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Performance Measures Predict the Onset of Basic ADL Difficulty in Community-Dwelling Older Adults

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Abstract

OBJECTIVES—To assess the predictive value of five performance-based measures for the onset of difficulty in basic activities of daily living (ADL).

DESIGN—A prospective cohort study; home visits every 6 months for 18 months.

SETTING—Community-based

PARTICIPANTS—Community-dwelling older adults, n=110, (mean age, 80; SD, 7.0; range, 67–98 years) who reported no difficulty in basic ADLs.

MEASUREMENTS—The Short Physical Performance Battery (SPPB), gait speed, Berg Balance Scale (BBS), grip strength, and Timed Up & Go Test (TUG) were evaluated at baseline. Seven ADL items were assessed at baseline, 6, 12 and 18 months. The onset of basic ADL disability was self-report of difficulty in any of the 7 ADL items. Logistic regression models were fitted for each of the physical performance measures to predict onset of basic ADL difficulty at 6, 12, and 18 months.

RESULTS—After controlling for age, co-morbid conditions, and gender, the BBS was the most consistent and best predictor for the onset of basic ADL difficulty over an 18-month period (6 months, *c*-statistic=.725 (.60, .85); 12 months, *c*-statistic=.840 (.75, .93); 18 months, *c*-statistic=.821 (.71, .93)). The SPPB showed excellent predictive value for the onset of difficulty at 12 months. The number of older adults completed the 6, 12, and 18-month follow-up visits were 95, 89, and 75, respectively.

CONCLUSION—BBS, followed by SPPB, TUG, gait speed and grip strength were predictive for the onset of basic ADL difficulty over an 18-month period in community-dwelling older adults.

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Screening nondisabled older adults with simple performance tests could allow clinicians to identify those at risk for ADL difficulty, and may help to detect early functional decline.

Keywords

activities of daily living; physical performance measure; Berg balance scale; short physical performance battery; gait speed

INTRODUCTION

Maintaining and restoring independence in activities of daily living (ADLs) is important for optimal quality of life in older adults. Biological, psychological and social factors have been linked to the onset of ADL disability.¹⁻³ Performance-based measures, which can be administered in clinical settings with little time and training, may enable clinicians to identify older adults at greater risk for ADL disability.

Measures of physical function including measures of mobility, balance, and strength have been investigated for their predictive value for future incidence of dependence in basic ADLs among older adults.⁴⁻⁹ Many previous studies^{5, 8-11} investigated predictive value of performance-based measures of physical function for the prediction of ADL dependence. One of the most common, gait speed, predicts functional dependence among older adults.⁴⁻⁹ The Short Physical Performance Battery (SPPB) predicts mobility and ADL disability at one and four years later among community-dwelling older adults,^{9, 11} and grip strength in middle age predicts functional limitations and disability 25 years later in old age.¹² Though the Berg Balance Scale (BBS) and Timed Up and Go test (TUG) have not been shown to predict disability in older adults, both have been associated with functional status based on ADLs among individuals with stroke, Parkinson's disease, traumatic brain injury and multiple sclerosis.^{10, 11, 13-18}

Different forms of questions have been used for the evaluation of ADL disability, including the rating of perceived difficulty and the rating of dependence on assistance. According to Jette,¹⁹ perceived difficulty may serve the researcher better when the interest is on the consequences of disease and impairments, and the objective is to evaluate health care treatment effectiveness. In contrast, dependency measure may be more useful for forecasting demand for particular types of long-term care services dependent upon the type and amount of assistance required.¹⁹ It has been found that the prevalence of ADL disability was higher when disability was defined as "difficulty" than "dependence".^{19, 20} Therefore, studies that measure ADL dependence and difficulty are likely to have different implications.

Although previous studies have shown predictive value of performance-based measures of physical function for the prediction of ADL dependence in community-dwelling older adults, to our knowledge, no studies have examined and compared their ability to predict ADL difficulty, which may be more amenable to intervention. Identifying older adults with ADL difficulties may help clinicians to detect early functional decline. Understanding the predictive value can be useful for choosing screening tools for identification of older adults at greater risk for future ADL disability. The purpose of the study was to evaluate and compare the predictive validity of five commonly used performance-based measures (SPPB, gait speed, BBS, grip strength, TUG) for the onset of basic ADL difficulty among community-dwelling older adults.

METHODS

Participants

A sample of 110 subjects with no reported ADL difficulty was identified from 237 subjects enrolled in a prospective cohort study. 21 The subjects for the cohort study were recruited from patients under the care of participating geriatricians from two geriatric clinics in Pittsburgh and Baltimore. Inclusion criteria were: (1) aged 65 years or older, (2) community-dwelling, (3) Mini-Mental State examination ≥ 24 , and (4) SPPB = 3-10 (inclusive). Exclusion criteria were: (1) terminal health condition, (2) nursing home dweller, and (3) diagnosis of progressive dementing condition. Subjects who reported no difficulties in seven basic ADLs (bathing, dressing, eating, getting in/out of bed/chairs, personal hygiene, walking, and using the toilet) at baseline were included for analysis (Table 1). University institutional review boards approved the study, and informed consent was obtained from all participants.

Measures

Comorbidity index—Subjects were asked about eighteen common conditions that a doctor had told them that they had at baseline. These conditions were classified into eight domains (cardiovascular, respiratory, musculoskeletal, neurologic, general, cancer, diabetes and visual) and summed to create the comorbidity index analysis.²²

Basic ADLs

Independence in activities of daily living (ADLs) may include basic personal care²³ or instrumental ADLs that encompass the more complex activities needed to be self-reliant in the community. Seven (bathing, dressing, eating, getting in/out of bed/chairs, personal hygiene, walking, using the toilet) of 16 ADL items of the National Health Interview Survey (NHIS)²⁴ were used to determine difficulty in basic activities of daily living (ADLs). For each item, the participants were asked if he/she had any difficulty performing an activity because of a health or physical problem, and the answer could be yes, no, or don't do. Those who answered "no" to the question were included for analysis.

Performance-based measures of physical function

Short Physical Performance Battery (SPPB): The SPPB consists of three tasks: gait speed, balance, and chair stands, using 4 point scales for each and a summary score that ranges from 0 to 12.⁹ 15 SPPB can usually be completed in five minutes with the use of a stopwatch, a four-meter tape, and a chair. Interrater reliability (ICC > 0.9) and test-retest reliability (ICC = 0.723) have been reported.²⁵

Gait speed—Gait speed was extracted from the SPPB testing. Gait speed was measured twice over a 4-meter distance, with the better of the two gait speeds used for analyses. Gait speed can usually be completed in two minutes with the use of a stopwatch and a four-meter tape. Test-retest reliability for gait speed in older adults is given by Pearson $r=0.93$ and ICC=0.78,²⁶ and among frail, older adults, ICC=0.79.²⁷ Gait speed alone has been reported to be nearly as good a predictor of ADL and mobility disability as the total SPPB summary score.⁹

Berg Balance Scale (BBS): The BBS is a validated and widely used measure of balance in older adults.¹³ 28 29 The BBS involves performance on 14 tasks of balance, and has been shown to have excellent inter-rater (ICC=0.98) and intra-rater reliability (ICC=0.99),²⁹ and validity by correlations with the Tinetti's Performance-Oriented Mobility Index balance subscale ($r = 0.91$) and the TUG test ($r = -0.76$).¹³ 29 BBS can usually be completed in ten

to fifteen minutes with the use of a stopwatch, a chair, a 10-inch ruler and a standard stool. A BBS score of less than 45 was shown to be predictive for recurrent falls³⁰ and a future fall, 13 and a score less than 48 has identified older adults who would benefit from a referral for physical therapy (84% sensitivity and 78% specificity).³¹

Grip strength: Grip strength was measured with a hydraulic handheld dynamometer (Jamar® hydraulic hand dynamometer) for both hands. Subjects were seated with forearm resting on the table, elbow bent, wrist in neutral position, the position recommended by American Society of Hand Therapists.³² One practice trial and two test trials were performed, and the mean of the two trials, recorded in kilograms (Kg) was used for analysis. Grip strength can usually be completed in two minutes. Test reliability for left and right grip strength was 0.84 and 0.81, respectively, in women aged 60 to 90 years.³³ Grip strength in midlife has been shown to predict walking disability and self-care disability 25 years later.¹²

Timed Up and Go test (TUG): The TUG, modified from an observational mobility scale, 34 is the time to rise from a straight back chair with arms, walk 3-meters at usual speed, turn, return, and sit down again. 35 Subjects were instructed to rise in any way that is comfortable for them, and they can decide whether to use arms for support when they stand up. Due to the nature of home visits, the strict use of a chair with arms was not enforced in the study. TUG can usually be completed in two minutes with the use of a stopwatch, a ten-foot tape, and a chair. The mean time of the two trials of the TUG was used for analyses. Inter-rater (ICC=.99) and intra-rater reliability (ICC=.99) are high for the TUG, and construct validity for balance, mobility and ADL demonstrated by correlations with the BBS ($r = -0.81$), gait speed ($r = -0.61$), and Barthel Index ($r = -0.78$) is satisfactory.³⁵

Procedures

Participants were visited in their homes at baseline, and 6, 12 and 18 months later by assessors trained to conduct the ADL and performance-based measures. The SPPB, gait speed, BBS, grip strength and TUG recorded at baseline were evaluated and compared for their predictive validity for the onset of basic ADL difficulty at 6, 12, and 18 months. Onset of basic ADL difficulty was defined by self-report of difficulty in one or more of the seven basic ADLs at 6 months, 12 months, or 18 months. Since the onset was defined by new onset in comparison to the baseline status, those who reported ADL difficulty at 18 months may or may not have reported difficulty at 6 or 12 months.

Statistical analysis

Rates of basic ADL difficulty were calculated for 6-, 12-, and 18-month follow-up visits. Baseline characteristics between older adults who developed and who did not develop basic ADL difficulty for each time period were compared using independent samples *t*- and chi-square tests. To evaluate the predictive value of the five performance-based measures, logistic regression models were fitted each with basic ADL difficulty at 6, 12 and 18 months as the dependent variable, and baseline data of SPPB, gait speed, BBS, grip strength, and TUG as main independent variables of interest. The analysis for grip strength was further stratified by gender. After controlling for covariates age, gender and co-morbidity, the best model was chosen based on the value of the *c*-statistic and the odds ratios. The *c*-statistic, the area under the receiver operator characteristic (ROC) curve, provides a basis for comparing different models fitted to the same data set, and is used as a measure of the predictive performance of the performance-based measures. A *c*-statistic closer to 1 indicates that the model assigns higher probabilities (based on combinations of independent variables) to all observations with the event outcome, compared with the non-event observations.³⁶ According to Hosmer and Lemeshow,³⁷ the area under the ROC curve

between 0.7 and 0.8 ($0.7 \leq c < 0.8$) is considered acceptable discrimination, between 0.8 and 0.9 ($0.8 \leq c < 0.9$) is considered excellent discrimination, and greater than 0.9 ($c \geq 0.9$) is considered outstanding discrimination.

Relation between sensitivity and specificity of physical performance measures for the prediction of onset of basic ADL difficulty was examined by construction of sensitivity and specificity curves. An optimal cutpoint that maximizes both sensitivity and specificity for each performance-based measure was determined from the intersection of the sensitivity and specificity curves from the graph for each performance-based measure.³⁷ Baseline score of each performance test at the intersection point of sensitivity and specificity curves was determined for each time period. The baseline cutoff score for 90% sensitivity and 90% specificity of each performance measure was also determined for each time period. All analyses were performed using SAS® software, version 9.2 (SAS Institute, Inc., Cary, North Carolina).

RESULTS

Among 237 subjects in the original cohort, 110 older adults who reported no basic ADL difficulties at baseline were included. At 6-, 12-, and 18-month follow-ups, 27 (28%), 27 (30%), and 24 (32%) subjects reported onset of one or more basic ADL difficulty, respectively (Figure 1). Because the original design of the study required evaluation from the primary care physician of the subjects, the follow-up visits were not continued and follow-up data was not recorded for subjects who changed their physician to a physician who did not participate in the study during the study period. Other reasons for missing follow-up data include missing scheduled home visits, subject death, voluntary drop-off, and unanswered ADL questions during follow-up visits (Figure 1).

Comparisons of basic characteristics were made between older adults who developed basic ADL difficulty and those who did not at 6, 12 and 18 months. For all three follow-up periods, older adults who developed difficulty had higher co-morbidity indices, and lower SPPB and BBS scores ($p < 0.05$) at baseline. Although subjects who reported onset of basic ADL difficulty at three follow-up periods walked at slower gait speed at baseline, the differences in gait speed were only statistically significant at 6 months. Older adults who developed ADL difficulty at 6 months had longer TUG times at baseline, and female older adults who developed ADL difficulty at 12 months had weaker baseline grip strength at baseline (Table 1).

After controlling for age, gender and co-morbid conditions, logistic regression analysis of the data identified BBS as the most consistent and strong predictor for the onset of difficulty in basic ADLs over an 18-month period. The results suggested the predictive ability of BBS was excellent with respective c -statistics of 0.840 (95% CI: 0.75–0.93) and 0.821 (95% CI: 0.71–0.93) at 12 and 18 months and acceptable with respective c -statistics of 0.725 (95% CI: 0.60–0.85) at 6 months (Table 2). The predictive ability of SPPB was excellent at 12 months with respective c -statistics of 0.827 (95% CI: 0.74–0.92) and acceptable at 6 and 18 months (Table 2). The predictive ability of TUG was acceptable at 6, 12, and 18 months, and gait speed was acceptable at 12 and 18 months (Table 2). Grip strength was only reported in female subjects due to a small number of male subjects (Table 2). After controlling for age and co-morbid conditions, the predictive ability of female grip strength was acceptable at 12 and 18 months with respective c -statistics of 0.762 (95% CI: 0.64–0.89) and 0.704 (95% CI: 0.55–0.86) (Table 2). The odds ratios from logistic regression analyses indicated BBS as the only significant ($p < 0.05$) performance measure throughout the 18-month period. The odds ratios for developing ADL difficulty for BBS were 0.861, 0.802, and 0.851 at 6, 12 and 18 months, respectively ($p < 0.05$; Table 2). The odds ratios for developing ADL difficulty were

not significant for other performance measures except for TUG at 6 months (OR=1.138; Table 2).

The predictive value for onset of basic ADL difficulty for each of the performance-based measures is illustrated by the intersection of the sensitivity and specificity curves constructed for each measure at each time period. The sensitivity and specificity curves for baseline BBS to predict 6-month ADL difficulty are shown in Figure 2. From the intersection of the sensitivity and specificity curves for ADL difficulty at 6 months, we defined a BBS score of 49.5 as an optimal cutpoint that maximizes both sensitivity and specificity (68%) for prediction of ADL difficulty (Figure 2). The same plot also shows BBS scores of 46 and 53 had 90% sensitivity and specificity, respectively, for the prediction of 6-month ADL difficulty (Figure 2). Summary data for similar plots constructed for all measures for onset of ADL difficulty at all time points is presented in Table 3. Among the five performance-based measures, although BBS generates the strongest *c*-statistic, SPPB generates the highest optimal sensitivity and specificity value for the baseline cutoff score throughout the 18-month period.

DISCUSSION

This paper examines and compares the predictive value of five performance-based measures for the onset of ADL difficulties during an 18-month period. Unlike much of the previous research examining the relationship between performance-based measures and ADL dependency,^{5, 8-11} self-reported ADL difficulty was used as the outcome measure in this study.

Among the five performance-based measures, BBS was the most consistent and strong predictor for the onset of basic ADL difficulty over the 18-month study period. The *c*-statistics suggested the predictive ability of BBS was excellent at 12 and 18 months, and the odds ratios found BBS the only significant performance measure throughout the 18-month period. From the sensitivity and specificity curves, we identified BBS scores of 46 and 53.5 achieved 90% of sensitivity and 90% of specificity, respectively, for the prediction of ADL difficulty over an 18-month period. Thus, older adults with BBS score less than 46 were more likely to develop basic ADL difficulty, and including them for early interventions may delay their onset of ADL difficulty. Older adults with BBS score greater than 53.5 can be excluded from early interventions because they were less likely to develop basic ADL difficulty. Those with BBS score between 46 and 54 can be included when the resources are available. Several studies have investigated the relationship between BBS and ADL disability among individuals post stroke, with Parkinson's disease, traumatic brain injury and multiple sclerosis.^{13, 14, 18} Paltamaa et al.¹⁶ identified BBS as the strongest predictor for both perceived difficulties and dependence in self care, mobility, and domestic life when comparing to selected performance measures including Box and Block Test, Kela Coordination test, postural stability tests, ten-meter walk test and six-minute walk among individuals with multiple sclerosis. However, no cutoff score for prediction was identified, and thus no comparison with the BBS scores identified in this study can be made. In addition, the predictive value of BBS for incident ADL difficulty in community-dwelling older adults has not been previously reported. Based on the results, we suggest the BBS can be useful in identifying community-dwelling older adults at risks for incident basic ADL difficulty over an 18-month period of time.

In the study, SPPB was an excellent predictor for onset of basic ADL difficulty at 12 months. The SPPB has been shown to predict self-reported disability, nursing home admission, and mortality.¹¹ Previous studies have investigated the predictive value of SPPB for onset of ADL dependence, but not difficulty. Guralnik et al. in 2000 found SPPB

allowed for the estimation of incident disability of ADLs at 1-year and 4-year follow-up in community-dwelling populations, and compared to older adults with a SPPB score of 9-12, those with a score of 4-6 had a relative risk ranging from 3.4 to 5.1 of developing ADL dependence.⁹ From the sensitivity and specificity curves for the SPPB in this study, scores of 6 and 8 represented 90% sensitivity and 90% specificity, respectively, for the prediction of ADL difficulty at 12 months. Although the two studies investigated different aspects of ADL disability, both studies suggest a SPPB score of 6 or less is highly indicative of one-year ADL disability, as indicated by difficulty or dependence. Among the five performance-based measures, the SPPB generated the highest optimal sensitivity and specificity value (6 months, 71%; 12 months, 74%; 18 months, 72%) of baseline cutoff score for onset of ADL difficulty over the 18-month period. Older adults with SPPB score less than 6 are more likely to benefit from early interventions than those with SPPB score greater than 8. SPPB, which takes only a short time to administer, can be useful clinically for screening older adults for onset of ADL difficulty.

In the current study, gait speed was an acceptable predictor ($0.7 \leq c < 0.8$) for the onset of basic ADL difficulty at 12 and 18 months. Gait speed is a common physical performance measure used in clinical practice, and it has been shown to be a good predictor of ADL dependence in previous studies. Guralnik et al.⁹ in 2000 found gait speed (c -statistic, 0.70) was nearly as good as SPPB (c -statistic, 0.75) in predicting mobility and ADL disability at 1 year. Similar relationship between gait speed and SPPB were observed in the current study at one year (gait speed, $c=0.797$; SPPB, $c=0.827$). Although the predictive value of gait speed is not as good as BBS and SPPB, it can be measured in a very short time, which may be useful for very frail elderly who are unable to complete SPPB in clinical settings.

In the study, baseline grip strength was an acceptable predictor for onset of basic ADL difficulty at 12 and 18 months for female elderly. Grip strength was found to be an independent predictor of disability among older Mexican men and women.³⁸ In a 25-year prospective study, Rantanen et al.¹² found the risk of self-care disability, defined as self-reported ADL difficulty, was more than 2 times greater in male subjects with baseline grip strength in middle age less than 37 kg compared to those with grip strength greater than 42 kg. In this study, the sensitivity and specificity curves constructed identified grip strength of 12 kg and 25 kg achieved 90% of sensitivity and 90% of specificity, respectively, for the prediction of ADL difficulty in female subjects over an 18-month period (Table 3). The results suggest older female adults with grip strength less than 12 kg were more likely to develop basic ADL difficulty, and those with grip strength greater than 25 kg were less likely to develop basic ADL difficulty over an 18-month follow-up period.

Although the TUG has been used to identify older adults who are independent in transfer tasks (TUG time <20 seconds) and older adults dependent in ADLs (TUG time > 30 seconds), the predictive validity of TUG for onset of ADL difficulty was not established.¹⁷ Results from the study suggested the TUG was an acceptable ($0.7 \leq c < 0.8$) predictor for onset of basic ADL difficulty at 6, 12, or 18 months.

Many studies have investigated the predictive value of performance-based measures for onset of ADL disability. However, due to the differences in the operational definitions of disability, the results can be quite different. Jette reported 1.2 to 5 times greater estimates of the prevalence of ADL disability using difficulty scale than dependency scale.¹⁹ The onset rates of disability, defined by ADL difficulty, were much higher comparing to previous studies. In the study, the onset rates of disability among community-dwelling older adults who did not report ADL difficulties at baseline were 28%, 30%, and 32% at 6, 12, and 18 months, respectively. In two studies conducted by Gill et al.^{4, 7}, ADL disability, defined as the onset of functional dependence (receiving personal assistance or being completely

dependent) in one or more of the seven basic ADLs, developed in 9% and 16% of community-living older adults at one-year follow-up. In other studies investigators found a 27% onset rate of functional dependence at 6 years⁵ and 46% self-reported rate of at least one episode of functional dependence in basic ADLs at 3 years.⁶ In Guralnik's study⁹, the onset rates of functional dependence (inability to perform basic ADLs without help) for older adults who scored 4 to 6, 7 to 9, and 10 to 12 in SPPB were 8%, 2%, and 1%, respectively, at one year. In the current study, stratifying older adults by SPPB scores, the rates of ADL difficulty onset at one-year follow-up for those scored 4 to 6 and 7 to 9 in SPPB were 47% and 27%, respectively. Since the onset of ADL difficulty usually happens before dependence, and the rates of ADL disability are higher in this study. In addition to the differences between the measure of dependence and difficulty, the types of ADL tasks chosen can also generate different results and clinical implications. In Guralnik's study⁹, older adults reported mobility-related disability (inability to walk 0.5 mile or climb stairs without help) plus the inability to perform one or more of the four activities (moving from a bed to a chair, using the toilet, bathing, and walking across a small room) were recruited.⁹ In Shinkai's study⁵, older adults were independent in five basic ADLs at baseline. In the current study, older adults who reported difficulties in one of the seven items (bathing, dressing, eating, getting in/out of bed/chairs, personal hygiene, walking, using the toilet) were classified as having ADL disability. The greater range of types of ADL disability (any one of 7 basic activities) used in this study may have contributed to a greater number of older adults identified as having disability.

Characteristics of subjects also contribute to the differences in results between studies. Although most previous studies included older adults who were independent in ADLs at baseline, the baseline physical function levels were not similar. First, the mean age of the subjects in our study was 80 years, older than those who participated in previous studies.^{4, 6-8} Secondly, the subjects in our study had poorer physical function. Our participants scored 3 to 10 on the summary score of SPPB and mean gait speed for the sample was 0.68 m/s. In Guralnik's study⁹, older adults scored 4 to 12 on the summary SPPB score. In Shinkai's study⁵, older adults walked at a mean gait speed of 1.09 m/s at baseline. Older adults with gait speed of 1.0 m/s may be at the starting point of steepest decline in function.²⁵ In the current study, older adults with a mean gait speed of 0.68 m/s, thus, the slope of decline is less likely to be as steep and lead to non-ambulatory status. It is possible that the rates of ADL disability are higher in this study due to the poorer condition of subjects.

The results of the study suggested BBS, followed by SPPB, TUG, gait speed and grip strength was the most predictive performance-based measure for onset of ADL difficulty. Since BBS encompasses some components (standing balance and sit-to-stand) of other performance-based measures, it is not surprising to find BBS the most significant predictor for ADL difficulty. Similarly, SPPB encompasses the gait speed component, and the predictive value of SPPB is higher than gait speed alone. The five performance tests examined in the study are performance-based tests that can be administered easily in the clinical settings. However, the different nature and requirement of the clinical tests are likely to influence their clinical use. For example, BBS appears to be the most consistent and strong predictor for ADL difficulty, but it takes more time to administer in clinical settings. For older adults with poor physical tolerance or in situations with time constraints, SPPB or gait speed, which also predicts ADL difficulty, can be used. Primary care physicians who have limited time in clinics may also use SPPB or gait speed to decide necessity for further referrals. On the other hand, BBS can be a very useful tool in rehabilitation settings as it provides more information about which tasks should be prioritized in treatment. TUG was an acceptable predictor for ADL difficulty, but its role in predicting disability has not been supported by as many previous studies as other tests. Grip strength is also an acceptable

predictor for ADL difficulty at 12 months. However, it is a measure of upper extremity strength, which may not provide as many insights for treatment planning.

The present study has several limitations. Older adults in this study were followed for 18 months, which is shorter than the follow up period in previous studies.⁴⁻¹⁰ It is possible that some performance-based measures are more predictive of ADL disability with longer follow-up periods. Because the subjects for the current analyses were identified from older adults enrolled in a prospective cohort study which requires subjects to be under care of participating physicians, many older adults who changed their primary care physicians were lost to follow-ups at 18 months (about 10%) and the overall rate of subjects lost to follow up (31% at 18 months) was greater than in previous studies.⁴⁻⁶⁻⁸ However, comparisons of baseline characteristics revealed no significant differences between subjects who were lost-to-follow-up and who were not. The results of the study cannot be generalized to all community-dwelling older adults as 90% of the subjects in the study were Caucasians with the mean age of 80 years old and mild to moderate frailty (SPPB=3-10). The number of subjects is relatively small compared to previous studies. In the current study, the number of subjects was far less than previous studies⁶⁻⁸⁻⁹ which included 754 to over 4000 subjects.

To our knowledge, this is the first study investigating and comparing the predictive value of performance-based measures for the onset of ADL difficulty. This is also the first study confirming the predictive value of BBS for incident ADL disability. The results from the study also raised questions regarding to the sensitivity of different performance-based measures. It is possible that a performance-based measure is more sensitive to certain ADL tasks in certain populations. Future studies may examine the BBS for a longer follow-up time, and include different types of ADL disability. Gill et al.⁶ found bathing as the most common ADL disability to develop among 754 non-disabled community-living older adults. Several common ADL disabilities assessed, such as dressing, eating, and personal hygiene, are partly or mostly upper extremity related tasks. Future studies may also investigate differences between the onset of ADL disability related to primarily upper versus lower extremity tasks.

CONCLUSION

Performance-based measures can be administered in clinical settings in little time, training and cost. We studied multiple performance-based measures at repeated follow-up visits to compare the predictive value of each for basic ADL disability, defined as onset of difficulty, among community-dwelling older adults. The BBS, followed by the SPPB, TUG, gait speed and grip strength were predictive for the onset of basic ADL disability over an 18-month period in community-dwelling older adults. The predictive validity of the BBS for onset of ADL disability is an addition to the prognostic value of current performance-based measures in community-dwelling older adults. Screening nondisabled older adults with simple clinical tests of performance-based measures such as BBS and SPPB can provide clinicians information about incident functional disability during routine practice. The additional information about physical function could improve the clinicians' ability to make a prognosis and improve early recognition of the need for intervention.

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Figure 1.
Flow of participants through the study.

Figure 2. The sensitivity and specificity curves for baseline BBS to predict 6-month ADL disability (self-report of difficulty in one or more of the seven basic ADLs at 6 months, 12 months, or 18 months)

Table 1
Baseline characteristics of sample and comparisons of baseline characteristics between older adults who developed and who did not develop disability at 6, 12, and 18 months

	Baseline mean ($\pm$ SD) or N (%)	6-month mean ($\pm$ (SD) or N (%)		12-month mean ($\pm$ (SD) or N (%)		18-month mean ($\pm$ (SD) or N (%)	
	All participants (n=110)	No Disabilities (n=68)	Disabilities (n=27)	No Disabilities (n=62)	Disabilities (n=27)	No Disabilities (n=51)	Disabilities (n=24)
Age	80.28 ($\pm$ 6.95)	79.72 ($\pm$ 6.75)	82.07 ($\pm$ 7.03)	79.32 ($\pm$ 6.70)*	83.22 ($\pm$ 7.13)	80.08 ($\pm$ 6.44)	81.50 ($\pm$ 9.06)
Female	78 (70.9)	48 (70.6)	21 (77.8)	39 (62.9)	24 (88.9)	31 (60.8)	21 (87.5)
White	98 (89.1)	61 (89.7)	24 (88.9)	55 (88.7)	25 (92.6)	49 (96.1)	20 (83.3)
Education (high school or more)	85 (77.3)	55 (80.9)	19 (70.4)	48 (77.4)	22 (81.5)	36 (70.6)	21 (87.5)
Comorbidity	3.18 ($\pm$ 1.46)	3.02 ($\pm$ 1.35)*	3.77 ($\pm$ 1.61)	2.95 ($\pm$ 1.35)*	3.92 ($\pm$ 1.53)	3.00 ($\pm$ 1.22)*	4.04 ($\pm$ 1.57)
Mini-mental state examination	28.02 ($\pm$ 1.89)	28.40 ($\pm$ 1.67)*	27.37 ($\pm$ 2.31)	28.29 ($\pm$ 1.69)	27.67 ($\pm$ 2.24)	28.12 ($\pm$ 1.87)	28.13 ($\pm$ 2.07)
Short Physical Performance Battery (0-12)	7.53 ($\pm$ 1.95)	7.88 ($\pm$ 1.70)*	6.63 ($\pm$ 2.13)	7.97 ($\pm$ 1.75)*	6.85 ($\pm$ 1.79)	7.92 ($\pm$ 1.61)*	7.04 ($\pm$ 1.85)
Gait speed, m/sec	0.68 ($\pm$ 0.18)	0.71 ($\pm$ 0.18)*	0.61 ($\pm$ 0.19)	0.70 ($\pm$ 0.18)	0.65 ($\pm$ 0.21)	0.71 ($\pm$ 0.18)	0.65 ($\pm$ 0.17)
Berg Balance Scale (0-52)	49.8 ($\pm$ 4.85)	50.79 ($\pm$ 4.01)*	47.00 ($\pm$ 5.80)	50.82 ($\pm$ 4.07)*	47.09 ($\pm$ 4.65)	50.71 ($\pm$ 3.67)*	48.05 ($\pm$ 5.06)
Grip strength, kg Female	18.34 ($\pm$ 6.66)	18.16 ($\pm$ 6.38)	15.60 ($\pm$ 4.15)	18.80 ($\pm$ 6.20)*	15.48 ($\pm$ 4.21)	19.18 ($\pm$ 5.15)	17.00 ($\pm$ 6.46)
Male	28.50 ($\pm$ 10.33)	29.78 ($\pm$ 8.94)	29.67 ($\pm$ 11.48)	30.93 ($\pm$ 9.15)	24.00 ($\pm$ 8.00)	29.23 ($\pm$ 8.99)	31.67 ($\pm$ 2.02)
Timed up & go test, seconds	13.91 ($\pm$ 4.25)	12.90 $\pm$ 4.17*	15.55 $\pm$ 4.62	13.27 ($\pm$ 4.23)	14.81 $\pm$ 4.98	12.56 ($\pm$ 3.26)	14.17 ($\pm$ 3.58)

* p<.05

^Δ Timed up & go test was only administered at Pittsburgh site (n=78).

Table 2

Summary of c-statistics and logistic regression analysis

Physical Performance Measure	6 months		12 months		18 months	
	c-Statistic (95% C.I.)	Odds Ratio (95% C.I.)	c-Statistic (95% C.I.)	Odds Ratio (95% C.I.)	c-Statistic (95% C.I.)	Odds Ratio (95% C.I.)
SPPB	.703 (.59, .82)	.761(.57, 1.01)	.827 (.74, .92)	.739 (.53, 1.03)	.792 (.68, .90)	.798 (.57, 1.11)
Gait Speed	.672 (.56, .79)	.128 (.006, 2.644)	.797 (.70, .89)	.568(.02, 16.00)	.771 (.66, .88)	.286 (.01,8.79)
Berg Balance Scale	.725 (.60, .85)	.861 (.76, .97)*	.840 (.75, .93)	.802 (.69, .94) [†]	.821 (.71, .93)	.851 (.74, .99)*
Grip Strength (female)	.675 (.54, .81)	.937 (.84, 1.05)	.762 (.64, .89)	.882 (.77, 1.01)	.704 (.55, .86)	.914 (.81, 1.03)
Timed Up & Go Test	.734 (.62, .84)	1.138 (1.02, 1.28)*	.799 (.70, .90)	1.079 (.95, 1.23)	.792 (.68, .91)	1.142(.97,1.35)

* p<.05

[†] p<.01

Table 3
Baseline cutoff score for optimal sensitivity and specificity (intersection of sensitivity and specificity plots) and baseline cutoff score for 90% sensitivity and 90% specificity of each performance measure for onset of ADL disability at 6, 12, and 18 months

	Optimal Sensitivity & Specificity (%), Baseline cutoff value			Baseline cutoff score for 90% sensitivity, Baseline cutoff score for 90% specificity		
	6-month	12-month	18-month	6-month	12-month	18-month
SPPB (0-12)	71 7.5	74 7.4	72 7.6	6.2 9.1	6.4 8.1	6.5 9
Gait speed, m/s	59 .66	60 .66	62 .67	.5 .78	.52 .97	.54 .9
BBS (0-52)	68 49.5	70 49.5	66 50	46 53	46 51.5	46.5 53.5
Grip Strength, kg (female)	59 16	64 16.5	64 17.5	12 21	12.5 21	14 25
TUG (s) ^Δ	65 13	62 13	70 12.5	11 17	11 18	9.5 15.8

SPPB (Short Physical Performance Battery), BBS (Berg Balance Scale), TUG (Timed Up & Go Test)

^ΔTUG data was collected only from the Pittsburgh site