 (33)	13 (24)	
Outside	14 (67)	41 (76)	
AP index			0.04
Within	16 (76)	26 (48)	
Outside	5 (24)	28 (52)	

BBS = Berg Balance Scale; BBSNORM = BBS score ≥ normative value; BBSBELOW = BBS score < normative value; %BWSTAND = percentage of body weight borne on the paretic leg; RMS-AP = root mean square of the centre of pressure displacement in the anterior–posterior direction; RMS-ML = root mean square of the centre of pressure displacement in the mediolateral direction; AP index = index of RMS-AP values of the paretic and non-paretic limbs.

Table 4 Counts and Percentages of Individuals Post-Stroke with BBS Values below and above Falls Risk Cutoff

RMS-ML	BBSNORISK, no. (%) $n = 35$	BBSRISK, no. (%) $n = 40$
Below cutoff- (no risk of falls)	20 (57)	17 (43)
Above cutoff- (risk of falls)	15 (43)	23 (57)

Note: $p = 0.25$.
BBS = Berg Balance Scale; BBSNORISK = BBS score > 49; BBSRISK = BBS score ≤ 49; RMS-ML = root mean square of the centre of pressure displacement in the mediolateral direction.

force-plate measures revealed that the BBSNORISK group had larger %BWLOAD values than the BBSRISK group, $F(70, 1) = 16.48$, $p < 0.001$, $d = 0.51$. No significant differences were found in the proportion of individuals with an RMS-ML value below the cutoff value for risk of falls (see Table 4).

DISCUSSION

The main finding of this study is that a BBS score indicating either normal (i.e., within the range for healthy adults) or at risk of falls (i.e., BBS score less than the falls risk cutoff) is not necessarily associated with normal or poor quiet standing-balance control, as measured by force plates. These results suggest that the BBS is more a reflection of an individual's capacity to use compensatory strategies to achieve standing function than it is a direct measure of underlying impairments.

Interpreting normal BBS scores informed by force-plate measures

Post-stroke individuals with normal BBS scores had less lower extremity motor impairment (larger CMSA scores) than individuals with BBS scores below a normative value. This coincides with previous results showing an association between BBS scores and motor impairment.[33] However, despite better motor control (measured by a clinical scale), individuals with normal BBS scores were not more likely to exhibit normal weight bearing on the paretic limb (%BWSTAND, %BWLOAD) or an equal contribution of their paretic lower limb to standing-balance control (AP index). The current findings parallel those of Garland and colleagues,[18] who found that some individuals post-stroke improved on the BBS during rehabilitation but did not improve on a measure of underlying physiological impairment—in this case, anticipatory muscle activity in the hamstrings.[18] The same trend is observed in post-stroke gait function, which is interdependent with balance function and is similarly affected by multiple stroke-related impairments. Individuals post-stroke can exhibit functional gait improvement, measured as maximum gait velocity, without a change in lower extremity electromyogram activity.[34]

Interpreting disordered BBS scores informed by force-plate measures

The post-stroke individuals with BBS scores below a published falls-risk cutoff (BBS score ≤ 49) were older, had longer lengths of stay in the rehabilitation hospital, and had greater motor impairment (smaller CMSA scores) than individuals with BBS scores above this cutoff; this finding correlates with previous work.[12,33,35] In addition, the individuals with a BBS score less than 49 had less capacity to load their paretic limb maximally when standing; this is not surprising given their greater motor impairment (as measured by the CMSA). It is important to note that individuals classified as not at risk of falls by their BBS score (i.e., BBS score > 49) were not more likely to exhibit ML COP displacement values indicating no risk of falls (i.e., RMS-ML < 3.5 mm). In fact, of the 35 individuals who had BBS scores greater than 49, 15 (43%) exhibited ML COP displacement values related to an increased falls risk.

Clinical implications for using the BBS with stroke patients

The current results are clinically important; they can inform physiotherapists' interpretations of BBS scores and guide their use of the BBS in practice. Individuals deemed to have normal balance on the basis of BBS score may still have persisting impairments, revealed by force-plate measures. For example, the paretic limb may make only a limited contribution to control of standing, as measured by the AP index. Furthermore, those individuals with BBS scores that indicate no falls risk may still have ML instability, which could increase their risk of falling.

We suggest that it is important for clinicians to consider the fact that some individuals post-stroke may use compensatory strategies that result in superior BBS performance but indicate continued underlying impairment. This can be related to the interaction between the unilateral nature of post-stroke deficits and the manner in which the BBS is administered (i.e., a performance-based test using an ordinal scale). For example, for BBS item 2, standing unsupported, the individual is asked to "please stand for 2 minutes without holding on." The person achieves a maximum score of 4 if he or she can stand safely for 2 minutes. The results of the current study suggest that an individual can achieve a 4 on this item while the paretic limb makes a limited active contribution to standing-balance control. This compensatory strategy would be revealed only by measures that sample from both limbs, such as the index of the COP displacement under each limb.

This study has several limitations. First, the results may apply only to individuals who can stand independently because those who required an aid to stand for 30 seconds were excluded from the analysis. Another limitation may be the retrospective design, using data collected by four different raters; however, this may not be a significant concern because the balance variables extracted from the charts were measured in a clinic following standardized protocols, and interrater reliability for the BBS is high (intra-class correlation coefficient = 0.98).[16] Finally, the standard error of measure for the BBS is about 2 points,[36] so it is possible that some individuals who scored close to the threshold values were misclassified (i.e., BBSNORM vs. BBSBELOW or BBSRISK vs. BBSNORISK) because of variability in scoring.

CONCLUSIONS

The ability to identify and distinguish primary impairments from compensatory strategies is essential to tailor post-stroke balance interventions to individuals' needs.[20] The present results suggest that the BBS may not be suitable for this purpose and that BBS scores equal to normative values and those greater than the falls risk cutoff should be interpreted with caution. The current study demonstrates the clinical utility of two force-plate measures, the index of COP displacement and loading of the paretic limb, but this is not an exhaustive list. These force-plate measures (or related measures), coupled with ubiquitous gaming technology (e.g., Wii Fit), may provide a cost-effective approach to achieving better measures of standing-balance impairment in clinical practice. They have the potential to direct treatment at patient-specific deficits, but further work is needed to understand their clinical implications.[37] Alternative tools for measuring continued balance impairments, despite the fact that they result in normal performance on functional clinical tests, should be a priority area of research.

KEY MESSAGES

What is already known on this topic

The Berg Balance Scale (BBS) is a performance-based measure of standing balance commonly used in stroke rehabilitation. Individuals with stroke may be able to achieve good BBS scores despite having persisting underlying impairments by using compensatory strategies; however, this may interfere with how their BBS scores—for example, determining a falls risk cutoff and normative values—are interpreted.

What this study adds

Individuals post-stroke with BBS scores that indicate either normal balance (i.e., within the range for healthy older adults) or being at risk of falls (i.e., BBS score less than the falls risk cutoff) do not necessarily have normal or poor quiet standing-balance control; force-plate measures can reveal that these individuals are using compensatory strategies. These results highlight the limitation of the BBS in identifying and distinguishing compensatory strategies during standing post-stroke.

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