Research Report

The Community Balance and Mobility Scale Alleviates the Ceiling Effects Observed in the Currently Used Gait and Balance Assessments for the Community-Dwelling Older Adults

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ABSTRACT

Background and Purpose: Currently used balance assessments show a ceiling effect and lack activities essential for community mobility in higher-functioning older adults. The aim of this study was to investigate the reliability and validity of the Community Balance and Mobility (CB&M) Scale in a high-functioning community-dwelling older adult population since the CB&M Scale includes assessment of several challenging tasks and may alleviate the ceiling effects observed in commonly used gait and balance assessments for this cohort.
Methods: A convenience sample of 40 older adults (73.4 ± 6.9 years) participated in this cross-sectional study. Previously standardized balance and mobility assessments measuring similar constructs as the CB&M were used for validation. Outcomes included Timed Up and Go Test, Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Functional Reach Test (FRT), Short Physical Performance Battery (SPPB), 6-Minute Walk Test (6MWT), Activities Specific Balance Confidence scale (ABC), gait speed, and intraindividual gait variability. A falls questionnaire documented the history of falls.
Results: Rater reliability (ICC $>$ 0.95) and internal consistency (α = .97) of the CB&M scale were high. CB&M scores demonstrated strong correlations with DGI, BBS, SPPB, and 6MWT (ρ = 0.70-0.87; $P < .01$); moderate correlations with falls history, TUG, ABC, and gait speed (ρ = 0.44-0.65; $P <$ .01); and low correlations with FRT, swing and stance time variability (ρ = 0.34-0.37; $P < .05$). Dynamic Gait Index, BBS, SPPB, and ABC assessments demonstrated ceiling effects (7.5%-32.5%), while no floor or ceiling effects were noted on the CB&M. Logistic regression model showed that the CB&M scores significantly predicted falls history (χ^2= 6.66, odds ratio = 0.92; $P < .01$). Area under the curve for the CB&M scale was 0.80 (95% CI: 0.65-0.95). A score of CB&M $\leq$ 39 was the optimal trade-off between sensitivity and specificity (sensitivity = 79%, specificity = 76%) and a score of CB&M $\leq$ 45 maximized sensitivity (sensitivity = 93%, specificity = 60%) to discriminate persons with 2 or more falls from those with fewer than 2 falls in the past year.
Discussion and Conclusions: CB&M scale is reliable and valid to evaluate gait, balance, and mobility in community-dwelling older adults. Unlike some currently used balance and mobility assessments for the community-dwelling older adults, the CB&M scale did not show a ceiling in detection of balance and mobility deficits. In addition, cutoff scores have been proposed that might serve as criteria to discriminate older adults with balance and mobility deficits. The CB&M scale might enable assessment of balance and mobility limitations masked by other assessments and help design interventions to improve community mobility and sustain independence in the higher-functioning community-dwelling older adult.
Key Words: assessment, gait and balance, older adults

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INTRODUCTION

Mounting evidence suggests that currently used assessments of gait and balance have ceiling effects when used in the higher-functioning community-dwelling older adults.[1-3] Higher-functioning older adults refer to older adults aged 65 years and older who are active, ambulatory, and living independently in the community (eg, residential homes, independent living facilities, and retirement facilities). Considering that gait and balance assessments are routinely used to screen falls risk and determine need for physical therapy in community-dwelling older adults population, ceiling effects pose a serious measurement concern. Ceiling effects refer to assessments being too easy and may mask the underlying balance deficits in this high-functioning population limiting their access to physical therapy services. For example, the Berg Balance Scale (BBS), which is considered

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a gold standard for balance assessment, is found to be less sensitive in predicting falls in older adults who are in good health and more active.[3] Similarly, the Performance-Oriented Mobility Assessment and Dynamic Gait Index (DGI), which are commonly used screening measures for gait, balance, and mobility deficits, are reported to show ceiling effects for the community-dwelling older adults.[2,4,5]

Furthermore, Boulgarides et al[1] reported that 5 balance tests (BBS, DGI, Timed Up and Go Test [TUGT], Modified Clinical Tests of Sensory Interaction for Balance, and 100% limits of stability test) could not predict falls in a sample of older adults who were active and independent.[1] Boulgarides et al[1] concluded that "these commonly used performance-based tests are not suitable for older adults who are high functioning, even when they are at a risk for falls."(p337) Similarly, Pardasaney et al[2] reported ceiling effects and limited responsiveness of 4 balance measures (BBS, DGI, Performance-Oriented Mobility Assessment, and Short Physical Performance Battery [SPPB]) in community-dwelling older adults.[2] Therefore, current evidence specifically highlights the need for development and validation of new challenging assessment tools for an increasingly active aging population.

The Community Balance and Mobility (CB&M) scale is a relatively challenging assessment and is reported to evaluate high-level deficits in gait, balance, and mobility. The CB&M scale was originally developed for and validated in high-functioning young and middle-aged ambulatory adults with traumatic brain injury (TBI).[6] In addition, the clinimetric properties of the scale have been investigated in children and adolescents with acquired brain injury and persons with mild to moderate stroke.[7,8] However, the CB&M scale has not been systematically used in the community-dwelling older adult population. Since the CB&M scale incorporates several demanding tasks commonly performed in the community environment, it may be a sensitive assessment to evaluate context-specific balance and mobility in community-dwelling older adults.

Clinimetrics of the CB&M scale have been demonstrated in other populations by an analysis of associations with assessments of related theoretical constructs. For instance, Inness et al[9] demonstrated construct validity of the CB&M scale in young and middle-aged adults with TBI by reporting moderate to high correlations of the CB&M scale scores with self-paced and maximal gait speed, laboratory measures of gait and dynamic stability (ie, variability in spatiotemporal gait parameters), and measures of balance confidence (ie, Activities-specific Balance Confidence scale). Importantly, they reported that the CB&M scale was less susceptible to a ceiling effect when compared to the commonly used BBS. Howe et al[6] also demonstrated discriminant validity by showing that the self-report of community participation differed in persons with TBI scoring more than 50 on the CB&M scale. Similarly, Knorr et al[8] demonstrated moderate to high convergent validity of the CB&M scale by reporting correlations between CB&M, BBS, TUGT, and other stroke-specific impairment measures in persons with mild to moderate stroke. Particularly, they reported that while the CB&M was highly correlated with BBS and TUGT, the CB&M showed the greatest sensitivity to detect change between baseline and follow-up when compared to BBS and TUGT.

Overall, the evidence from these studies supports the initial assumption that the CB&M scale can be used to evaluate high-level balance, gait, and mobility deficits. Furthermore, a systematic investigation of the measurement properties of the CB&M scale in community-dwelling older adults may assist in determining the utility of a challenging balance and mobility assessment for the current active and high-functioning aging population since there is a lack of sufficient high-level challenging assessments for this cohort. If the CB&M scale is determined to be appropriate for use in community-dwelling older adults unlike the ceiling effects observed on the currently used gait and balance assessments, it may enable physical therapists to unmask balance deficits and assist this cohort in accessing rehabilitative services to maintain their level of independence. Therefore, the purposes of this study were:

1. To establish reliability of the CB&M scale in community-dwelling older adults: Rater reliability and internal consistency of the CB&M scale were examined.
2. To validate the CB&M scale in community-dwelling older adults: Constructs measured by the CB&M scale are suggested to be gait, balance, and mobility.[6] Valid and reliable assessments measuring similar constructs currently used in the community-dwelling older adults were selected for validation of the CB&M scale.
3. To evaluate the floor or ceiling effects of the CB&M scale in comparison to ceiling effects of clinical assessments measuring similar constructs: Floor and ceiling effects were compared between the CB&M scale and routinely used clinical assessments measuring similar constructs as the CB&M scale.
4. To determine a cutoff score on the CB&M scale that can classify those with and without a history of falls.

METHODS

This study was a cross-sectional design. Community-dwelling older adults were recruited from the community. The community was defined as regular residential homes, retirement communities, and churches. Data were collected at 3 different sites: (1) University of North Florida Clinical and Applied Movement Sciences Research Laboratory, (2) local retirement facility, and (3) local YMCA (Young Men's Christian Association). Advertisement flyers were mailed out to residential, retirement, and independent living facilities. Targeted recruitment included talking to a group of seniors at the local YMCA regarding the purpose of the study. In addition, seniors were contacted via word

of mouth. Forty-seven community-dwelling older adults contacted the investigator regarding participation.

Participants

Inclusion criteria for participation were community-dwelling adults aged 65 years or older residing independently in the community (as defined previously); able to walk at the minimum indoors and outdoors with supervision or independently; ambulate without assistive devices other than a straight cane; and able to follow verbal requests for movement or tasks (eg, write a sentence, place a foot on a 6-inch step in front of a chair). Exclusion criteria were unstable acute or chronic disease; Folstein Mini-Mental State Examination score less than 23 suggestive of cognitive impairments[10]; severe neurologic and orthopedic impairments that limit balance and mobility; and severe cardiorespiratory symptoms and/or unstable cardiovascular disease. The study was approved by the University of North Florida Institutional Review Board for the protection of human subjects. All study participants provided informed consent. In addition, all rights of the participants were protected during the study.

Outcome Measures

Outcome measures included in this study to validate the CB&M scale are presented in Table 1. Six performance-based clinical assessments, 2 self-report assessments, and 2 laboratory-based assessments of gait addressing similar constructs of gait, balance, and mobility as the CB&M scale were utilized to validation. These assessments are described in Table 1, along with the construct that they measure. Originally, the Rivermead Mobility Index (RMI) was collected on a small sub-set (n = 16). However, the RMI was found to be too easy for this study sample. Therefore, data for the RMI have not been included here. The CB&M scale is described later.

The CB&M scale can be used to evaluate higher-level balance and mobility on 13 tasks scored from 0 to 5 and is suggested to represent underlying functional skills required in the community.[6] The items on the CB&M scale are "Unilateral Stance," "Tandem Walking," "180 degree Tandem Pivot," "Lateral Foot Scooting," "Hopping Forward," "Crouch and Walk," "Lateral Dodging," "Walking & Looking," "Running with Controlled Stop," "Forward to Backward Walking," "Walk, Look & Carry," "Descending Stairs," and "Step-Ups x1." Higher scores are indicative of better balance and mobility. One item (descending stairs) is scored from 0 to 6, with an extra point given for carrying a basket while descending stairs. The maximum score is 96 points. The scale has shown to be valid and reliable in ambulatory persons with TBI and those with mild to moderate stroke.[6,8] High rater reliability and internal consistency have also been reported in high-functioning school-aged children and adolescents with acquired brain injury.[7] Other clinimetric properties tested for the CB&M include floor and ceiling effects in persons with TBI and mild to moderate stroke and responsiveness in persons with mild to moderate stroke and children with cerebral palsy.[8,27]

Instrumentation

Study assessments required minimal equipment except the laboratory-based gait assessments that were conducted using an instrumented mat (GAITRite version 4.0) 20 feet in length. GAITRite is shown to be valid and reliable to evaluate spatiotemporal gait measures.[28] The standard GAITRite is an electronic walkway containing 9 sensor pads encapsulated in a roll-up carpet to produce an active area 24 inches wide and 240 inches long. The sampling rate of the GAITRite is 120 Hz. Outcomes from the GAITRite that were included in the study were average gait speed and intraindividual variability in spatiotemporal gait measures (gait variability).

Procedures

Participants wore their own low-heeled shoes. All testing was conducted in 1 session in 1 day. Testing began with a short warm-up walk and proceeded in sets to minimize fatigue. In each set, performance-based assessments were conducted before self-report questionnaires and walking assessments before nonwalking to avoid fatigue-related bias on test performance. In set 1, GAITRite measures were collected, followed by the CB&M assessment. Set 1 ended with the participants completing the falls history questionnaire. For the GAITRite measures, participants were asked to start walking in response to a "go" signal and stop at a designated finish position. Three trials each were collected at the self-selected gait speed. Set 2 consisted of SPPB and DGI assessments followed by the 6MWT. Finally, in the last set, performance on the BBS, TUGT, and FRT was assessed and at the end of this set, participants completed the ABC questionnaire. Two to 3 scheduled rest periods for up to 10 minutes each were incorporated between testing sets. Participants were also allowed sufficient rest periods (within the sets) at any time they wished.

At the beginning of the study, the 2 physical therapists involved in the study completed a similar training session using sample videos from representative participants to score their performance on the CB&M scale. A safety walking belt worn around the waist was used to protect the participant in the event of balance loss during the testing. A physical therapist with 10 years of experience in gait and balance testing administered all the testing for all study participants. The CB&M testing sessions were videotaped. To evaluate the intrarater reliability of the CB&M, the videotaped assessments were scored by the same physical therapist. For the intrarater reliability, 1 assessment was scored in front of the participant during the testing,

Table 1. Outcome Measures Selected for Validation of the Community Balance and Mobility Scale

Study Outcomes	Construct Measured	Valid Reliable	Cutoff Score	Brief Description
Performance-based clinical assessments				
DGI	Balance Gait	Yes[11]	Score < 19 indicates increased falls risk	Assesses a person's ability to adapt to gait challenges on 8 gait tasks scored from 0 to 3
BBS	Balance Mobility	Yes[11,12]	Score < 36 suggests 100% fall risk	Evaluates balance on 14 tasks of varying difficulty (including sitting and standing tasks) scored from 0 to 4
SPPB	Balance Gait Mobility	Yes[13]	Score ≤ 10 predictive of future mobility disability[14,15]	Evaluates standing balance, gait speed, and repeated chair rise and scored from 0 to 4
TUGT	Balance Gait Mobility	Yes[16,17]	Score > 14 s has high sensitivity and specificity in correctly predicting patients with and without history of falls[18]	Measures the time taken to stand up from a chair, walk 3 m, turn around, walk back to the chair, and return to a seated position
FRT	Balance	Yes[19,20]	Score < 7 inches[19,20]	Quick screen for balance problems and measures the maximum distance traversed when reaching as far forward
6MWT	Gait Community Participation	Yes[15,21,22]	Normative distances for 70-79 years[15,21,22] 527 m for males, 471 m for females	Records the distance covered while walking continuously for 6 min
Self-report assessments				
FALLS[a]	Gait Balance Mobility	NA	NA	Questions modified from the Falls Questionnaire of the National Health Interview Survey were utilized to document the history of falls in the past 3 mo and in the past year[a]
ABC	Balance (Fear of falling) Community Participation	Yes[23]	Score < 67% used as a predictor for falls risk[24]	16-item self-report questionnaire where individuals rate their degree of confidence to perform common activities within the home and community
Laboratory-based gait assessments				
GAIT SPEED	Gait Community Ambulation	Yes[25]	Speed > 0.8 m/s suggests unlimited community ambulatory	Assessed by having participants walk on a 20-foot instrumented walkway (GAITRite)
GAIT VARIABILITY	Balance Gait	Yes[26]	None	Assessed by having participants walk on a 20-foot instrumented walkway (GAITRite)

Abbreviations: ABC, Activities-Specific Balance Confidence; BBS, Berg Balance Scale; DGI, Dynamic Gait Index; Falls, number of falls in the past year; FRT, Functional Reach Test; NA, not applicable; 6MWT, Six-Minute Walk Test; SPPB, Short Physical Performance Battery; TUGT, Timed Up and Go Test.
[a]A fall was defined as any event that led to an unplanned, unexpected contact with a supporting surface like the floor, ground, a bed, or a chair. Standardized types of falls were listed on the survey and participants indicated the most likely causes for their falls based on this itemized list.

whereas the other was scored by the same physical therapist approximately 3 weeks later from the video recording during the testing. To evaluate the interrater reliability, another physical therapist with 25 years of experience blinded to the initial score independently scored the videotaped CB&M assessments.

Data Reduction

Performance-based and self-report clinical assessments data

Individual items on the ordinal assessments of CB&M, DGI, BBS, and SPPB were scored and the summed total score was utilized for analyses. For the ABC, an average percent score was utilized for analyses since individual items on the ABC are scored as a percentage. The FRT, TUGT, and 6MWT generate ratio-level data, which were directly utilized for data analyses.

Laboratory-based gait assessment data

The average number of footfalls collected and analyzed per subject was 28 ± 5 steps at the self-selected gait speed. Footfalls from all trials were analyzed. Spatiotemporal variables included in this study were average self-selected gait speed and intraindividual gait variability in step lengths, stance and swing times, and stride time and stride width. Individual trials were averaged together to determine the average spatiotemporal data for each participant. For gait variability data, standard deviation in spatiotemporal characteristics across steps was computed.[29]

Statistical Analyses

Reliability of the CB&M scale

Intraclass correlation coefficients were utilized for interrater ($ICC_{2,k}$) and intrarater ($ICC_{3,k}$) reliability. The Cronbach alpha statistic evaluated internal consistency of the CB&M scale. Desired standards for reliability coefficients are reported to range from 0.90 to 0.95.[30]

Validity of the CB&M scale

Nonparametric spearman correlations evaluated the concurrent validity of the CB&M scale. Spearman coefficients were utilized since the data measured on one (eg, CB&M and TUGT) or both (eg, CB&M and DGI) correlating variables were ordinal level. Correlation coefficients $P < 0.25$ were considered to indicate little or poor relationship; those between 0.25 and 0.50, a moderate relationship; those between 0.50 and 0.75, a good relationship; and values greater than 0.75, an excellent correlation.[31]

Floor and ceiling effects on clinical assessments

The floor and ceiling effects were calculated as the percentage of the sample scoring the minimum or maximum possible scores, respectively. Specifically, ceiling effects were defined only in clinical assessments that had a clear maximum (ie, ceiling on BBS is 56, DGI is 24, SPPB is 12, ABC is 100%).

Determining a cutoff score on the CB&M scale

A logistic regression model (with age and gender as covariates) investigated the likelihood of a history of falls using CB&M as the predictor and the dichotomous response of "two or more falls" versus "fewer than two falls" as the response. We used "two or more falls" as the response since persons having fallen 2 or more times in the past year are reported to be at a high risk for falls.[32]

For assessing the diagnostic power and determining a cutoff score for the CB&M scale, a receiver operating characteristic (ROC) curve was constructed for the response of "2 or more falls" and "fewer than 2 falls." Area under the curve (AUC) was used to assess the screening ability of the CB&M scale. Hosmer and Lemeshow[33] suggest that $0.7 \leq AUC \leq 0.8$ is acceptable, with AUC = 0.50 corresponding to random classification. Two cutoff scores were investigated: (1) that was the optimal trade-off between sensitivity and specificity and (2) that maximized the sensitivity to 0.90 or greater.

The optimal balance/trade-off between sensitivity and specificity is the point on the ROC curve that is "highest" in the direction of the upper left-hand corner of the graph. On the contrary, in the context of fall risk classification, maximizing sensitivity is suggested to be more important since a false-negative result (where a person is misclassified as not being at risk for falls when that person is at high risk for falls) carries more significant consequences than a false-positive result (where a person is misclassified as being at high risk for falls when that person is not at high risk).[34]

Sensitivity and specificity of the cutoff scores were also calculated. Sensitivity is the true positive ratio and was computed as the proportion of those who are at high risk for falls that will be classified by the assessment cutoff as being at high risk. Specificity is the true negative ratio computed as the proportion of those in the population who are not at high risk that will be classified by the assessment as being not at high risk. Last, Mann-Whitney *U* tests examined the ability of the proposed cutoff score for the CB&M scale to discriminate individuals in their gait and balance abilities.

RESULTS

A convenience sample of 40 community-dwelling older adults (73.3 ± 6.9 years, 14 men) was eligible and participated in the study. Twenty-six study participants resided in their own homes, 11 in independent living facilities, and 3 in retirement communities. Data for the 6MWT were collected only in 37 of 40 study participants because 3 participants were unable to test because of personal time constraints. Similarly, spatiotemporal gait data were collected on only 36 of the 40 participants. Two persons were unable to test because of personal time constraints and the equipment (GAITRite) was unavailable for the other 2 participants (Figure 1).

Rater Reliability and Internal Consistency of the CB&M Scale

Inter- and Intrarater reliability coefficients were high, with $ICC_{2,k}$ evaluating interrater reliability at 0.953 (95% CI = 0.88-0.98) and $ICC_{3,k}$ evaluating intrarater reliability at 0.962 (95% CI = 0.928-0.98). The Cronbach alpha was also high at 0.962.

Concurrent Validity of the CB&M Scale

Excellent correlations were found between CB&M and DGI, BBS, and SPPB (ρ = 0.75-0.87; $P < .01$) as shown in Table 2. Good correlations were found between CB&M and 6MWT, TUGT, and self-selected gait speed (ρ = 0.65-0.71; $P < .01$). Significant moderate correlations were found between CB&M and falls in the past year, ABC, FRT, swing time, and stance time variability (ρ = 0.34-0.47; $P < .01$). Correlations between CB&M, age and step length, step time, stride time, and stride width variability were low and insignificant (ρ = 0.05-0.26; $P > .05$).

Score Characteristics of the CB&M in Comparison to Other Study Assessments

The range of scores was the widest for the CB&M compared with other clinical assessments and the CB&M scale demonstrated no floor or ceiling effects (Table 3). Contrarily, ceiling effects were demonstrated on the ABC, DGI, BBS, and SPPB clinical assessments (7.5%-32.5%)

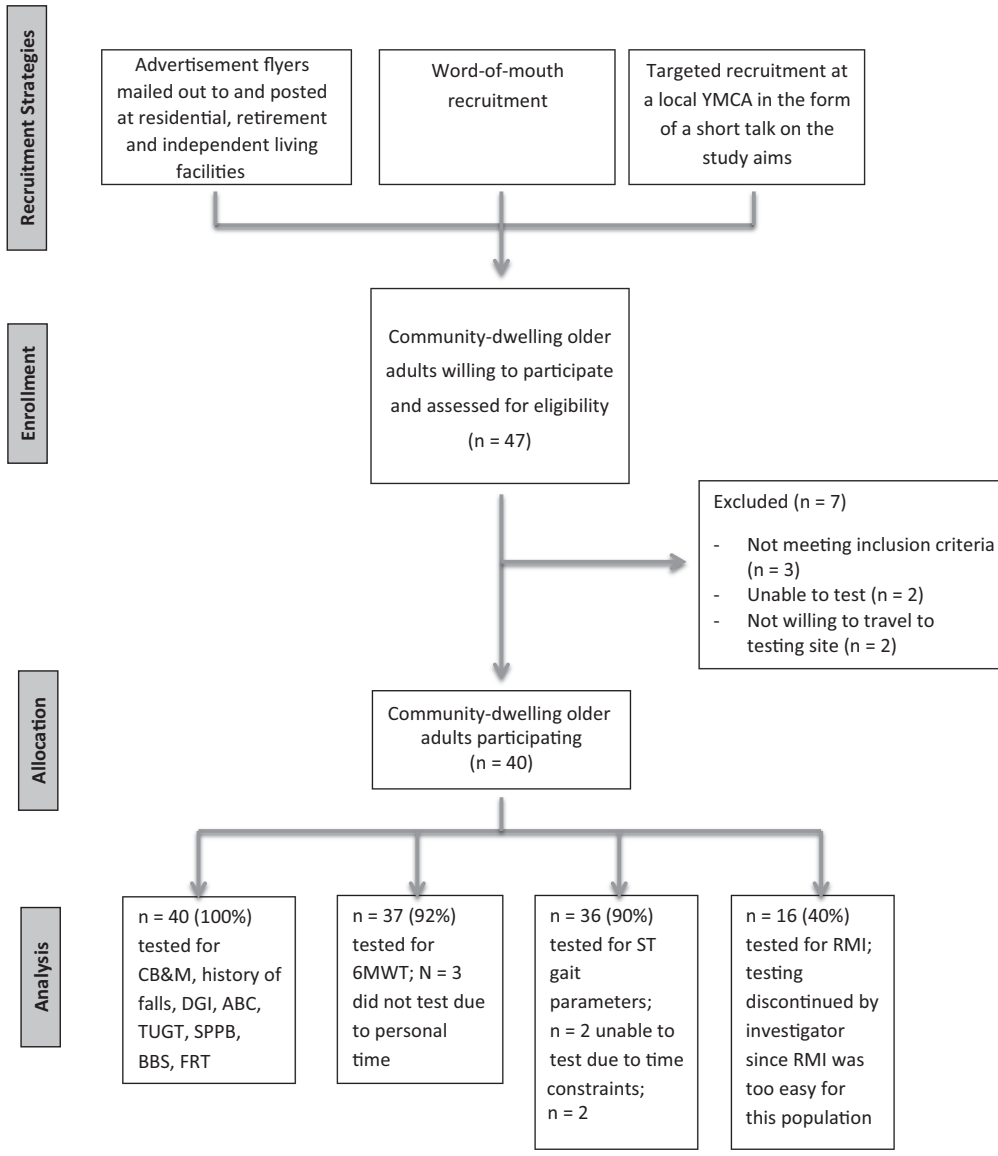

Figure 1. Flowchart explaining how the study sample was arrived at. ABC indicates Activities-Specific Balance Confidence; CB&M, Community Balance and Mobility; DGI, Dynamic Gait Index; RMI, Rivermead Mobility Index; SPPB, Short Physical Performance Battery; TUGT, Timed Up and Go Test.

(Table 3). Note that no floor effects were found for any clinical assessment and, therefore, floor effects are not reported in Table 3.

Determining a Cutoff Score for the CB&M Scale to Predict Falls History

The logistic regression model showed that CB&M was a significant predictor of falls history ($\chi^2 = 6.66$; $P < .01$), with the probability for "2 or more falls" increasing as the CB&M scores decrease (Table 4, Figure 2). Figure 2 presents the raw scatter plot to demonstrate the relationship between CB&M scale scores and falls history. A Poisson trend line was superimposed on Figure 2 to display the trend of the relationship.

Area under the curve was 0.8 (95% CI = 0.65-0.94) (Figure 3). CB&M $\leq$ 39 was the optimal trade-off between sensitivity and specificity, with the sensitivity of 79% and specificity of 76%. CB&M $\leq$ 45 yielded a sensitivity of greater than 90%, with the sensitivity of 93% and specificity of 60% in discriminating those at "2 or more falls" from those at "fewer than 2 falls" (Figure 3, Table 5). In addition, when persons were dichotomized in 2 categories using each of the cutoff scores of 39 and 45, their DGI, BBS, 6MWT, ABC, SPPB, and TUGT scores and self-selected gait speed significantly differed (Figure 4). On the contrary, FRT and gait variability measures were not significantly different in persons dichotomized in these categories. Only significant differences have been illustrated in Figure 4.

Table 2. Correlations Between Community Balance and Mobility and Gait, Balance, and Walking Outcomes

Outcomes	Spearman rho	*P*
Number of falls in the past year	−0.44[a]	0.005
Activities-Specific Balance Confidence Scale	0.47[a]	0.002
Dynamic Gait Index	0.79[a]	<0.001
Berg Balance Scale	0.87[a]	<0.001
Short Physical Performance Battery	0.75[a]	<0.001
Timed Up and Go Test	−0.69[a]	<0.001
Functional Reach Test	0.35[b]	0.026
6-Minute Walk Test[c]	0.71[a]	<0.001
Gait speed[d]	0.65[a]	<0.001
Step length variability[d]	−0.16	0.343
Step time variability[d]	−0.26	0.118
Stride time variability[d]	−0.12	0.491
Swing time variability[d]	−0.37[b]	0.028
Stance time variability[d]	−0.34[b]	0.041
Stride width variability[d]	−0.06	0.738

[a]$P < .01$. [b]$P < .05$.
[c]Data are reported on 37 participants.
[d]Data are reported on 36 participants.

DISCUSSION

The purpose of this study was to investigate the measurement properties of a challenging assessment, the CB&M scale in high-functioning community-dwelling older adults since it is reported that currently used gait and balance assessments may be too easy for this population.[1-5] The specific findings from this study are as follows: (1) The CB&M scale is valid and reliable to evaluate gait, balance, and mobility in the active, ambulatory, and independently living community-dwelling older adults, (2) no ceiling effects were found on the CB&M scale, whereas varying degrees of ceiling effects were observed on clinical assessments of ABC, DGI, BBS, and SPPB, (3) the CB&M scores predicted falls history and cutoff scores of CB&M ≤ 45 (sensitivity > 90%) and CB&M ≤ 39 (balance between sensitivity and specificity) may serve as criteria to discriminate persons with impaired gait, balance, and mobility function.

The CB&M scale demonstrated excellent reliability. Rater reliability was high at ICC > 0.95, exceeding the recommended standards of 0.90 to 0.95 for clinical assessments.[30] The Cronbach alpha was also high, suggesting that the items in the CB&M scale reflect the same construct of gait, balance, and mobility.

In addition, concurrent validity of the CB&M scale was revealed in the good to excellent correlations between CB&M scores and other performance-based and self-report clinical assessments, with the majority of the correlations being greater than 0.5, implying that the CB&M scale evaluates similar constructs of gait, balance, and mobility. Specifically, excellent correlations (>0.75) found between CB&M, DGI, BBS, and SPPB and good correlations (0.5-0.75) between CB&M and TUGT, suggest that the CB&M scale is valid to evaluate "gait," "balance," and "mobility" in the community-dwelling older adult. While strong correlations assist in validating the similarity of constructs measured by assessments, poorer and lower correlations highlight those constructs that are differentially measured by assessments. For instance, the moderate relationship between CB&M scale and FRT (0.25-0.5) suggests that,

Table 3. Score Characteristics of the Community Balance and Mobility and Other Study Assessments (n = 40)

Study Outcomes	Mean ± SD	Median	Minimum Score	Maximum Score	Ceiling Effect
CB&M	47.6 ± 18.7	42.0	17.0	86.0	0%
FALLS	01.3 ± 01.6	1.0	0.0	6.0	NA
ABC, %	87.8 ± 12.1	92.2	56.6	10.0	7.5%
DGI	19.8 ± 03.5	21.0	13.0	24.0	10.0%
BBS	53.1 ± 02.5	54.0	47.0	56.0	22.5%
SPPB	10.5 ± 01.6	11.0	6.0	12.0	32.5%
TUGT, s	10.4 ± 02.2	10.4	6.3	15.6	NA
FRT, inches	11.1 ± 02.2	11.0	6.0	16.0	NA
6MWT,[a] m	406.8 ± 90.5	413.7	199.6	594.0	NA
Gait speed,[b] cm/s	115.7 ± 29.1	118.0	42.2	190.4	NA

Abbreviations: ABC, Activities-Specific Balance Confidence; BBS, Berg Balance Scale; CB&M, Community Balance and Mobility Scale; DGI, Dynamic Gait Index; Falls, number of falls in the past year; FRT, Functional Reach Test; NA, not applicable; 6MWT, Six-Minute Walk Test; SPPB, Short Physical Performance Battery; TUGT, Timed Up and Go Test.
[a]Data are reported on 37 participants.
[b]Data are reported on 36 participants.

Table 4. Logistic Regression Model to Predict Fall History Using Community Balance and Mobility Scale Scores

Parameter	β	χ^2	*P*	Model R^2	OR
Constant	2.745	4.81	0.0282[a]	…	…
CB&M	−0.075	6.66	0.0099[b]	0.206	0.93

Abbreviation: OR, odds ratio.
[a] $P < 0.05$.
[b] $P > 0.01$.

while FRT assesses the limits of stability, the CB&M scale may primarily evaluate dynamic aspects of balance. Similarly, the moderate relationship between CB&M scale and ABC may imply that the construct of confidence in doing activities without losing balance may not be well captured by the CB&M scale.

Contrary to the associations between CB&M scores and performance-based and self-report assessments, the CB&M scores significantly correlated only with some laboratory-based gait assessments. The CB&M scores revealed a good positive correlation with gait speed, with CB&M scores increasing with increasing gait speed. The positive correlation with gait speed may suggest greater physical functioning level for those with higher CB&M scores since gait speed is reported to be a clinically meaningful indicator of physical health status and community mobility in the senior population.[25] Importantly, a large study in community-dwelling older adults aged 65 years and older showed that gait speed was associated with survival rates, with older adults walking at speeds faster than 0.8 m/s having better life expectancy.[35] In this study, the slowest participant who walked at 0.42 m/s also scored low on the CB&M (30), while DGI, BBS, and FRT scores were high at 19, 52, and 10 inches, respectively. Another participant walking at 0.68 m/s, also scored low on the CB&M (39), while similarly scoring high on the DGI, BBS, and FRT (22, 52, and 13 inches, respectively). These representative data highlight the relationship between CB&M scores and gait speed in relation to other clinical assessments and suggest a strong relationship between CB&M scores and gait speed. Importantly, while gait speed serves as a quick screen of mobility deficits, assessment with the CB&M scale may reveal deficits in remediable risk factors of gait, balance, and mobility that may be masked by other assessments. For example, an evaluation with CB&M in slow walking seniors may assist in designing intervention strategies to improve balance and mobility function to maintain independence.

Furthermore, contrary to the strong correlation with gait speed, only low correlations were found between CB&M scores and some gait variability measures. Gait variability is reported to be a robust clinical outcome shown to predict the risk for future falling.[26,36] However, it has been reported that not all step variability measures uniformly correlate with underlying impairments. For instance, stance time variability has been related to

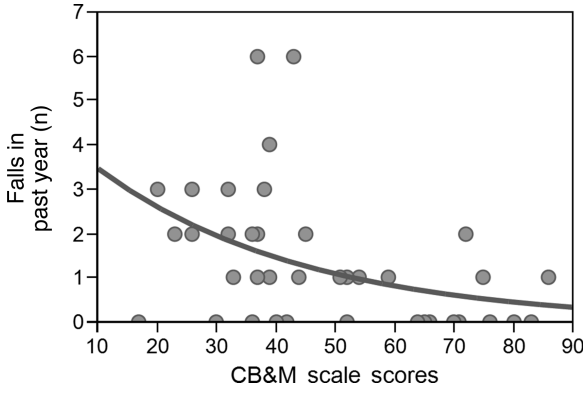

Figure 2. Scatterplot showing the relationship between performance on the Community Balance and Mobility (CB&M) scale and the number of falls in the past year. As the CB&M scale score increases, the number of falls in the past year decreases. The trend line displayed in the Figure is a Poisson trend line. CB&M indicates Community Balance and Mobility.

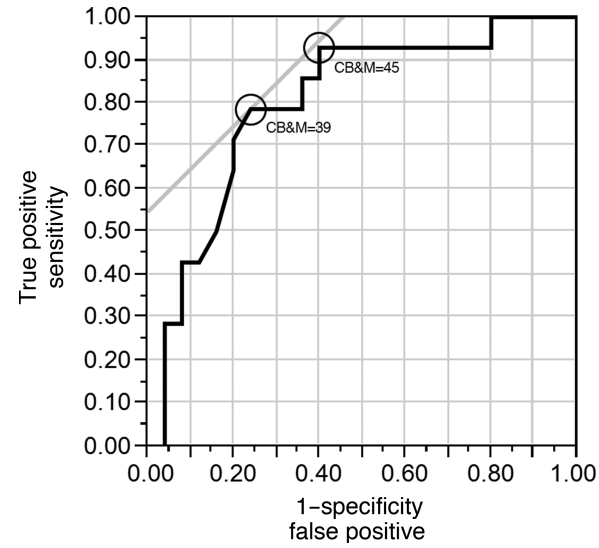

Figure 3. Receiver operating characteristic curve illustrating the validity of the Community Balance and Mobility (CB&M) scale for predicting fall history. The area under the curve was 0.8 (95% CI: 0.65-0.95). CB&M = 39 was the optimal trade-off between sensitivity and specificity and is the point on the ROC curve that is "highest" in the direction of the upper left-hand corner of the graph. CB&M = 45 maximized sensitivity to greater than 90%. CB&M indicates Community Balance and Mobility.

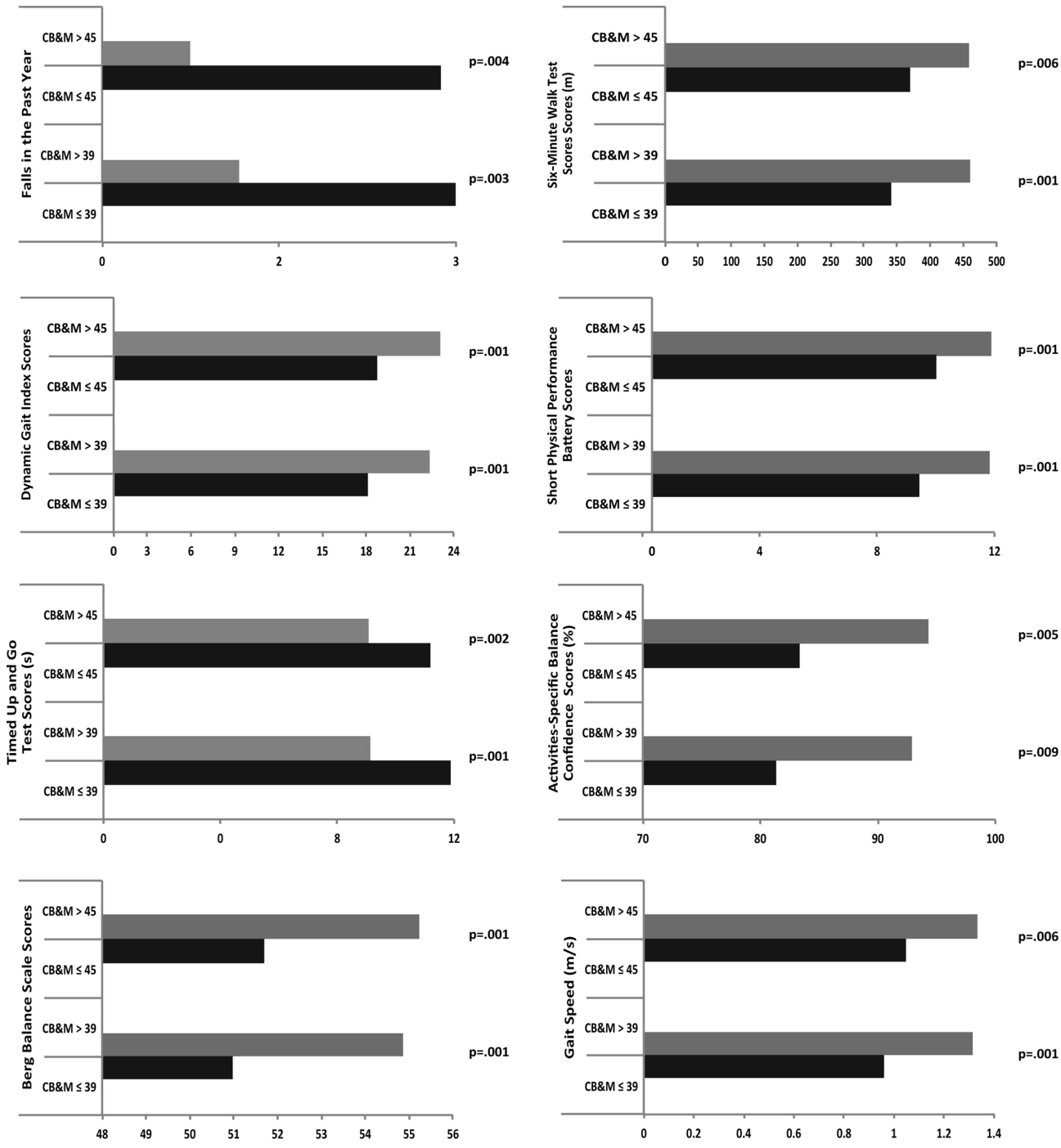

Figure 4. Significant differences in study outcomes across participants dichotomized by the cutoff scores of CB&M ≤ 45 and CB&M ≤ 39. Persons who scored CB&M ≤ 45 and CB&M ≤ 39 had a greater history of falls, DGI, BBS, 6MWT, and SPPB scores were lower, and TUGT times and gait speeds were faster in persons who scored CB&M > 45 and CBM > 39. Note that only the significant differences have been displayed. BBS indicates Berg Balance Scale; CB&M, Community Balance and Mobility; DGI, Dynamic Gait Index; 6MWT, Six-Minute Walk Test; SPPB, Short Physical Performance Battery; TUGT, Timed Up and Go Test.

cognitive impairments, whereas swing time variability was a strong predictor of future falls in a large study.[37,38] In this study, negative correlations (while low in strength) were found between swing time and stance time variability and CB&M scores, suggesting that increased step variability was related to poorer performance on the CB&M scale. Specifically, the correlation between CB&M score and swing time variability highlights the need for investigating the relationship between CB&M scores and future falls. Whereas the correlation between CB&M score and stance

Table 5. Sensitivity and Specificity of the Proposed Cutoff Scores for the Community Balance and Mobility Scale

Cutoff Score for the CB&M scale	Sensitivity (True Positive Rate)	Specificity (True Negative Rate)	PPV	NPV	Prevalence	Expected Number of Falls at the Cutoff
39	0.79	0.76	0.65	0.86	0.36	1.52
45	0.93	0.60	0.57	0.94	0.36	1.28

Abbreviations: CB&M Scale, Community Balance and Mobility Scale; NPV, Negative Predictive Value; PPV, Positive Predictive Value.

time variability suggests that at least some items on the CB&M scale may measure cognitive function in addition to balance in older adults. Indeed, some of the assessment items on the CB&M scale were originally intended to test sequencing complex motor tasks. However, the strength of correlations between CB&M scores, stance, and swing time variability was low, limiting the suggestion of a clear relationship between CB&M scores and gait variability. A larger sample size may reveal stronger correlations and correlations of the CB&M scores with other gait variability parameters (like step length, step width, and stride time variability).

An important result from this study was that the CB&M scale did not demonstrate any ceiling effects, whereas ceiling effects of varying degrees were demonstrated in routine clinical assessments like ABC, DGI, BBS, and SPPB. The CB&M evaluates several high-level tasks required for community participation and may be an appropriate assessment for older adults who are in good health and more active but who also may be at a risk for falls. It is also important to note that while the majority of the items of the CB&M scale seemed to be at the target level, some items on the CB&M scale may be too challenging even for the high-functioning ambulatory community-dwelling older adults. For instance, for 3 items of the CB&M scale ("Lateral foot scooting," "Hopping forward," and "Running with controlled stop"), 35% to 40% of the study sample scored a minimum score of zero and were unable to perform these items, suggesting that these items may be too challenging for the older adult population. A modified short form for the community-dwelling older adults could be tested in future studies by eliminating these difficult items. Ultimately, utilization of an item response theory model like the Rasch Model may assist in specifically measuring the match of population ability to individual item ability levels.

The other challenging assessments for this population included the ABC and DGI, as revealed by lower ceiling effects on these assessments. These assessments seemed to include items that evaluate community ambulation and participation. For example, the ABC is a self-report questionnaire assessing confidence level while performing several activities in the community.[23] The DGI assesses dynamic gait activities and includes relevant tasks required for community mobility like stepping over obstacle and turning head while walking.

Similar to other reports, this study found that the gold standard BBS showed ceiling effects. Specifically, the BBS demonstrated greater ceiling effects than other assessments like the ABC and DGI. While the BBS includes some challenging items like standing on one leg and tandem stance, the majority of the items on the BBS may be too easy for the community-dwelling older adults. Importantly, all participants in this study also scored more than 36, highlighting the lower discriminatory ability of the BBS in higher-functioning seniors. The SPPB showed the greatest ceiling effect and may be more appropriate for lower-functioning older adults.

Furthermore, it is important to note that while there are several balance tests that are readily available for clinical use, any one test may not necessarily address all measurement purposes in a given context.[39,40] Results from this study suggest that a continuum of assessments may be available to measure functional balance and mobility for older adults with some tests being more challenging evaluating higher ability levels and others seemed being easier evaluating lower ability levels. For instance, 37% of the study sample was faster than the normative TUGT value of 9.2 for their age group.[16] Ninety-seven percent of the sample reached a distance greater than 7 inches on the FRT.[20] Nineteen percent of the study sample walked greater than 499 m, the average distance for their age group.[15] Overall, these data suggest that TUGT, FRT, and 6MWT are somewhat easy assessments for a community-dwelling elderly population. This observation, combined with the finding of ceiling effects on BBS, DGI, ABC, and SPPB, suggests that many of the assessments currently used for the high-functioning community-dwelling older adults may be relatively easy for this cohort.

Furthermore, the results of logistic regression analysis showed that the CB&M scores predicted falls history. However, a large amount of variance in falls history was unexplained by the CB&M scale, highlighting the multifactorial nature of falls. While the overall prediction was low, probability of falls decreased with increasing scores on the CB&M scale. In addition, AUC was high (AUC = 0.80) and was of acceptable diagnostic power ($0.7 \leq AUC \leq 0.8$). By constructing the ROC curve, 2 cutoff scores for the CB&M scale were proposed in this study: a cutoff score that was the optimal trade-off between sensitivity and specificity and another that maximized the sensitivity. While optimizing the balance between sensitivity and specificity is routinely employed in the literature to determine cutoff

scores, this study also specifically investigated the cutoff score that maximized sensitivity. Maximizing sensitivity has earlier been recommended in the context of fall risk categorization in an attempt to reduce a false-negative outcome.[34] Specifically, CB&M ≤ 39 was the best trade-off between sensitivity and specificity, with a sensitivity of 79% and a specificity of 76%, whereas the CB&M ≤ 45 yielded a sensitivity of greater than 90%, a sensitivity of 93%, and specificity of 60% in discriminating those at 2 or more falls from those at fewer than 2 falls.

In addition, these cutoff scores were validated since the performance on other study gait, balance, and mobility assessments significantly differed in these dichotomous categories. Note that FRT and gait variability measures did not differ between the dichotomous categories, further highlighting the low or insignificant associations between these outcomes and the CB&M scale scores.

While both of the cutoff scores proposed in this study could serve as criteria to evaluate persons with gait, balance, and mobility deficits, choice of the cutoff score would depend on the purpose of the evaluation. If the purpose of a gait, balance, and mobility evaluation is to screen those at falls risk, there is a high likelihood that CB&M ≤ 45 may categorize an individual correctly as being at falls risk since this cutoff score maximizes the true positive rate (high sensitivity). On the contrary, if the purpose of the evaluation is to determine the need for skilled intensive physical therapy services, a more rigorous cutoff score of CB&M ≤ 39 may prove to be a cost-effective approach since it optimizes the balance between true positives and true negatives. For instance, for an individual scoring CB&M ≤ 45 but CB&M > 39, an intensive one-on-one physical therapy may be deferred and this individual may be counseled on alternative therapeutic options, such as community- or home-based exercises designed to improve balance. On the contrary, for an individual scoring CB&M ≤ 39 skilled physical therapy services may be indicated. However, the suggested cutoff scores should be interpreted with caution since our sample size was relatively small and the fall risk data were retrospectively assessed using falls history.

Overall, this study has critical limitations and the study findings should be cautiously interpreted. Although the research plan and data gathering were prospective, we relied on each participant's self-reported fall history as the diagnostic gold standard for fall risk and subsequently used the falls history as a standard for computing the cutoff scores. A possibility of under- or misreporting of fall events exists. In addition, self-report of falls was not validated with medical records or documentation. A similar method should be applied with prospective observation of falls as the diagnostic gold standard. Future directions should also include determining the responsiveness of the CB&M scale to rehabilitative interventions. Finally, since the CB&M scale is a lengthy assessment, development of a short-form demands consideration.

CONCLUSIONS

CB&M is suggested to be a valid and reliable assessment to evaluate gait, balance, and mobility limitations in the higher-functioning older adults. Second, it is suggested that CB&M may be an appropriate challenging test reflective of the higher level of function in older adults who are active and living independently in the community but who may also be at risk for falling since the CB&M did not demonstrate floor or ceiling effects whereas varying degrees of ceiling effects were found on clinical assessments of ABC, DGI, BBS, and SPPB. Third, 2 cutoff scores have been presented; CB&M ≤ 45 (sensitivity of 93% and specificity of 60%) and CB&M ≤ 39 (sensitivity of 79% and specificity of 76%) to discriminate higher-functioning seniors with 2 or more falls from those fewer than 2 falls. Future research is recommended to develop a short form of the CB&M scale, investigate the ability of CB&M scores to predict future falls in community-dwelling seniors, and evaluate the sensitivity of the CB&M scores to intervention.

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