Research Report

Preliminary Assessment of Balance With the Berg Balance Scale in Adults Who Have a Leg Amputation and Dwell in the Community: Rasch Rating Scale Analysis

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Background. Self-report measures of balance and multidimensional mobility assessments are common for people with a leg amputation, yet clinical assessment of balance ability remains less explored. The Berg Balance Scale (BBS), typically used for other populations with impaired balance, has been used for young people with a high level of functioning after traumatic amputation but rarely for older people after vascular amputation.

Objective. The study objective was to examine the psychometric properties of the BBS with Rasch rating scale analysis to determine the validity and utility of the BBS in assessing balance ability in adults who have a leg amputation and dwell in the community.

Design. Rating scale analysis was applied to BBS scores obtained from a single assessment.

Methods. Adult volunteers (men and women) who had a leg amputation (any level and etiology) and dwelled in the community were recruited from a hospital-based community support group and a prosthetic clinic. Rating scale analysis of the BBS was used to assess unidimensionality, internal validity, goodness of fit, structural integrity, and person and item analyses.

Results. The study participants were 40 people (26 men and 14 women; 57.8 [SD=9.7] years old) with leg amputations (24 transtibial, 13 transfemoral, and 3 bilateral) of mixed etiology (32 vascular and 8 nonvascular). The psychometric properties of the BBS confirmed that it measures the unidimensional construct of balance ability with adequate validity and with goodness of fit and structural integrity that meet the acceptability criteria. Person measures revealed that some participants scored near the top of the BBS, suggesting a ceiling effect; item measures revealed that participants with leg amputations had the most difficulty performing the following tasks: standing with 1 leg in front, turning 360 degrees, and placing alternate foot on a stool.

Limitations. Limitations included a convenience sample and a lack of rater reliability testing.

Conclusions. The BBS cohered with the unidimensional construct of balance ability and had strong internal validity for use in a variety of people with leg amputations.

After a leg amputation, balance impairment and an associated decrease in function are common problems.[1] Although postural balance control has been well studied with various instrumented measures, such as force platforms and computerized posturography, clinical assessments of functional balance performance that challenge the dynamic balance ability of people with a leg amputation have been less frequently reported.[2] Assessments of functional balance have been limited to commonly used self-report measures, such as the Prosthetic Evaluation Questionnaire[3] and the Activities-specific Balance Confidence Scale.[4] Performance-based clinical measures often are used indirectly to assess balance ability in people after a leg amputation; these measures include the Timed "Up & Go" Test[5–7] and the Amputee Mobility Scale,[8,9] which involve tasks that require balance within a broader assessment of prosthetic or mobility functions and thus do not specifically assess balance ability.

Among rehabilitation practitioners, the most commonly used performance-based clinical assessment of balance ability is the Berg Balance Scale (BBS).[10] The BBS consists of 14 items that challenge functional balance ability and are rated on a 5-category scale from a lowest level of 0 to a highest level of 4, with a cumulative score being reported.[11] Studies with the BBS have included participants with a leg amputation among patients undergoing rehabilitation for a variety of disorders.[12] The few studies specifically examining the balance ability of people with a leg amputation by use of the BBS had small samples—12 or fewer participants—limited to specific subgroups, such as athletes,[13] young people after a traumatic amputation,[14] or elderly people after a vascular amputation.[15] The psychometric properties of the BBS as an assessment of balance ability have been well documented in studies of people who have survived a stroke, elderly people dwelling in the community, and patients with mixed neurologic deficits.[11,16–19] Some investigators have explored whether all BBS items were useful,[19] whether the rating structure was acceptable,[20] and whether the BBS should be revised.[21] For example, a revised rating structure and subset of BBS items to classify people who fall and people who do not fall more accurately than the original BBS were examined in people who had survived a stroke.[19] In 2 studies, Rasch rating scale analysis (RSA) was used to evaluate the internal validity, reliability, and rating scale properties of the BBS in elderly people dwelling in the community[20] and people with neurologic conditions.[21] In both studies, Rasch RSA confirmed that the BBS, at both the scale level and the item level, measured the unidimensional construct of balance ability with acceptable validity and reliability in the specific populations studied.[20,21] Beyond the summed BBS scores, Rasch RSA provides interval-level data for each participant and item while simultaneously taking into consideration the ability of the participant sample and the hierarchy of item difficulty to determine whether the BBS can be used as a valid assessment of balance in a particular population.

People with a leg amputation face different balance challenges during functional activities than elderly people or people with neurologic disorders. If validated, the BBS may be a useful functional balance assessment for people with a leg amputation and may have potential for comparisons among disorders given its wide acceptance in clinical settings and for other diagnoses.[21,22] The main purpose of this study was to use Rasch RSA to examine the psychometric properties of the BBS in a diverse sample of people with a leg amputation. Additional purposes were to determine whether the BBS distinguished different levels of balance impairment within the sample and to identify items that were particularly difficult for the study participants to perform. We hypothesized that the BBS would have acceptable psychometric properties and could be applied as a valid clinical measure of balance in people with a leg amputation.

Method

Participants

Adult volunteers who had a leg amputation of any etiology and dwelled in the community were recruited from a prosthetic clinic and a hospital-based community support group for people with amputations. Potential participants were excluded if they had unstable medical conditions or were unable to understand an explanation of the study. Adults who used assistive devices to walk were included, although balance testing was performed without the use of the assistive devices. Potential participants with known conditions affecting balance, such as blindness, vestibular dysfunction, or central nervous system disorders, also were excluded. The minimum sample size was based on the criteria of Linacre, such that to obtain stable person and item estimates with no more than ± 1 logit error at 95% confidence, 30 participants were needed.[23] After informed consent was obtained, each participant provided demographic data and medical, amputation, and prosthetic history.

Assessments

Balance ability was assessed once for each participant with the BBS as part of clinical assessments obtained for other research. Each participant was asked to perform all 14 BBS items: sit to stand, standing unsupported, sitting unsupported, stand to sit, transferring to chair, standing with eyes closed, standing with feet together, reaching forward with arm outstretched, retrieving object from floor, looking behind over shoulders, turning 360 degrees, placing alternate foot on stool, standing with 1 foot in front, and standing on 1 leg.[11] It was anticipated that not all participants would complete all BBS items. Therefore, BBS items were attempted at least twice, but attempts were discontinued if they were deemed unsafe, and the appropriate item category score was assigned. For people with a leg amputation, BBS items such as standing with 1 foot in front and standing on 1 leg can be performed in ways that emphasize or minimize prosthetic leg use; in this study, such items were performed both ways, and the best score was recorded. Participants unable to wear a prosthesis were unable to attempt items such as standing with feet together, placing alternate foot on stool, and standing with 1 foot in front; therefore, their score on such items was recorded as zero.

Four physical therapists and 4 doctor of physical therapy students were trained by the primary author (C.K.W.) to assess balance in people with a leg amputation by using the BBS. The BBS had good interrater and test-retest reliability in past research with various patient populations[24–26] for as many as 18 experienced, novice, and physical therapist student testers within a single study.[25,26]

Data Analysis

Data were compiled and descriptive data were summarized with SPSS version 18.0 (SPSS Inc, Chicago, Illinois).[27] The Winsteps 3.74 program (Winsteps, Chicago, Illinois)[28] was used to carry out the Rasch RSA, a Rasch measurement model analysis used for rating scales with an equal number of rating categories. The Rasch measurement model, based on item-response theory, proposes that when all items represent 1 underlying construct, the response patterns can be explained by the probabilistic estimates of person ability and item difficulty.[29] The RSA tests the Rasch measurement model assumption of unidimensionality; examines its premises for internal validity, including person and item separation and goodness of fit; conveys important information about the structural integrity of the scale, including response category usage; and simultaneously calibrates person and item measures.

Unidimensionality. A unidimensional construct to which all scale items cohere must be established, although dimensionality is by no means an all-or-none phenomenon.[30] Dimensionality can be investigated with Rasch principal components analysis of the standardized residuals. When the data fit the model well, a large percentage (>50%) of the observed raw score variance will be accounted for by the model.[31] The residuals of the unexplained variance can be further separated into contrasts, which suggest a potential secondary factor when the first contrast eigenvalue exceeds 2.0.[31]

Person and item separation. The validity of the scale must be determined by person and item separation and the associated reliability values. *Person separation* refers to the fact that the scale should separate people into several strata of abilities (person separation index [PSI]), and the same results should be obtained if the assessment is repeated with another sample of people with similar abilities (person separation reliability). *Item separation* refers to the fact that a set of items should completely represent the range of difficulty within the measured construct (item separation index [ISI]) for acceptable assessment of the sample.[32] To be considered acceptable, values for the separation indexes (PSI and ISI) should be greater than 2.0, and the associated reliability values should be greater than 0.8.[32]

Person and item fits. The overall usefulness of the scale must be confirmed by the fit of the data to the measurement model, as implied by the goodness of fit of item and person measures. Rating scale analysis will identify large misfits for people and items; large misfits can decrease unidimensionality as well as person and item separation and thus scale validity and reliability. The reasons for large misfits must be investigated to determine whether items, people, or the scale should be revised. Item fit statistics were represented by mean-square statistics. "Infit" indicates irregular or unexpected responses for items close to a person's ability. "Outfit" is sensitive to unexpected responses for items far from a person's ability. Infit and outfit statistics identify people and items that may not fit the model. No rigid rules exist for misfit statistics because of idiosyncrasies in the context of the assessment; clinical observations, in particular, are acknowledged to produce values higher than the mean-square value of 1.3, which is common to multiple-choice questions.[33] Therefore, person and item fit values of less than 2.0 are acceptable for the purpose of clinical scale validation but not development, and values of greater than 2.0 require interpretation.

Structural integrity. The structural integrity of the scale should be confirmed by use of all categories for all items, acceptable linearity of the categories, and the absence of misordered category steps. Therefore, the frequency distributions of each rating category, the average category measures, and the step measures, provided in the Winsteps output tables, were examined to allow judgments of whether the rating scale was well constructed and whether the rating categories were used as a ranking of ability as intended.[32]

Person ability and item hierarchy. Person ability measures and item difficulty hierarchy describe people's performances and difficulties with items, respectively. These linear measures reflect probabilistic estimates in log odds units (logits), calibrated by Winsteps and reported for each person and item measure at distinct ability strata and on a hierarchy of item difficulty.[29,33]

Results

A convenience sample of 40 adult volunteers (57.8 [SD=9.7] years old) who had a leg amputation of any etiology and dwelled in the community was recruited over a period of 3 years (Tab. 1). They had undergone amputation an average of 5.3 (SD=10.7) years previously, and 75% used their prostheses 4 or more hours per day.

Table 1.
Characteristics of Participants (N=40)

Characteristic	No. of Participants
Age (y)	
≥65	11
18–64	29
Sex	
Women	14
Men	26
Race	
White	11
African American	11
Hispanic	15
Native American	1
Unspecified	2
Amputation etiology	
Vascular disease	15
Vascular disease and diabetes	17
Trauma	2
Other medical etiology (eg, cancer)	6
Amputation level	
Unilateral transtibial	24
Unilateral transfemoral	13
Bilateral transtibial	2
Bilateral transfemoral-transtibial	1
Years since amputation(s)	
≥2	15
<2	25
Prosthesis	
Able to wear	32
Unable to wear	8

Unidimensionality

The principal components analysis results for the RSA indicated that the BBS items cohered to a single dominant dimensionality, as most of the raw variance (70.4%) was explained by the model. The eigenvalue of the first contrast, 2.4, suggested a potential secondary factor, although such a factor would not affect the estimate of the dominant dimensionality.[30,31] Close inspection revealed that some items (13 and 14, with loadings of −0.58 and −0.53, respectively) measured static balance with an emphasis on 1 leg, whereas other items (11 and 12, with loadings of 0.72 and 0.58, respectively) measured dynamic balance requiring 2 legs.

Person and Item Separation

The scale validity of the BBS was shown to be excellent. The PSI of 2.72, with a reliability of .88, indicated that the BBS could reliably separate participants into 4 distinct ability strata. The ISI of 4.70, with a reliability of .96, indicated that the items assessed an acceptable range of difficulty for the participants. Figure 1 shows the person-item distribution.

Person and Item Fits

Overall, the goodness of fit for items was acceptable, although 3 items showed large misfits. Item 13 (standing with 1 foot in front) had a large infit (mean square value of 2.25), and items 1 (sit to stand) and 14 (standing on 1 leg) had large outfits (mean square values of 2.94 and 2.07, respectively) (Tab. 2). The reasons for such misfits are explained in the "Discussion" section.

Structural Integrity

The structural integrity of the BBS was acceptable. The RSA revealed that not all response categories were equally used, reflecting an uneven response distribution (Tab. 3). The 2

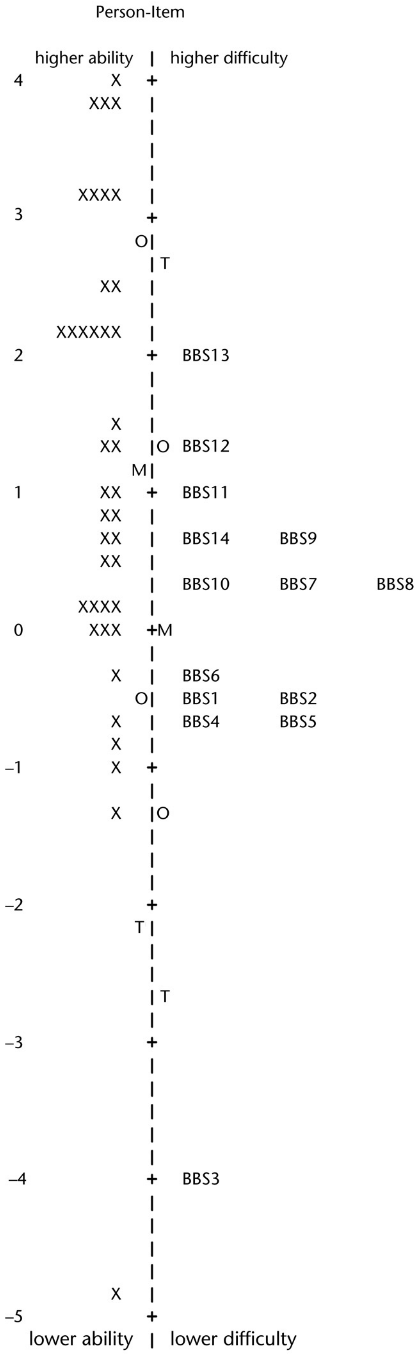

Figure 1.

Person-item measure map. Person (X) performance measures and Berg Balance Scale (BBS) item difficulty for all 40 participants and the 14 items are shown. M=mean, O=1 standard deviation, T=2 standard deviations.

most frequently used rating categories both indicated good performance, with 50% of participants using category 4 and 19% of participants using category 3; 17% of participants used category 0, representing the poorest performance. The categories used least often were categories 1 (6%) and 2 (8%). Average category measures, the mean of the person measures for participants choosing each category across items, increased as the ratings increased, indicating that the BBS was used as intended: lower rating categories were used when participants performed poorly, and higher rating categories were used when participants performed well (Fig. 2). The intermediate measures were misordered, largely because categories 1 and 2 were underused. However, combining categories 1 and 2 did not produce substantial improvements in the PSI, the ISI, or their associated reliability values. Because the sample represented a new population assessed with the BBS and the sample size was small, the current response category structure was deemed acceptable and maintained for analysis.

Person Ability and Item Hierarchy

Item and person measures revealed that some items were more difficult than others and provided information about the participants who performed at distinct ability strata. Table 2 shows the hierarchy of item difficulty in logits (item measure and standard error), infit and outfit mean-square values, and the point-measure correlation between each item and the entire BBS. The items that were most difficult to perform, starting with the most difficult, were item 13 (standing with 1 foot in front), item 12 (placing alternate foot on stool), and item 11 (turning 360°). The item order seemed to be consistent with the clinician assessment of item difficulty; the point-measure correlation demonstrated a high association between the score on each item and scores on the entire BBS.

Person measures for BBS performance ranged from a low of −4.76 logits to a high of 5.1 logits, with a mean of 1.24 logits. The disparity between mean person ability and mean item difficulty (0.0 logit) suggested that some BBS items were relatively easy for this particular population. Examination of how participants performed on the items (Tab. 4) revealed patterns within different strata of performance. Inspection of the logit pattern revealed 4 distinct strata: less than 0.4 logit, 0.4 to 1.5 logits, 1.51 to 2.5 logits, and greater than 2.5 logits. The top stratum of participants (stratum 4) performed all items at rating category 3 or 4, with total BBS scores approaching the maximum score of 56 (Tab. 4). The participants with the next highest level of performance (stratum 3) performed all items at category 3 or 4, but a few were challenged by at least 1 of items 11, 12, 13, and 14—with item 13 being the most difficult. In stratum 2, fewer participants performed at category 3 or 4, except for items requiring only static balance (items 2, 3, 6, and 7). Although 91% wore prostheses, stratum 2 participants had difficulties performing most dynamic standing balance tasks (items 9–14), and 27.3% to 63.6% performed at the lowest levels (categories 0 and 1). In the lowest stratum, with person measures ranging from −4.76 to 0.14 logits, only 6 of 13 participants wore prostheses, and more than half were unable to perform functional items in a standing position (items 6–14).

Discussion

The results of the present study demonstrated that the BBS measured the unidimensional construct of balance ability in participants with leg amputations at various levels and of mixed etiology. Both PSI and ISI values

Table 2.
Hierarchy of Item Difficulty, Fit Statistics, and Correlation of Item to Measure

Item	Item Description	Item Measure (SE)	Infit (Mean Square)	Outfit (Mean Square)	Point-Measure Correlation
13	Standing with 1 foot in front	1.95 (0.19)	2.25	1.54	.68
12	Placing alternate foot on stool	1.35 (0.18)	1.77	1.61	.71
11	Turning 360°	0.93 (0.18)	0.81	0.65	.81
14	Standing on 1 leg	0.65 (0.18)	1.76	2.07	.65
9	Retrieving object from floor	0.62 (0.18)	1.24	0.90	.74
8	Reaching forward with arm outstretched	0.40 (0.18)	0.60	1.16	.78
7	Standing with feet together	0.37 (0.18)	0.75	0.50	.77
10	Looking behind over shoulders	0.27 (0.18)	0.37	0.73	.80
6	Standing with eyes closed	−0.28 (0.20)	0.78	0.48	.73
1	Sit to stand	−0.45 (0.21)	0.72	2.94	.74
2	Standing unsupported	−0.50 (0.22)	0.77	0.41	.73
5	Transferring to chair	−0.65 (0.23)	1.17	0.92	.71
4	Stand to sit	−0.70 (0.23)	0.63	0.48	.84
3	Sitting unsupported	−3.97 (0.68)	0.40	0.04	.54

were high, indicating excellent person and item validity with high associated reliability. Therefore, the psychometric properties of the BBS met the Rasch RSA acceptability criteria and supported the clinical use of the BBS to obtain valid scores for assessing balance ability in people with a leg amputation.

The goodness of fit for the BBS items was acceptable. It is not unusual for the most or least difficult item to show misfits, as demonstrated in the present study; the items showing the most misfits were item 13 (standing with 1 foot in front), which had a large infit, and item 1 (sit to stand) and item 14 (standing on 1 leg), which had large outfits. Close inspection of participant data revealed that item misfits could have been related to a few participants who had unexpected performances. In particular, these participants performed better at standing on 1 leg than at standing with 1 foot in front. Consideration of the unique attributes of people with a leg amputation may provide an explanation. People with a leg amputation depend on their intact leg for balance and learn to compensate with increased intact leg strength[34,35] as they develop this critical ability immediately after surgery in order to be discharged home.[36] As a result, participants with a unilateral leg amputation preferentially used the sound limb—only 4 attempted to balance on the prosthetic leg, with none maintaining single-limb stance on the prosthetic leg for even 5 seconds. People without prostheses could still stand on 1 leg but would be unable to complete bilateral items such as turning 360 degrees (item 11) without assistance, and some might be too weak to perform sit to stand without assistance. Half of the participants performed standing on 1 leg, an activity that people with a unilateral leg amputation practice often through necessity, with a perfect score but performed standing with 1 foot in front less well. The items showing large misfits appeared to be exceptions related to the unique characteristics of the study participants.

Examination of person misfits revealed that the participant with the largest outfit had an unexpected rating of 1 for item 1 (sit to stand) but ratings of 0 for all other items. The 2 participants with the largest infits were each unable to perform 1 item (items 12 and 13) but had top scores for almost all other items. Item 8 (reaching forward with arm outstretched) also showed misfits. Although item 8 and item 7 (standing with feet together) were similarly ranked on the item difficulty hierarchy, participants tended to do better on item 8 than on item 7. Standing with feet together required leg adduction to result in shoes touching and to obtain a narrow base of support; this position was difficult to achieve for a variety of reasons, including limb girth, genu valgum, impaired coordination, prosthetic alignment, socket pressure on the residual or sound limb, and insufficient balance.

Similar to earlier findings,[20,21] not all rating categories were uniformly used in the present study. As in previous studies of elderly people and

Table 3.
Distribution of Ratings for All Berg Balance Scale Item Categories

Item	Rating Category				
	0	1	2	3	4
1	1	2	1	18	18
2	4	0	5	3	28
3	1	0	0	0	39
4	1	0	1	19	19
5	1	1	2	15	21
6	5	1	3	5	26
7	9	3	2	3	23
8	5	2	6	15	12
9	11	3	0	7	19
10	6	2	7	5	20
11	10	2	12	0	16
12	14	5	2	8	11
13	19	6	1	4	10
14	9	5	3	4	19

people with neurologic disorders, the second and third lowest rating categories (1 and 2) were used the least (Tab. 3). Although combining these 2 categories improved the distribution of BBS ratings, no substantial statistical advantage for PSI and ISI values was derived for the participants in the present study. Without agreement among researchers[20,21] as to whether all 14 BBS items should be retained or how response categories should be revised and without other Rasch analyses of BBS use in people with a leg amputation for comparison, the original BBS items and rating structure met the acceptability criteria and were maintained.

The hierarchy of item difficulty results (Tab. 2) showed that sitting unsupported was the easiest item to perform, consistent with past research for elderly people and people who were neurologically impaired.[20,21] The 3 items that were most difficult for people with a leg amputation to perform were item 13 (standing with 1 foot in front), item 12 (placing alternate foot on stool), and item 11 (turning 360°). Only the best score was recorded after standing with 1 foot in front (the most difficult item) was attempted with both leg positions, although participant performance may have been improved by preferential emphasis on the intact leg. All 3 items required weight bearing and shifting on 2 legs; although these items enhanced balance ability, they were impossible to perform without a prosthesis. Placing alternate foot on stool and turning 360 degrees required moments of full weight bearing on the prosthetic leg alone, as in gait. Turning 360 degrees also required prosthetic leg transverse-plane rotation, a component movement not featured in most prostheses, making turning difficult for study participants using prostheses. Standing with 1 foot in front is a complex task for a person using a prosthesis because it requires substantial plantigrade weight bearing on the prosthetic leg or ankle plantar-flexion or dorsiflexion range of motion—a component motion not usually provided without substantial weight bearing—to place the prosthetic foot flat on the ground. Without a plantigrade prosthetic foot, hip rotation strength often maintains the foot position, although study participants used a variety of strategies. The findings of the present study were consistent with those of an early pilot study of 7 older people with vascular lower limb amputation; in the earlier study, items 11 to 13 were the only items with mean scores of less than 2 at admission and less than 3 at follow-up.[15]

To investigate whether item difficulty was different for participants who used prostheses and those who did not, we conducted a differential item functioning analysis. Significant differential item functioning occurs when the probability of an item response is different ($P<.05$) for people who have equal overall ability but belong to different groups, such as people who use prostheses and those who do not. Two items within the item difficulty hierarchy exhibited significant differential item functioning: item 5 (transferring to chair) was more difficult ($P=.03$) and item 6 (standing with eyes closed) was less difficult ($P=.01$) for participants who used prostheses than for those who did not. Standing with eyes closed may be more difficult for people who did not use prostheses because of decreased base of support and somatosensory feedback when only 1 leg is used.[37] Positioning a prosthesis correctly in preparation for a transfer is an important safety measure but is made difficult by the limited ability to actively flex the knee and hip that results from impaired muscle strength.[38] Differential item functioning statistics are interpreted conservatively with the primary aim of understanding the source of differences.[39] The differences for these 2 items did not affect the use of the 14-item BBS for the participants in the present study, regardless of prosthetic use.

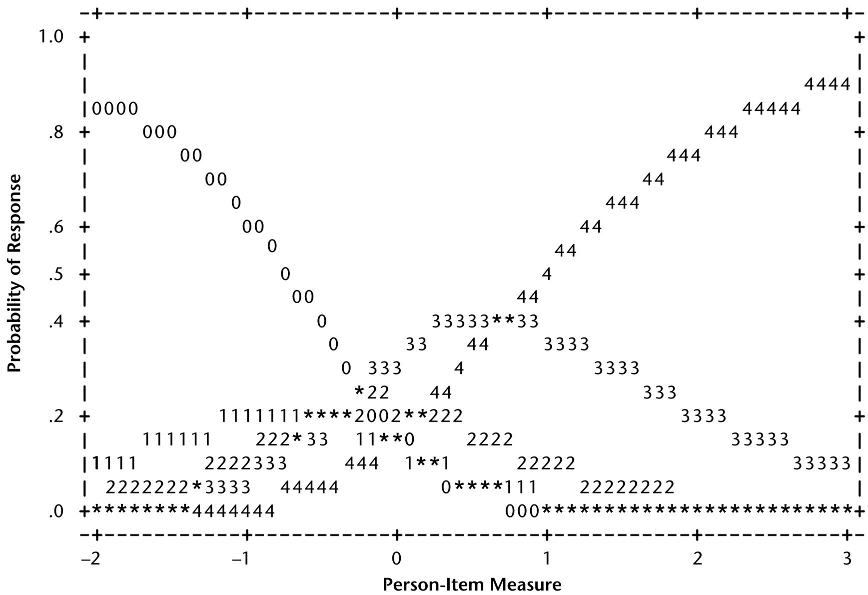

Figure 2.
Category probability curves.

Some participants scored near the maximum score on the BBS, indicating a ceiling effect, consistent with the findings of the early pilot study.[15] The health status of people after a leg amputation varies, depending on etiology, age, and other comorbidities.[40–42] Those with nonvascular etiologies are often young, otherwise healthy, and capable of performing at levels equivalent to those of people who are able-bodied.[43] The sample in the present study included 8 people with nonvascular etiologies; 7 of them performed at the 2 highest ability strata. This finding was consistent with those of previous studies in which the BBS was used to assess young people with nonvascular amputations; average BBS scores of 49.0 for people more than 2 years after transfemoral amputations[14] and 53.7 for athletes with transtibial amputations[13] were found. For people who have nonvascular amputations, are otherwise healthy, and have used a transtibial prosthesis for many years,[13] prosthetic leg use may become normal for them and the BBS may not identify balance performance deficits because of effectively learned compensations.[34] In contrast, for people with neurologic dysfunction such as stroke, visual or vestibular impairments may persist.[44] The participant with the highest level of performance in the present study had a traumatic amputation but was otherwise healthy and had used a prosthesis for 40 years.

At the other end of the spectrum, participants with the lowest scores were less likely to wear a prosthesis. More were unable to perform functional items while standing (items 6–14) and thus could be described as having difficulty maintaining dynamic standing balance. Wearing a prosthesis for standing weight-bearing activities may provide enhanced balance ability for people with a leg amputation. In addition, activities that require full weight bearing through the prosthetic leg (even for a short time, such as during stepping) and tasks that require transverse plane motion through the prosthesis (such as turning activities) may require more attention for the development of better balance dur-

Table 4.
Clinical Characteristics of Participants by Balance Ability Strata

Ability Stratum	No. of Participants	Age (y)		Person Measure			Berg Balance Scale Score			No. of Amputations		% of Participants	
		$\overline{X}$	SD	Logits	SD	Range	Total	SD	Range	Transfemoral	Transtibial	With a Vascular Etiology	Wearing a Prosthesis
4	8	55.6	10.4	3.66	0.68	3.15 to 5.1	54.75	0.71	54 to 56	4	4	50	100
3	8	54.1	9.4	2.25	0.11	2.2 to 2.43	51.25	0.46	51 to 52	7	1	62.5	100
2	11	59.3	6.0	0.95	0.35	0.47 to 1.47	40.18	4.24	34 to 46	7	4	100	90.9
1	13	60.1	12.0	−0.63	1.33	−4.76 to 0.14	21.15	9.15	1 to 29	9	4	92.3	46.2

ing rehabilitation after a leg amputation.[45]

Limitations

The limitations of the present study included a convenience sample of a small size recruited from a hospital-based support group and a prosthetic clinic. Although the sample size was not large, it exceeded the size of 30 recommended given the number of items in the BBS.[23] Clinical information that may have influenced balance, such as lower limb strength and range of motion, sensation, visual acuity, vestibular function, and prescribed medications, was not recorded.

The present study represents only the first step in the validation of the BBS for use with people after a leg amputation. Additional research with larger samples of people with a leg amputation is warranted so that subsets of participants can be examined separately to determine, for instance, whether balance ability in those without a prosthesis influences future prosthetic function or whether balance ability differs among those with different levels of amputation and affects the incidence of falls.

In addition, no attempt was made to determine interrater reliability or repeatability of BBS scores in the present study; these examinations will be undertaken in future research. Finally, only limited information regarding the participants' prostheses was obtained; features that may affect balance, such as specific prosthetic components, design, make, classification, fit, and alignment, were not recorded. Therefore, no conclusion regarding balance and specific prosthetic variables can be drawn.

Conclusions

In the present study, we examined balance ability, as measured by the BBS, in people with a leg amputation across the age-, etiology-, and amputation-level spectra. Rasch RSA confirmed the unidimensionality of the BBS for the assessment of balance and the internal validity of the scale, as reflected by the person and item separation values and the high associated reliabilities. Person and item goodness of fit was acceptable for ensuring the usefulness of the BBS. Although several items showed misfits, the misfits were explained by the unique characteristics of the study participants. The structural integrity of the BBS was satisfactory for the sample, and the BBS was used as a rating of balance ability, as intended. The BBS items that were most difficult for the study participants to perform were standing with 1 foot in front, placing alternate foot on stool, and turning 360 degrees. This finding may provide direction for rehabilitation after an amputation and future research into balance ability.

Dr Wong and Dr Chen contributed equally to the manuscript and provided concept/idea/research design and data analysis. All authors provided writing. Dr Wong and Dr Welsh provided data collection. Dr Wong provided project management, study participants, facilities/equipment, institutional liaisons, and clerical support. Dr Chen also provided consultation (including review of manuscript before submission).

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Study procedures followed the protocol approved by the Institutional Review Boards of Columbia University Medical Center.

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