ORIGINAL ARTICLE

Mobility Assessment: Sensitivity and Specificity of Measurement Sets in Older Adults

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ABSTRACT. Panzer VP, Wakefield DB, Hall CB, Wolfson LI. Mobility assessment: sensitivity and specificity of measurement sets in older adults. Arch Phys Med Rehabil 2011;92: 905-12.

Objective: To identify quantitative measurement variables that characterize mobility in older adults, meet reliability and validity criteria, distinguish fall risk, and predict future falls.

Design: Observational study with 1-year weekly falls follow-up.

Setting: Mobility laboratory.

Participants: Community-dwelling volunteers (N=74; age, 65–94y) categorized at entry as 27 nonfallers or 47 fallers by using Medicare criteria (1 injury fall or >1 noninjury fall in the previous year).

Interventions: None.

Main Outcome Measures: Test-retest and within-subject reliability, criterion and concurrent validity; predictive ability indicated by observed sensitivity and specificity to entry fall-risk group (falls status), Tinetti Performance Oriented Mobility Assessment (POMA), computerized dynamic posturography Sensory Organization Test (SOT), and subsequent falls reported weekly.

Results: Measurement variables were selected that met reliability (intraclass coefficient of correlation >.6) and/or discrimination (P<.01) criteria (clinical variables: turn steps and time, gait velocity, step-in-tub time, downstairs time; forceplate variables: quiet standing Romberg ratio sway area, maximal lean anterior-posterior excursion, sit-to-stand medial-lateral excursion, sway area). Sets were created (3 clinical, 2 forceplate) using combinations of variables appropriate for older adults with different functional activity levels, and composite scores were calculated. Scores identified entry falls status and concurred with POMA and SOT scores. The full clinical set (5 measurement variables) produced sensitivity of 80% and specificity of 74% to falls status. Composite scores were more sensitive and specific overall in predicting subsequent injury falls and multiple falls compared with falls status and POMA or SOT score.

Conclusions: Sets of quantitative measurement variables obtained with this mobility battery provided sensitive prediction of future injury falls and screening for multiple subsequent falls by using tasks that should be appropriate to diverse participants.

Key Words: Elderly; Geriatric assessment; Mobility limitations; Outcome measures; Rehabilitation.

MOBILITY DISORDERS compromise quality of life and limit an older person's level of independence.[1] Maintenance of the center of gravity over the base of support[2] or balance is required for safe functional activity. However, mobility function is complex, including such tasks as maintaining stance during limb movements, performing transfers, and stepping up or down.[3]

Measurement of mobility is essential for developing and evaluating interventions to prevent chronic disability and acute morbidity. Although existing screening tools are valuable to identify those not needing treatment, diagnostic and outcome measures are needed to assess efficacy. The most commonly used mobility assessments are self-reported capacity to climb stairs or walk one-half mile[4] and rating scales, such as the Tinetti Performance Oriented Mobility Assessment (POMA).[5] Rating scales use subjective categorical determinations to create ordinal measurements, may be time consuming, and are subject to inter-rater reliability concerns.

Objective performance indexes (eg, Short Physical Performance Battery [SPPB],[6] Timed Up & Go [TUG],[7] Sensory Organization Test [SOT][8]) also are commonly used. These continuous measures offer interval or ratio measurements and therefore finer performance distinctions. However, the tasks included may offer limited challenge to high-functioning individuals or include elements that are too difficult for impaired older adults. To address these issues, we developed a mobility battery based on activities of daily living (ADL) that includes tasks representing progressively more difficult mobility components (see Appendix 1 for details). The tasks in the battery range from simple to complex[9] and are designed to challenge performance abilities across the spectrum of older adults. Using progressively complex tasks, including standing balance, maximal leaning, reaching and pulling, sit to stand, gait, turns, stair descent, and sideways step in tub, offers the potential to avoid ceiling and floor effects.[10]

List of Abbreviations

ADL	activities of daily living
CDE	community-dwelling elders
COP	center of pressure
ICC	intraclass correlation coefficient
POMA	Performance Oriented Mobility Assessment
ROC	receiver operating characteristic
SOT	Sensory Organization Test
SPPB	Short Physical Performance Battery
TUG	Timed Up & Go

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Supported by the National Institute on Aging, National Institutes of Health (grant nos. AG022092, AG012595); the New York Academy of Medicine, Mary & David Hoar Foundation; and University of Connecticut Health Center, Health Center Research Administration Committee.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

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0003-9993/11/9206-00468$36.00/0
doi:10.1016/j.apmr.2011.01.004

Because there is no accepted criterion standard for mobility measurement, we compared the proposed measures with several that have achieved broad use. A recent history of falls has been used as an indicator of functional decline.[11] Because falls may precede or follow mobility changes,[12] we adopted the criteria of future injury and multiple falls as sentinel events for change in mobility status. Sensitivity rather than specificity was emphasized because the focus was on recognizing individuals requiring intervention, rather than screening those who did not.

The purpose of this study was to identify quantitative measurement variables that characterize diverse mobility tasks in older adults, meet reliability and validity criteria comparing favorably with other approaches, distinguish entry fall-risk group (falls status) by using Medicare criteria, and offer sensitivity to changes in mobility status as evidenced by subsequent falls.

METHODS

Participants and Procedure

This study was approved by the Institutional Review Board at the University of Connecticut Health Center. Subjects were recruited by means of a letter using a mailing list provided by the university Center on Aging and initially were screened by telephone. On their first visit, 74 community-dwelling elders (CDE) provided informed consent and mental status, medical, and falls histories and underwent physical examination by a physician. Exclusion criteria were cognitive impairment (Mini-Mental Status Examination[13] score $<$24), legally blind, obesity (body mass index $\geq$ 30kg/m^2), and non–English speaking. To eliminate the influence of known pathologic states, volunteers with a diagnosis of neurologic, orthopedic, or visual disorders (eg, Parkinson's disease, knee replacement, macular degeneration) directly impairing mobility were excluded. Common orthopedic limitations (eg, osteoarthritis, knee pain) were not considered exclusion criteria.

Using Medicare[14] fall-risk screening criteria, participants reporting 2 or more noninjury falls in the past year or 1 or more injury fall were categorized as fallers. The rest of the subjects were considered nonfallers. Subjects also completed the Tinetti POMA[5] and SOT[8,a] (see Appendix 1). The mobility battery was conducted on the subsequent visit, and nonfallers repeated the battery the same day to assess test-retest reliability. Test-retest data from nonfallers provided a preliminary reliability screen. Health changes and falls were reported weekly by postcard for up to 1 year or until 1 month or more of nonambulatory status. Nonreceipt of postcards, changes, or falls triggered telephone inquiries. All follow-up participants were included in analyses of predictive validity.

Selection of Measurement Variables

We started with diverse measurement variables from the various tasks and sought to retain only those that were both reliable and repeatable. Measurement variables for each task derived from the biomechanics literature (see Appendix 1) were assessed with semiautomated calculations by using computer algorithms. Variables were evaluated for normality and normalized if necessary.

During mobility testing, subjects practiced and rested as needed, then performed tasks at a self-selected pace 3 times (except as noted) in their habitual manner. Tasks and/or variables with very low test-retest reliability (nonfaller intraday Pearson $r<0.3$) were excluded from consideration. Within-subject reliability of variables in the first session for all subjects was evaluated by computing the intraclass correlation coefficient (ICC) (defined as the ratio of across-subject to total variance) by using a linear mixed model[15] with a random subject-specific intercept. We assessed criterion-related validity based upon the ability of the group mean value of each variable to distinguish entry fall-risk group by using the Medicare criterion (falls status: faller or nonfaller). Variables showing moderate reliability (ICC$>$0.6)[16] and/or those that clearly distinguish falls status ($P<.01$) were selected for further examination and categorized as clinical or forceplate measures.

Tasks are described further in Appendix 1, and those with variables meeting the mentioned criteria were assessed as follows.

Quiet standing. The clinical Romberg test[17] of standing balance with eyes open and closed was conducted using a forceplate.[b] Data were collected for 1 minute and sway area (enclosed center of pressure [COP] path) was evaluated over the middle 30 seconds of 2 trials in each condition. The Romberg ratio compared eyes closed with eyes open.

Maximal lean. Subjects leaned as far forward and backward as they could without bending their hips or knees or losing their balance. Anterior-posterior forceplate COP excursion was calculated as the distance between the maximum forward and backward positions.[18]

Sit to stand. Sitting (seat, 41.4cm height) with arms crossed below the sternum and feet on the forceplate, subjects were asked to stand. Sit-to-stand time was measured from the onset of anterior-posterior force until vertical force reached body weight. Sway area was calculated from this point until variance was less than 1 SD for more than 5 seconds. Medial-lateral and anterior-posterior excursion values were determined for anterior-posterior and vertical[19] phases (see Appendix 1).

Gait. Two self-paced out and back[20] walks (8.1m) were performed, average velocity was calculated, and velocity for the fastest performance was used.

Turn. Subjects started 2 strides (self-selected, 1.8–2.8m) from a chair. Time from the first step until the subject began to sit and number of steps to turn taken were assessed.

Step in tub. Subjects stepped sideways (hips perpendicular) into a simulated tub (33-cm high), and a vertical grab bar was used if needed. Time from initiation of weight transfer until end of 1-legged stance was measured.

Down stairs. Subjects descended 3 steps (17.8cm), using the handrail if desired. Time from initiation of descent to touchdown was measured.

Creating Composite Scores

To evaluate these variables as mobility criteria, we created composite scores by standardizing each measure and summing the z scores of subsets of individual variables. Using 9 selected measurement variables (5 clinical: gait velocity, turn steps, turn time, down-stairs time, step-in-tub time; 4 forceplate: quiet standing Romberg ratio sway area, maximal lean anterior-posterior excursion, sit-to-stand medial-lateral excursion, and sit-to-stand sway area upon standing), 5 measurement sets were created. Three sets are appropriate for use in clinical settings, and 2, when a forceplate is available. All 5 clinical measures comprised the full clinical set. The intermediate clinical set excluded step-in-tub time, and the brief clinical set further excluded down-stairs time. There were 2 forceplate sets. The intermediate forceplate set included all 4 forceplate measures, and the brief forceplate set excluded sit-to-stand medial-lateral excursion and sway area upon standing. By excluding more difficult tasks, brief sets may be appropriate for frail older adults, whereas elimination of tiring tasks for intermediate sets may enable assessment of those with marginal endurance.

Sensitivity and Specificity

Sensitivity and specificity were calculated by varying the composite score threshold and using receiver operating characteristic (ROC) curve analysis to categorize individual performance. ROC curve analysis requires an established cutoff value or criterion.[21] Because no quantitative standards for mobility exist, we used published standards for POMA, SOT, and entry Medicare[14] fall-risk group (falls status) as criteria. POMA score was considered normal if 1 item had a point deducted and abnormal if 2 items had a point deducted or 1 item had 2 points deducted.[22] SOT score was considered normal[23] if the participant scored higher than the 70- to 79-year-old mean value (>729), and abnormal if lower (≤729). The ability of composite scores to accurately determine falls status was compared with POMA and SOT scores by using these values. Next, concurrence between composite scores and falls status, POMA, and SOT criteria was evaluated. Finally, we examined the potential of the composite scores, POMA and SOT, to predict sentinel events by using 2 prospective criteria: an injury fall or multiple falls (≥2 noninjury falls or ≥1 injury fall). Confidence intervals for observed prospective sensitivity and specificity were calculated on the logit scale.

RESULTS

Participants were separated into falls-status entry groups: 27 nonfallers (age range, 65–87y; mean ± SD age, 75.1±6.5y) and 47 fallers (age range, 70–94y; mean ± SD, 80.1±6.2y). Fallers were older than nonfallers (Mann-Whitney, P=.008). There was no difference between fall-status groups by sex (χ^2=.33; P=.56). Four clinical and 2 forceplate variables showed both reliability (ICC>0.6) and fall-status discrimination (P<.01). Two forceplate sit-to-stand variables and number of steps measure from the turn task, which distinguished falls status (P<.01), also were included in further analyses. Distributional properties of number of steps (either 3 or 4) precluded calculation of reliability. Table 1 lists statistical profiles of these 9 variables.

Prospective follow-up was completed by 62 participants, and 12 declined weekly follow-up. Falls and medical changes were reported by means of postcard for up to 1 year or until subjects were nonambulatory for a month. Five reached the endpoint after sending postcards for 3 to 32 weeks because of stroke, serious illness, or injury sequelae.

There was no difference in falls-status entry groups, with 4 of 27 (15%) nonfallers and 8 of 47 (17%) fallers declining follow-up (P=.80). During follow-up, 3 of 23 (13%) nonfallers and 9 of 39 (23%) fallers sustained an injury fall (P=.51), whereas 17 of 23 (74%) nonfallers and 23 of 39 (59%) fallers were multiple fallers (P=.24). Our community-dwelling volunteers were separated into 2 entry groups, and statistical criteria were used to select measures that accurately identified falls status. No treatment or intervention was undertaken. Therefore, in subsequent analyses of the proposed measures, no statistical inference was employed. We report the observed sensitivity and specificity of the measurement sets by using various criteria.

Entry Falls-Status Criterion

The sensitivity and specificity with which the 5 measurement sets identified entry falls-status group was compared with POMA and SOT scores (fig 1). The full clinical set produced both sensitivity and specificity (.80 and .74 respectively). Removing step-in-tub time (intermediate clinical set) markedly decreased specificity (from .74 to .52). When both downstairs and step-in-tub times were removed (brief clinical set), both sensitivity (from .80 to .57) and specificity (from .74 to .59) were decreased. The brief forceplate set provided higher sensitivity (.77) than both the intermediate (.75) and brief (.57) clinical sets. By comparison, both POMA and SOT scores showed lower sensitivity and high specificity (POMA, .51 and 1.00; SOT, .32 and .93 respectively) to entry falls status.

Concurrent Validity

Concurrence of the 5 measurement sets with falls status, POMA score, and SOT score is listed in table 2. Sets were sensitive to POMA score, although less so to falls status and SOT score. The full clinical set was the most sensitive overall, identifying those who would fail the POMA criterion with 100% sensitivity; falls status, 80%; and SOT score, 79%. The intermediate clinical set showed 83% to 75% sensitivity to these criteria, whereas both brief sets were sensitive to POMA score (71%). Only the full and intermediate clinical sets offered concurrence with SOT score.

Predictive Validity

Predictive ability of the measurement sets was evaluated by using prospective criteria obtained during 1-year follow-up of 62 participants. The sensitivity and specificity with which each set predicted a participant's subsequent injury fall (12 of 62) or multiple falls (40 of 62) during the follow-up period is com-

Table 1: Characteristics of Clinical and Forceplate Measurement Variables

Variables	Reliability (ICC)	Nonfallers (n=27)	Fallers (n=47)	P (nonfallers vs fallers)*
Clinical variable				
Gait velocity (m/s)	.745	0.86±0.13	0.64±0.18	<.001
Turn steps (no.)	†	3.04±0.20	3.31±0.46	<.001‡
Turn time (s)	.709	1.06±0.32	1.48±0.77	.002
Down-stairs time (s)	.626	3.47±0.69	4.45±0.90	<.001
Step-in-tub time (s)	.702	1.90±0.52	2.93±1.22	<.001
Forceplate variables				
Quiet standing Romberg ratio, sway area (cm^2)	.993	6.77±1.35	11.55±11.87	.007
Maximal lean anterior-posterior excursion (cm)	.754	16.28±3.58	12.93±3.48	<.001
Sit-to-stand sway area (cm^2)	.367	3.27±6.58	7.47±3.44	.001
Sit-to-stand medial-lateral excursion (cm)	.562	2.54±1.68	4.04±3.66	.006

NOTE. Values expressed as mean ± SD unless noted otherwise.
*P values obtained by using linear mixed models.
†Only 2 values observed; ICC cannot be calculated.
‡P values obtained by using a logistic quasi-likelihood model.

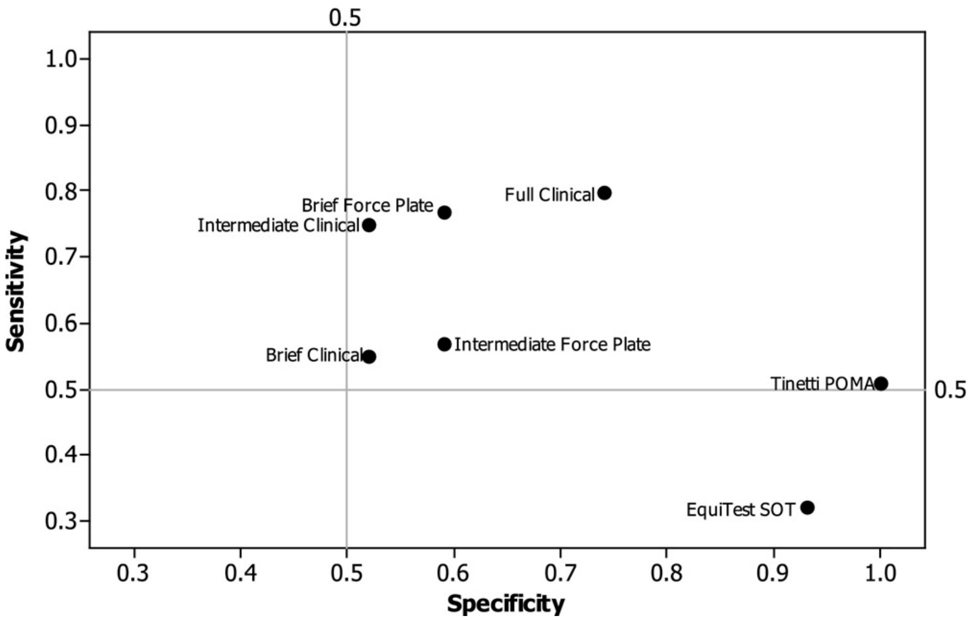

Fig 1. Sensitivity and specificity of measurement sets, POMA score, and SOT score to entry fall-risk group. Sensitivity and specificity values were calculated by using entry falls status (faller or nonfaller) as the criterion. Composite scores consisted of the full clinical set (gait velocity, turn steps, turn time, down-stairs time, step-in-tub time), intermediate clinical set (gait velocity, turn steps, turn time, down-stairs time), brief clinical set (gait velocity, turn steps, turn time), brief forceplate set (Romberg ratio, maximum lean), Tinetti POMA criterion (total of subscales in which ≤26 of 28 was the threshold[22]), and EquiTest SOT criterion (total score in which ≤729 was the threshold[23]).

pared with that of entry group falls status, POMA, and SOT criteria in figure 2. Entries in the upper right-hand quadrant show both sensitivity and specificity.

Mobility measurement sets were more sensitive and less specific than falls status, POMA score, or SOT score in predicting an injury fall (fig 2A). The brief forceplate set yielded the highest sensitivity (.68) to injury falls and should allow testing of frail individuals. For multiple falls (fig 2B), SOT score, POMA score, and falls status showed sensitivity, but not specificity. Measurement sets offered both sensitivity and specificity, with the intermediate forceplate set showing the highest sensitivity (.78).

DISCUSSION

A battery of common mobility activities was decreased to 9 physical performance measurement variables representing 7 tasks through evaluation of their reliability and ability to discriminate entry falls status. Measurement sets that would be appropriate for frail or easily fatigued, as well as high-functioning, individuals were constructed with combinations of these 9 variables (5 clinical, 4 forceplate). Composite scores created from the measurement sets identified falls status with sensitivity superior to POMA and SOT scores and concurred with these measures. Finally, these sets predicted individuals who would experience an injury fall and those who would not experience multiple falls better than falls status, POMA, or SOT criteria.

Maurer and Commenges[24] emphasized the importance of sensitivity when measures are intended to assess changes and demonstrated its basis in validity and reliability. We deliberately set a moderate reliability[16] standard because a measure lacking high reliability may discriminate if differences between groups are sufficiently large, as observed with sit-to-stand variables. Whereas the full and intermediate clinical sets had excellent concurrence with POMA and SOT scores, those excluding complex tasks (brief clinical, intermediate and brief forceplate) concur less well with POMA score and insufficiently with SOT score. POMA and SOT scores showed high

Table 2: Concurrent Validity of Quantitative Measurements With Existing Standards

Variables	Entry Falls Status*	POMA Score†	EquiTest SOT Score‡
Clinical measurement sets			
Full complement: gait velocity, turn time, turn number of steps, down 3 stairs, step in tub	A-.80 (.65–.90)	1.00	.79 (.51–.93)
	B-.74 (.55–.87)	.57 (.43–.70)	.66 (.52–.77)
Intermediate: gait velocity, turn time, turn number of steps, down 3 stairs	A-.75 (.59–.86)	.83 (.59–.95)	.79 (.51–.93)
	B-.52 (.34–.70)	.71 (.57–.82)	.74 (.60–.84)
Brief: gait velocity, turn time, turn number of steps	A-.57 (.43–.71)	.71 (.50–.85)	.41 (.21–.65)
	B-.59 (.40–.76)	.50 (.36–.64)	.54 (.41–.67)
Forceplate measurement sets			
Intermediate: quiet standing, maximal leaning, sway area, medial-lateral excursion	A-.55 (.41–.69)	.63 (.42–.79)	.53 (.30–.74)
	B-.52 (.34–.70)	.52 (.38–.65)	.51 (.38–.64)
Brief: quiet standing, maximal leaning	A-.77 (.62–.87)	.75 (.54–.88)	.47 (.26–.70)
	B-.59 (.40–.76)	.50 (.36–.64)	.58 (.45–.70)

NOTE. Values expressed as A-sensitivity (confidence interval) and B-specificity (confidence interval).
*Entry falls status is classification as nonfaller or faller based on self-reported history of 1 or more injury fall or 2 or more falls.[14]
†Tinetti POMA score is total of balance and gait subscales, for which 26 or less of 28 indicates problems.[22]
‡EquiTest SOT total score for 6 conditions of 729 or less (70- to 79-year-old mean value) was abnormal.[23]

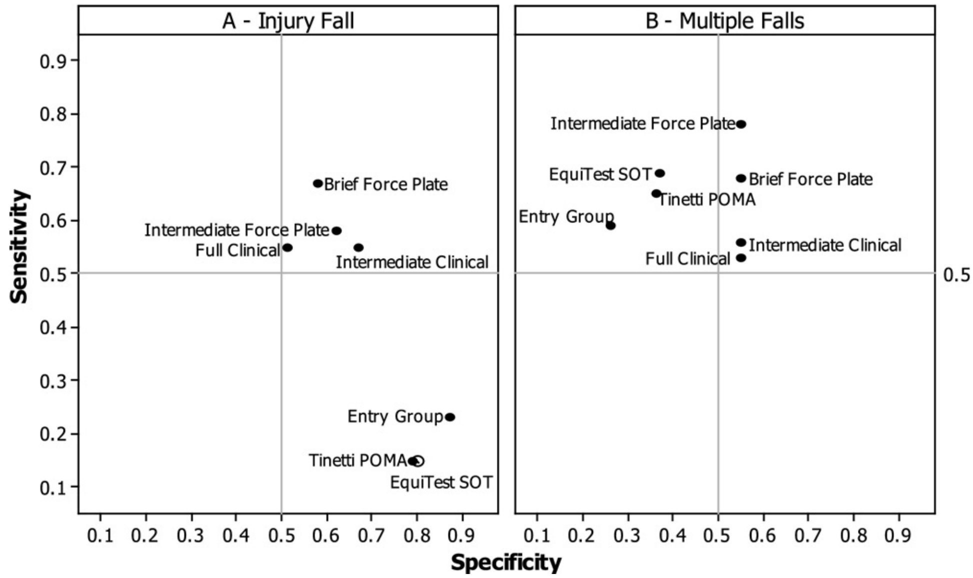

Fig 2. Predictive value of mobility measurement sets, group, POMA score, and SOT score. Sensitivity and specificity values were calculated by using 2 falls criteria (shown in panel A- Injury Fall and shown in panel B- Multiple Falls) from weekly reports during the 1-year follow-up. Composite scores consisted of the full clinical set (gait velocity, turn steps, turn time, down-stairs time, step-in-tub time), intermediate clinical set (gait velocity, turn steps, turn time, down-stairs time), brief clinical set (gait velocity, turn steps, turn time), intermediate forceplate set (Romberg ratio, maximum lean, medial-lateral excursion, sit-to-stand sway area), brief forceplate set (Romberg ratio, maximum lean), Tinetti POMA criterion (total of subscales in which ≤26 of 28 was the threshold[22]), and EquiTest SOT criterion (total score in which ≤729 was the threshold[23]).

specificity to falls status, supporting their value for screening those who may not require intervention. Both these widely used measures provide disappointing sensitivity to entry falls status and subsequent injury falls. They were insufficient for situations requiring both sensitivity and specificity.

Raiche et al[25] found POMA score to be sensitive (.70 with .52 specificity) to 1 or more falls in 225 CDE. With a high cutoff score, 125 tested positive, but sensitivity decreased rapidly with other cutoff values. They recommended including more challenging items or those addressing medical factors associated with falls. In a residential care facility,[26] POMA score predicted those requiring further physical therapy assessment (68 sensitivity and 78 specificity), but not as well as simple gait velocity (80 and 89 respectively) in this population. We hoped to identify measures that could be used together to permit accurate evaluation in diverse situations. Quantitative measurement sets offer several advantages; with fewer components than POMA (3–5 compared with 16), clinical assessments take less time and qualitative judgment is eliminated. Turns, necessitating control of 3-dimensional movement, may provide an important addition to gait for frailer older adults. Inclusion of down-stairs and step-in-tub tasks may eliminate the ceiling effect for the more robust. In the CDE, down stairs captured a wider spectrum of ADL limitations than climbing up.[27]

The SOT offers the potential to differentiate sensory deficits, but requires special equipment unavailable in many settings. Di Fabio[8] found that static posturography was more sensitive and equally specific when screening for vestibular deficits. We examined clinical and forceplate variables separately and found that forceplate measurements were especially good predictors. They provided tasks appropriate for older adults with existing impairments, including standing balance, maximal leaning to stress the postural control system, and sit-to-stand measures incorporating lower-body strength.

Predictive ability is the hallmark of assessments that can identify individuals requiring intervention, and sensitivity to change is critical to outcome evaluation. Although appropriate for screening, Medicare falls status seems inadequate for these purposes because similar proportions of fallers and nonfallers experienced an injury fall or became multiple fallers during follow-up. However, this may reflect self-selective enrollment by respondents who volunteered for mobility and falls studies because of underlying concerns.

Measurement sets offered superior sensitivity to participants who later sustained an injury fall, as well as specificity to those who did not subsequently have multiple falls. The personal cost of injury falls is significant, frequently resulting in ADL assistance for longer than 6 months.[28] Whereas multiple falls increase fall risk, 1 injury fall substantially increases risk[14] and generates additional 1-year medical costs of $27,745 to $30,038.[29] Only quantitative measurement sets provided sensitivity to injury falls. Sets requiring as few as 2 variables (when a forceplate is available) may provide an opportunity to focus scarce resources by identifying and treating those at risk for injuries.

Each of the tasks selected by using statistical criteria is an individually important component of mobility. Gait has been called a physical vital sign,[30] and velocity may be measured even in the home-care setting.[31] A consensus report found preferred pace to predict adverse outcomes in community dwellers.[32] Measurement of maximal lean,[33] sit to stand,[34] and stair descent[35] offer opportunities to identify remediable deficits. Step-in-tub,[36] sit-to-stand,[37] or turning-to-sit[38] tasks may highlight needed home safety modifications or unrealistic self-efficacy.[39] The Romberg ratio shows visual and somatosensory contributions to quiet standing.[40]

Sets of quantitative measures are proposed to suit diverse older adults and avoid the ceiling and floor effects commonly encountered. Stepping into a simulated tub presents the most complex task, included for high-functioning older adults. The time to complete this real-life task permits assessment of weight transfer and single-leg stance abilities without the ceiling effects observed with 1-legged standing when using the SPPB.[6] Changes in SPPB cannot be detected clinically,[41] possibly because frail participants cannot complete repeated sit-to-stand tasks, resulting in a floor effect. Brief sets omit this task, and intermediate sets, for the easily fatigued, use 3 single performances with as-needed rest. Sit to stand, gait, and turning are components of the TUG test,[7] which uses 1 combined score rather than single measurements. Our reliability and discrimination values were obtained for the individual measures and sets are composed of tasks considered appropriate for different settings and participant abilities.

Study Limitations

To establish the statistical underpinnings of the measurement variables, we excluded frail older adults and those with existing disorders that impair mobility. Our study was not intended to establish cutoff values for identification of mobility impairment, and these healthy community dwellers offer limited generalizability. Future studies must include a broader range of participants and patient cohorts.

CONCLUSIONS

The proposed battery offers diverse real-life mobility challenges that may accommodate different circumstances and varied levels of participant function. Mobility measurement variable sets distinguished falls status and concurred with POMA and SOT scores. These quantitative measures offer superior sensitivity in predicting injury falls and provide both sensitive and specific prediction of multiple falls.

Acknowledgment: We thank Harrison Waite, PhD, for the key contribution to software technical development, without which this work would not have been possible; Jennifer Brindisi, MA, for significant contributions to testing, data analysis, and recruitment; and Veronica Smith, MA, PT, for valuable suggestions to improve the manuscript.

APPENDIX 1: DESCRIPTION OF THE BIOMECHANICAL MEASUREMENT METHODS

SPECIFICATIONS FOR TASKS INCLUDED IN THE MOBILITY BATTERY

Quantitative measurement methods for components of these tasks were obtained from the extensive biomechanical literature; references follow the task descriptions.

Quiet standing

The clinical Romberg test compares quiet standing with eyes open to eyes closed with feet in a comfortable stance, and the "sharpened" Romberg uses feet together in tandem stance.[17] Forceplate data were collected for 1 minute, with the first and last 15 seconds discarded. Sway path and area were evaluated during the middle 30-second period and 3 ratios were calculated[40] (eyes closed to eyes open, feet together with eyes open to eyes open, feet together with eyes closed to feet together with eyes open).

Leaning

The base of support is the farthest position an individual allows his/her center of gravity to reach without moving the feet or falling. Subjects were asked to lean maximally forward, right, left, and backward without bending the hips or knees or losing balance.[18] This movement was practiced at least once on the forceplate before recording 3 trials. COP excursions measured by using the forceplate were calculated in each direction.[33]

Sit to stand

Subjects began in a sitting position (back touching the backrest) on a chair set[42] at 41.4cm, with arms crossed below the sternum and feet on the forceplate. On "go," the subject was asked to stand; if he/she could not arise without using the arms after 2 attempts, he/she was permitted to use 1 or both arms. Performance phases for sit to stand have been shown to be identical with or without hands.[34] Rise time was measured from the onset of anterior-posterior force until vertical force reached body weight. Phase 1 began at onset with movement in the anterior direction, whereas phase 2 began with vertical force causing liftoff from the seat and ended when these forces reached body weight.[43] Standing was defined as the time that vertical force reached body weight. Times, medial-lateral and anterior-posterior excursions, and force impulse values were determined for each phase.

Gait

Two 8.1-m out and back walks were performed at self-selected and as-fast-as-possible paces.[44] Gait velocity and COP excursions during initiation of gait were calculated. Anterior-posterior moment generated at gait initiation[45] was obtained from the forceplate and normalized by foot length.

Turns

Subjects started 2 strides (1.8–2.8m) from the chair used in sit to stand. Time from the first step until the subject began to sit and number of steps taken were measured.[38] The turning moment about the vertical axis was obtained from the forceplate.[46]

Reaching in a cabinet

A small (16oz) empty glass bottle was placed on a shelf 15.3 to 30.5cm below the waist. The subject stood on a chalk mark placed at a horizontal distance equal to measured arm length plus 15cm from the shelf and was asked to reach for the bottle and, after retrieving it, stand still, holding it in his/her hand. Maximum excursion forward from the initial COP position, sway area during forward reach, and velocity of the movement were calculated.[47]

Pulling open a door

The subject was asked to briskly open a door with the left hand using a left-facing shallow handle commonly used as a shopping center entry door. The subject stood on a chalk mark placed at a horizontal distance equal to measured arm length plus 15cm from the door handle. Maximum excursion backward of initial COP position, sway area during the pull, and movement velocity were calculated.[48]

Stepping into a bathtub

Subjects were asked to step sideways into the tub (33cm side), keeping the hips perpendicular during the weight transfer.[49] They were allowed to practice and select the lead leg and could use a vertical grab bar if necessary. Three phases were measured; anticipatory weight adjustment, transfer of body weight to the standing leg, and position maintenance. The anticipatory phase began with COP movement away from the tub and ended when the farthest point was reached, beginning the weight transfer. Transfer ended when vertical force decreases to less than body weight.[50] Times, medial-lateral and anterior-posterior excursions,[33] sway path, peak acceleration, and force impulses were determined for each phase.

Walk down stairs

The subject was asked to descend three 17.8cm steps using the handrail[35] if desired. Time from the initial unweighting of the lead leg[50] until completion of the stair descent and amount of pause in contact with the forceplate at the bottom before walking forward were measured. COP excursions and anterior-posterior moment (normalized by foot length) during gait initiation were obtained from the forceplate.

OTHER PHYSICAL PERFORMANCE MEASURES

Tinetti POMA total score

Balance (9 components: sitting balance, arises, attempts to arise, immediate standing balance, standing balance, nudged, eyes closed, turning 360°, sitting down; maximum, 16 points) and gait (7 components: initiation of gait, step length, step height, step symmetry, step continuity, path, trunk and walking stance; maximum, 12 points) subscales were measured as abnormal (0) or normal (1), although in some cases, as adaptive (1) and normal (2).[5] Subscale scores are combined to calculate the total score, which has a maximum of 28 points.[22]

EquiTest SOT

Six sensory conditions (normal vision/fixed support, absent vision/fixed support, sway-referenced vision/fixed support, normal vision/sway-referenced support, absent vision/sway-referenced support, sway-referenced vision/sway-referenced support) are each measured 3 times. Sway referencing describes a servomotor-controlled movement of the forceplate or visual surround to directly follow anterior-posterior body sway.[8] Sway referencing the support surface and/or visual surround provides inaccurate somatosensory and visual information. A composite score is calculated across all 6 conditions.[23]

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Suppliers

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