2.2.2.5. Hand-grip strength. We measured hand-grip strength using a hand-held dynamometer (GRIP-D, T.K.K 5401; Takei Scientific Instruments, Tokyo, Japan). Participants were in a standing position with their arms hanging naturally at their sides. They were instructed and verbally encouraged to squeeze the hand-grip as hard as they could. Grip size was adjusted to a comfortable level for the participant. Participants performed two trials with each hand alternately, and the results were averaged to the nearest 0.1 kg. The reliability of the hand-grip strength was excellent, with an ICC of 0.95.

2.2.2.6. Manipulating pegs in a pegboard. For this test, we used a pegboard (hand working test instrument, T.K.K 1306; Takei Scientific Instruments, Tokyo, Japan) consisting of 48 pegs arranged in a six-by-eight matrix on the side of the board distal to where the participants stood. With the board situated close to and at the midline of the body, participants were instructed to manipulate the pegs as fast as possible, one by one, using both hands, from the far side of the board to the near side. We recorded the number of pegs relocated within 30 s during 1 trial (Shigematsu and Tanaka, 2000). Shigematsu and Tanaka (2000) demonstrated an ICC with the manipulating pegs in a pegboard test of 0.82.

2.2.2.7. Functional reach. According to the measuring method devised by Duncan et al. (1992), participants stood with their feet together, their bodies perpendicular to and with one shoulder adjacent to, but not touching, a wall which had a measuring yardstick affixed to it horizontally. They raised their arms in front of them to a horizontal position with their tips of the middle fingers positioned at the zero end of the measuring yardstick. They reached forward as far as possible, bending as necessary but keeping their arms straight and horizontal and their feet in the starting position. The distance from beginning position to ending position as measured at the tips of the middle fingers was the functional reach value. We measured functional reach two times and recorded the average to the nearest 1 cm. Although the functional reach test was originally developed as a measure of dynamic balance, it involves movement of the upper extremities and is required for many upper body tasks (Hazuda et al., 2005). The reliability of functional reach was excellent, with an ICC of 0.94.

2.2.3. Functional status

We looked at 5 levels of functional status: physical function, higher-level functional capacity, mobility limitation, ADLs disability, and falls. We assessed these in our participants using several criteria and indices including the physical function index (PFI) of the Medical Outcomes Study 36-item Short-Form Health Survey (SF-36) (Ware and Sherboume, 1992), the Tokyo Metropolitan Institute of Gerontology (TMIG) index of competence (Koyano et al., 1991), and questions on mobility limitation, ADLs disability, and any falls in the previous year.

The PFI is derived from 10 items in the SF-36 that assess whether a participant's health limits her ability to perform vigorous activities such as running; moderate activities such as vacuuming; lifting or carrying groceries; climbing several sets of stairs; climbing one set of stairs; bending, kneeling, or stooping; ability to walk various distances without difficulty; and self-care. Each item is scored according to whether a person's health does not limit the activity (10 points), limits it a little (5 points), or limits it a lot (0 points). Possible scores range from 0 to 100 with higher scores indicating better physical function. We considered a PFI score of less than 70 points as a determiner of low physical function (Studenski et al., 2003).

We used the TMIG index to assess higher-level functional capacity (Koyano et al., 1991). On the basis of Lawton's hierarchical model of behavioral competence (Lawton, 1972), the TMIG index of competence was developed to assess levels of functional competence greater than those required for ADLs, such as instrumental ADLs (IADLs), intellectual activity, and an individual's social role (Koyano et al., 1991; Ishizaki et al., 2000; Fujiwara et al., 2003a). The response to each item in this multidimensional, 13-item index of competence is either 'yes' (able to perform) for 1 point or 'no' (unable to perform) for 0 points. The total score is the sum of the 13 items with a total score less than 11 defined as a low higher-level functional capacity (Fujiwara et al., 2003b).

We identified mobility limitations through face-to-face interviews on a participant's self-reported difficulty in walking one-quarter of a mile or climbing 10 steps without resting (Guralnik et al., 1993). Participants were asked the following questions: "Can you walk one-quarter of a mile without resting?" and "Can you climb 10 steps without assistance?" The response options were "no difficulty", "some difficulty", or "inability" to perform. Those who reported at least some difficulty performing these activities were rated as having limited mobility (Kim et al., 2009).

ADLs disability was assessed using selected ADLs (Mahoney and Barthel, 1965). The ADLs include aspects of eating, moving from bed to chair, grooming, toilet use, bathing, ambulation, negotiating stairs, dressing, and emptying bowels and bladder. We defined a participant as having an ADLs disability if she was unable to perform or needed human help with one or more ADLs tasks.

Information on falls was obtained through face-to-face interviews. We asked the following questions: "Have you fallen in the past year?" A fall was defined as an unintentional change in position resulting in coming to rest on the ground or other lower level (Kellogg International Work Group on the prevention of falls by the elderly, 1987).

2.2.4. Potential confounders

Several potential confounders were included in our analyses: age; body mass index (BMI), defined as body weight divided by height squared (kg/m^2); frequency of weekly outings; clinical conditions (history of stroke, hypertension, diabetes mellitus, heart disease, respiratory disease, and dyslipidemia); and joint pain (presence of low-back pain, or knee pain). All of these were computed on the basis of self-reported questions.

2.3. Statistical analyses

We used descriptive statistics to characterize the study participants, and we performed multiple logistic regression analyses to evaluate whether UGS and the LEP score, UEP score, and overall score were significantly associated with any of our functional status. Cesari et al. (2005) demonstrated that the prognostic value of UGS for identifying people at high risk of health-related outcomes was 1.0 m/s. In our analyses, we used the 1.0 m/s cut-off value to dichotomize UGS into high- and low-performance groups. The LEP score, UEP score, and overall score were dichotomized using the same percentile (22.7%) as the chosen UGS cut-off value. We determined this percentile based on the distribution of the present study sample population. By choosing this same threshold to identify individuals at a low-performance level, we determined equal distributions of the performance measures of interest, consequently allowing fair comparisons (Cesari et al., 2009). We adjusted for potential confounders and calculated the odds ratio (OR) and 95% confidence interval (95% CI) for each functional status according to our two categories: the high-performance category, which we considered a reference group; and the low-performance category.

To compare the discriminating power of UGS, LEP score, UEP score, and overall score for each functional status, we conducted receiver operating characteristic (ROC) analyses. Areas under the

ROC curves of UGS, LEP score, UEP score, and overall score were compared using the DeLong method (DeLong et al., 1988) implemented in the statistical software Analyse-It for Microsoft Excel. Independent variables used in the present study included UGS, LEP score, UEP score, and overall score, whereas, each functional status was a dependent variable. An AUC between 0.7 and 0.8 is considered acceptable discrimination, between 0.8 and 0.9 is considered excellent discrimination, and greater than 0.9 is considered outstanding discrimination (Hosmer and Lemeshow, 2000).

We used an alpha level of 0.05 to determine statistical significance, and all statistical analyses were performed using SPSS statistics Version 18.0 (SPSS Inc., Chicago, IL, USA).

3. Results

Table 1 summarizes descriptive details of the study participants. Mean age ± SD of the study participants ($n = 701$) was 74.3 ± 6.3 (range 65–96). There were 252 (36.4%) participants with low physical function, 137 (20.7%) with low higher-level functional capacity, 287 (41.4%) with mobility limitation, 70 (10.1%) with ADLs disability, and 174 (25.1%) that had experienced falls.

Table 2 presents ORs and 95% CIs for our five functional status according to participants' UGS, LEP score, UEP score, and overall score results, with adjustment for potential confounders. In the sample participants, the 1.0 m/s cut-off value for UGS corresponded to the 22.7th percentile. We used the same percentile to identify the cut-off values for the LEP score (low-performance group < −0.60), UEP score (low-performance group < −0.72), and overall score (low-performance group < −0.55). The UGS, LEP score, UEP score, and overall score were all significantly associated with each functional status.

Table 1
Characteristics of the study participants ($n = 701$).

Characteristics	Mean ± SD or *n* (%)
Age, years	74.3 ± 6.3
Body mass index, kg/m^2 ($n = 699$)	23.6 ± 3.4
Frequency of weekly outings, days/week ($n = 680$)	5.8 ± 2.0
Conditions, *n* (%)	
Stroke ($n = 695$)	26 (3.7)
Hypertension ($n = 695$)	302 (43.5)
Diabetes mellitus ($n = 696$)	58 (8.3)
Heart disease ($n = 695$)	73 (10.5)
Respiratory disease ($n = 696$)	26 (3.7)
Dyslipidemia ($n = 695$)	92 (13.2)
Low-back pain ($n = 691$)	245 (35.5)
Knee pain ($n = 692$)	234 (33.8)
Performance measures	
UGS, m/s	1.2 ± 0.3
LEP score	−0.19 ± 1.10
Tandem stance, s	25.3 ± 8.3
chair stand test, s	8.5 ± 3.5
Alternate step, s	5.1 ± 1.8
Timed up-and-go, s	7.9 ± 3.8
UEP score	−0.02 ± 1.00
Hand-grip strength, kg	20.7 ± 4.5
Manipulating pegs in a pegboard, pegs	39.0 ± 6.8
Functional reach, cm	25.4 ± 6.6
Overall score	−0.01 ± 1.05
Functional status	
Medical outcomes study 36-item short-form survey, PFI ($n = 693$)	74.3 ± 22.3
Low physical function (PFI < 70)	252 (36.4)
TMIG index ($n = 663$)	11.5 ± 2.1
Low higher-level functional capacity (TMIG index < 11)	137 (20.7)
Mobility limitation, *n* (%) ($n = 694$)	287 (41.4)
ADLs disability, *n* (%) ($n = 690$)	70 (10.1)
Any falls in previous year, *n* (%) ($n = 693$)	174 (25.1)

UGS, usual gait speed; LEP, lower extremity performance; UEP, upper extremity performance; PFI, physical function index; TMIG, Tokyo Metropolitan Institute of Gerontology; ADLs, activities of daily living.
LEP score = 0.031 × tandem stance − 0.106 × chair stand test −0.192 × alternate step −0.096 × timed up-and-go + 1.672.
UEP score = 0.091 × hand-grip strength + 0.063 × manipulating pegs + 0.061 × functional reach −5.901.
Overall score = 0.036 × hand-grip strength + 0.040 × manipulating pegs + 0.026 × functional reach + 0.015 × tandem stance −0.063 × chair stand test −0.117 × alternate step −0.059 × timed up-and-go −1.746.

Table 3 shows the AUCs of the UGS, LEP score, UEP score, and overall score for each functional status. All ROC curves were significantly different from a diagonal line (AUC = 0.5) that indicates zero discriminating ability of the tests. The UGS, LEP score, UEP score, and overall score all had at least acceptable discriminating power (AUC ≥ 0.7) for each functional status with the exception of any falls (AUC = 0.61, 0.62, 0.59, and 0.62, respectively).

We did not detect any significant differences between the AUCs of UGS and LEP score for each functional status. The UEP score had significantly smaller AUCs for low physical function (0.73) and mobility limitation (0.78) than UGS alone (0.81 and 0.85, respectively), LEP score (0.81 and 0.85, respectively), and overall score (0.80 and 0.85, respectively). Although the overall score had a significantly greater AUC for low higher-level functional capacity (0.83) than UGS alone (0.78) and the other composite scores (0.80 for LEP; 0.80 for UEP), the difference was only 3-5%. Similarly, although the AUC of the overall score for ADLs disability (0.83) was significantly greater than the AUC of UGS alone (0.80), the difference was only 3%. We did not detect any other significant differences between the AUCs of any of our scoring methods for the other functional status.

4. Discussion

Despite UGS being only a single test, its discriminating power was similar to the LEP score for each functional status. Moreover, the UGS alone could discriminate low physical function and mobility limitation more accurately than the UEP score. Interestingly, even the overall score had only a 3–5% difference in AUCs for low higher-level functional capacity and ADLs disability compared with UGS alone, and there were no significant differences in AUCs for any other functional status. Although we investigated whether a derived composite score representing overall physical performance would be a stronger relevant indicator of health problems than UGS alone, our findings indicate that UGS alone may represent overall physical performance and is adequate for assessing a wide range of functional status in older women.

We added timed up-and-go and alternate step test, both of which indicate the ability to perform common mobility tasks integral to daily life, to the chair stand and balance tests for the LEP score, but the present results were not different from previous findings that compared UGS with SPPB (Guralnik et al., 2000; Onder et al., 2005). Therefore, we can conclude that there is no difference between the discriminating power of the UGS and a more complex battery of LEP tests regardless of the measures or method used to construct a performance score.

We consider a difference in the AUCs for low physical function and mobility limitation between UGS alone and UEP score to be meaningful, because the difference in the AUCs is greater than 5%, and 95% CIs did not overlap at all. Our previous study (Seino et al., 2011a) showed that the UGS can discriminate even upper extremity functional limitation almost as well as a combination of different UEP measures. On the other hand, the discriminating power of hand-grip strength alone for mobility limitation was 15% lower than the discriminating power of the LEP score (Seino et al., 2011b). These indicate that the UGS is certainly more important than UEP measures and the UEP score in the routine assessment of functional status.

Table 2
Adjusted* odds ratio and 95% confidence interval (95% CI) for each status according to UGS, LEP score, UEP score, overall score results (n = 701).

Performance measures	Low physical function		Low higher-functional capacity		Mobility limitation		ADLs disability		Any falls	
	Case/participants (%)	Adjusted* OR (95% CI)	Case/participants (%)	Adjusted* OR (95% CI)	Case/participants (%)	Adjusted* OR (95% CI)	Case/participants (%)	Adjusted* OR (95% CI)	Case/participants (%)	Adjusted* OR (95% CI)
UGS										
≥1.0 m/s (high-performance)	131/537 (24.4)	1 (reference)	70/525 (13.3)	1 (reference)	148/536 (27.6)	1 (reference)	25/533 (4.7)	1 (reference)	113/535 (21.1)	1 (reference)
<1.0 m/s (low-performance)	121/156 (77.6)	6.3 (3.8–10.5)	67/138 (48.6)	3.4 (2.0–5.7)	139/158 (88.0)	12.3 (6.8–22.4)	45/157 (28.7)	4.0 (2.1–7.7)	61/158 (38.6)	1.8 (1.1–3.0)
LEP score										
≥−0.60 (high-performance)	132/539 (24.5)	1 (reference)	64/527 (12.1)	1 (reference)	153/538 (28.4)	1 (reference)	23/535 (4.3)	1 (reference)	112/537 (20.9)	1 (reference)
<−0.60 (low-performance)	120/154 (77.9)	5.8 (3.5–9.7)	73/136 (53.7)	4.4 (2.5–7.6)	134/156 (85.9)	7.7 (4.4–13.6)	47/155 (30.3)	5.0 (2.5–10.0)	62/156 (39.7)	2.1 (1.3–3.5)
UEP score										
≥−0.72 (high-performance)	155/539 (28.8)	1 (reference)	72/531 (13.6)	1 (reference)	173/540 (32.0)	1 (reference)	28/535 (5.2)	1 (reference)	118/540 (21.9)	1 (reference)
<−0.72 (low-performance)	97/154 (63.0)	2.3 (1.4–3.7)	65/132 (49.2)	3.0 (1.8–5.0)	114/154 (74.0)	3.7 (2.3–6.2)	42/155 (27.1)	3.7 (1.9–7.2)	56/153 (36.6)	1.8 (1.1–2.9)
Overall score										
≥−0.55 (high-performance)	136/539 (25.2)	1 (reference)	66/529 (12.5)	1 (reference)	157/538 (29.2)	1 (reference)	21/534 (3.9)	1 (reference)	112/538 (20.8)	1 (reference)
<−0.55 (low-performance)	116/154 (75.3)	4.4 (2.6–7.4)	71/134 (53.0)	3.4 (2.0–5.9)	130/156 (83.3)	6.2 (3.6–10.9)	49/156 (31.4)	5.1 (2.5–10.2)	62/155 (40.0)	2.1 (1.3–3.5)

UGS, usual gait speed; LEP, lower extremity performance; UEP, upper extremity performance; ADLs, activities of daily living.
LEP score = 0.031 × tandem stance − 0.106 × chair stand test − 0.192 × alternate step − 0.096 × timed up-and-go + 1.672.
UEP score = 0.091 × hand-grip strength + 0.063 × manipulating pegs + 0.061 × functional reach − 5.901.
Overall score = 0.036 × hand-grip strength + 0.040 × manipulating pegs + 0.026 × functional reach + 0.015 × tandem stance − 0.063 × chair stand test − 0.117 × alternate step − 0.059 × timed up-and-go − 1.746.
Independent variables: UGS, LEP score, UEP score, and overall score.
Dependent variables: each functional status.
* Adjusted for age, body mass index, frequency of weekly outings, stroke, hypertension, diabetes mellitus, heart disease, respiratory disease, dyslipidemia, low back pain, knee pain.

A noteworthy finding of the present study is that UGS alone could discriminate for each functional status almost as well as an overall score derived from 7 performance measures. Although the overall score tended to have slightly greater AUCs for more complicated indicators (i.e., low higher-functional capacity and ADLs disability) which include many daily tasks, Guralnik et al. (2000) have concluded that a 3–5% difference between AUCs is negligible. Our result indicates that the UGS test should not be regarded solely as a measure of lower extremity function, and this single test represents the vast majority of information generally obtained through a number of physical performance tests. In addition, when considering the simplicity of the single measurement for UGS and the cost of spending additional time measuring the parameters for the overall score or any other composite score, UGS alone may suffice in a practical setting, and it would be quite useful as a first screening tool to catch any functional decline at the earliest stage in older women.

The UGS not only represents general physical performance, but may also reflect overall health status because the UGS has been associated with health-related status apparently unrelated to physical performance, such as multimorbidity (Cesari et al., 2006) and cognitive impairment (Deshpande et al., 2009). Studenski et al. (2011) has conducted a pooled analysis of 9 cohort studies (collected between 1986 and 2000), using data from 34,485 community-dwelling older adults aged 65 years or older with baseline UGS data. They showed that baseline UGS scores can predict 5-year and 10-year survival (AUC = 0.717 and 0.737, respectively). Additionally, they also demonstrated that the AUC of age, sex, and UGS model for survival was approximately equivalent to that of the age, sex, and multiple clinical data model (i.e., prevalent chronic diseases, BMI, systolic blood pressure, and history of prior hospitalization). Therefore, a decreasing UGS may be utilized as an important indicator of overall health status.

There were several limitations and agendas in this study. First, population studies of older adults may sometimes be affected by a selection bias, because relatively healthier people tend to participate. We consider that the importance of assessing UGS may increase in people with frailty or aged 75 years and older as shown by Shinkai et al. (2000). Second, this study was a cross-sectional study, which does not allow evaluation of the predictive ability of the composite scores and UGS that we studied. Third, although we were able to adjust our analyses for health information with this study, there could be unmeasured confounders for which we could not adjust. Finally, although the UGS is considered an indicator of overall well-being, it is unclear which status is most tightly associated with a decreasing UGS when we assessed the UGS in a practical setting. In addition, since the AUCs for "any fall" were lower than the AUCs for the other functional status, we see there are adverse-health outcomes that the UGS alone cannot discern (Quach et al., 2011). Detecting people who have a slow UGS at a first screening and then exploring which factors effect their deconditioning using detailed investigative techniques is a realistic method of study in the present stage. In the future, we need to explore how much UGS alone reflects overall health status. Moreover, there is extremely limited evidence as to whether improving a parson's UGS will improve that parson's health status (Hardy et al., 2007). Longitudinal and intervention studies are needed to confirm these agendas described above.

In conclusion, although we hypothesized that the composite LEP score, UEP score or, especially, the overall score would be more sensitive than UGS alone for assessing a wide range of functional status, we found UGS is almost as good as the overall score at discriminating older women with a declining functional status. Therefore, the UGS should not be regarded solely as a measure of lower extremity function, and this single test may represent overall physical performance. Furthermore, when considering the

Table 3
AUCs[a] and 95% confidence interval (95% CI) of UGS, LEP score, UEP score, and overall score for each status.

Physical performance	AUC (95% CI)				
	Low physical function	Low higher-level functional capacity	Mobility limitation	ADLs disability	Any falls
UGS	0.81 (0.78–0.84)	0.78 (0.73–0.82)	0.85 (0.82–0.87)	0.80 (0.73–0.86)	0.61 (0.56–0.66)
LEP score	0.81 (0.77–0.84)	0.80 (0.76–0.85)	0.85 (0.82–0.88)	0.82 (0.76–0.88)	0.62 (0.57–0.67)
UEP score	0.73 (0.70–0.77)*,**,****	0.80 (0.76–0.84)	0.78 (0.75–0.82)*,**,****	0.81 (0.75–0.86)	0.59 (0.54–0.64)
Overall score	0.80 (0.76–0.83)	0.83 (0.79–0.87)*,**,***	0.85 (0.82–0.88)	0.83 (0.78–0.89)*	0.62 (0.57–0.67)

AUC, area under the receiver operating characteristic curve; UGS, usual gait speed; LEP, lower extremity performance; UEP, upper extremity performance; ADLs, activities of daily living.
LEP score = 0.031 × tandem stance − 0.106 × 5 chair sit-to-stands − 0.192 × alternate step − 0.096 × timed up-and-go + 1.672.
UEP score = 0.091 × hand-grip strength + 0.063 × manipulating pegs + 0.061 × functional reach − 5.901.
Overall score = 0.036 × hand-grip strength + 0.040 × manipulating pegs + 0.026 × functional reach + 0.015 × tandem stance − 0.063 × chair stand test − 0.117 × alternate step − 0.059 × timed up-and-go − 1.746.
Independent variables: UGS, LEP score, UEP score, and Overall score.
Dependent variables: each functional status.
[a] Range 0.5–1.0. Degree of discrimination: 0.7–0.8 acceptable, 0.8–0.9 excellent, 0.9–1.0 outstanding.
* $p < 0.05$ vs UGS.
** $p < 0.05$ vs LEP score.
*** $p < 0.05$ vs UEP score.
**** $p < 0.05$ vs Overall score.

cost of additional time spent determining the composite score versus the simplicity of measuring only the UGS, UGS alone may suffice for assessing a wide range of functional status among community-dwelling older women.

Conflict of interest statement

None.

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References

A report of the Kellogg International Work Group on the prevention of falls by the elderly, 1987. The prevention of falls in later life. Dan. Med. Bull. 34, 1–24.
Cesari, M., Kritchevsky, S.B., Penninx, B.W., Nicklas, B.J., Simonsick, E.M., Newman, A.B., Tylavsky, F.A., Brach, J.S., Satterfield, S., Bauer, D.C., Visser, M., Rubin, S.M., Harris, T.B., Pahor, M., 2005. Prognostic value of usual gait speed in well-functioning older people-results from the Health, Aging and Body Composition Study. J. Am. Geriatr. Soc. 53, 1675–1680.
Cesari, M., Onder, G., Russo, A., Zamboni, V., Barillaro, C., Ferrucci, L., Pahor, M., Bernabei, R., Landi, F., 2006. Comorbidity and physical function: results from the aging and longevity study in the Sirente geographic area. Gerontology 52, 24–32.
Cesari, M., Kritchevsky, S.B., Newman, A.B., Simonsick, E.M., Harris, T.B., Penninx, B.W., Brach, J.S., Tylavsky, F.A., Satterfield, S., Bauer, D.C., Rubin, S.M., Visser, M., Pahor, M., 2009. Added value of physical performance measures in predicting adverse health-related events: results from the Health, Aging and Body Composition Study. J. Am. Geriatr. Soc. 57, 251–259.
Cooper, R., Kuh, D., Hardy, R., Mortality Review Group; FALCon and HALCyon Study Teams, 2010. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. Br. Med. J., doi:10.1136/bmj.c4467.
Cooper, R., Kuh, D., Cooper, C., Gale, C.R., Lawlor, D.A., Matthews, F., Hardy, R., FALCon and HALCyon Study Teams, 2011. Objective measures of physical capability and subsequent health: a systematic review. Age Ageing 40, 14–23.
DeLong, E.R., DeLong, D.M., Clarke-Pearson, D.L., 1988. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 44, 837–845.
Deshpande, N., Metter, E.J., Bandinelli, S., Guralnik, J., Ferrucci, L., 2009. Gait speed under varied challenges and cognitive decline in older persons: a prospective study. Age Ageing 38, 509–514.
Duncan, P.W., Studenski, S., Chandler, J., Prescott, B., 1992. Functional reach: predictive validity in a sample of elderly male veterans. J. Gerontol. 47, M93–M98.
Fujiwara, Y., Shinkai, S., Kumagai, S., Amano, H., Yoshida, Y., Yoshida, H., Kim, H., Suzuki, T., Ishizaki, T., Haga, H., Watanabe, S., Shibata, H., 2003a. Longitudinal changes in higher-level functional capacity of an older population living in a Japanese urban community. Arch. Gerontol. Geriatr. 36, 141–153.
Fujiwara, Y., Shinkai, S., Amano, H., Watanabe, S., Kumagai, S., Takabayashi, K., Yoshida, H., Hoshi, T., Tanaka, M., Morita, M., Haga, H., 2003b. Test-retest variation in the Tokyo Metropolitan Institute of Gerontology Index of Competence in community-dwelling older people independent in daily living. Nippon Koshu Eisei Zasshi 50, 360–367 (in Japanese with an English abstract).
Gill, T.M., Williams, C.S., Tinetti, M.E., 1995. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. J. Am. Geriatr. Soc. 43, 603–609.
Guralnik, J.M., LaCroix, A.Z., Abbott, R.D., Berkman, L.F., Satterfield, S., Evans, D.A., Wallace, R.B., 1993. Maintaining mobility in late life: I. Demographic characteristics and chronic conditions. Am. J. Epidemiol. 137, 845–857.
Guralnik, J.M., Simonsick, E.M., Ferrucci, L., Glynn, R.J., Berkman, L.F., Blazer, D.G., Scherr, P.A., Wallace, R.B., 1994. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J. Gerontol. 49, M85–M94.
Guralnik, J.M., Ferrucci, L., Simonsick, E.M., Salive, M.E., Wallace, R.B., 1995. Lower extremity function in persons over the age of 70 years as a predictor of subsequent disability. N. Engl. J. Med. 332, 556–561.
Guralnik, J.M., Ferrucci, L., Pieper, C.F., Leveille, S.G., Markides, K.S., Ostir, G.V., Studenski, S., Berkman, L.F., Wallace, R.B., 2000. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J. Gerontol. A Biol. Sci. Med. Sci. 55A, M221–M231.
Hardy, S.E., Perera, S., Roumani, Y.F., Chandler, J.M., Studenski, S.A., 2007. Improvement in usual gait speed predicts better survival in older adults. J. Am. Geriatr. Soc. 55, 1727–1734.
Hazuda, H.P., Dhanda, R., Owen, S.V., Lichtenstein, M.J., 2005. Development and validation of a performance-based measure of upper extremity functional limitation. Aging Clin. Exp. Res. 17, 394–401.
Hosmer, D.W., Lemeshow, S., 2000. Applied Logistic Regression, 2nd ed. John Wily & Sons, Inc., New York.
Ishizaki, T., Watanabe, S., Suzuki, T., Shibata, H., Haga, H., 2000. Predictors for functional decline among nondisabled older Japanese living in a community during a 3-year follow-up. J. Am. Geriatr. Soc. 48, 1–6.
Kim, M.J., Seino, S., Kim, M.K., Yabushita, N., Okura, T., Okuno, J., Tanaka, K., 2009. Validation of lower extremity performance tests for determining the mobility limitation levels in community-dwelling older women. Aging Clin Exp. Res. 21, 437–444.
Koyano, H., Shibata, H., Nakazato, K., Haa, H., Suyama, Y., 1991. Measurement of competence: reliability and validity of the TMIG-index of competence. Arch. Gerontol. Geriatr. 13, 103–116.
Lawton, M.P., 1972. Assessing the competence of older people. In: Kent, D., Kastenbaum, R., Sherwood, S. (Eds.), Research, Planning, and Action for the Elderly. Behavioral Publications Inc., New York, pp. 122–143.
Mahoney, F.I., Barthel, D.W., 1965. Functional evaluation: the barthel index. Md. State Med. J. 14, 61–65.
Menz, H.B., Lord, S.R., 2001. The contribution of foot problems to mobility impairment and falls in community-dwelling older people. J. Am. Geriatr. Soc. 49, 1651–1656.
Nakamura, E., Miyao, K., 2008. Sex difference in human biological aging. J. Gerontol. A Biol. Sci. Med. Sci. 63A, 936–944.
Nakamura, E., Miyao, K., Oseki, T., 1988. Assessment of biological age by principal component analysis. Mech. Ageing Dev. 46, 1–18.
Nakamura, E., Moritani, T., Kanetaka, A., 1989. Biological age versus physical fitness age. Eur. J. Appl. Physiol. 58, 778–785.
Nakamura, E., Moritani, T., Kanetaka, A., 1990. Biological age versus physical fitness age in women. Eur. J. Appl. Physiol. 61, 202–208.
Onder, G., Penninx, B.W., Ferrucci, L., Fried, L.P., Guralnik, J.M., Pahor, M., 2005. Measures of physical performance and risk for progressive and catastrophic disability: results from the Women's Health and Aging Study. J. Gerontol. A Biol. Sci. Med. Sci. 60, 74–79.

Podsiadlo, D., Richardson, S., 1991. The timed "Up & go": a test of basic functional mobility for frail elderly persons. J. Am. Geriatr. Soc. 39, 142–148.
Quach, L., Galica, A.M., Jones, R.N., Procter-Gray, E., Manor, B., Hannan, M.T., Lipsitz, L.A., 2011. The nonlinear relationship between gait speed and falls: the maintenance of balance, independent living, intellect, and zest in the elderly of Boston study. J. Am. Geriatr. Soc. 59, 1069–1073.
Rantanen, T., Volpato, S., Ferrucci, L., Heikkinen, E., Fried, L.P., Guralnik, J.M., 2003. Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. J. Am. Geriatr. Soc. 51, 636–641.
Rossiter-Fornoff, J.E., Wolf, S.L., Wolfson, L.I., Buchner, D.M., 1995. A cross-sectional validation study of the FICSIT common data base static balance measures, frailty and injuries: cooperative studies of intervention techniques. J. Gerontol. A Biol. Sci. Med. Sci. 50, M291–M297.
Sayer, A.A., Syddall, H.E., Martin, H.J., Dennison, E.M., Roberts, H.C., Cooper, C., 2006. Is grip strength associated with health-related quality of life? Findings from the Hertfordshire cohort study. Age Ageing 35, 409–415.
Seino, S., Yabushita, N., Kim, M.J., Nemoto, M., Matsuo, T., Fukasaku, T., Okuno, J., Okura, T., Tanaka, K., 2009. A functional fitness test battery for pre-frail older adults (so-called "specified elderly individuals"). Nippon Koshu Eisei Zasshi 56, 724–736 (in Japanese with an English abstract).
Seino, S., Yabushita, N., Kim, M.J., Nemoto, M., Jung, S., Osuka, Y., Okubo, Y., Matsuo, T., Tanaka, K., 2011a. Comparison of a combination of upper extremity performance measures and usual gait speed alone for discriminating upper extremity functional limitation and disability in older women. Arch. Gerontol. Geriatr., doi:10.1016/j.archger.2011.10.011.
Seino, S., Kim, M.J., Yabushita, N., Matsuo, T., Songee, J., Nemoto, M., Osuka, Y., Okubo, Y., Okura, T., Tanaka, K., 2011b. Discrimination of mobility limitation by hand-grip strength among community-dwelling older adults. Jpn. J. Phys. Fitness Sports Med. 60, 259–268 (in Japanese with an English abstract).
Shigematsu, R., Tanaka, K., 2000. Age scale for assessing functional fitness in older Japanese ambulatory women. Aging Clin. Exp. Res. 12, 256–263.
Shinkai, S., Watanabe, S., Kumagai, S., Fujiwara, Y., Amano, H., Yoshida, H., Ishizaki, T., Yukawa, H., Suzuki, T., Shibata, H., 2000. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Ageing 29, 441–446.
Studenski, S.A., Perera, S., Wallace, D., Chandler, J.M., Duncan, P.W., Rooney, E., Fox, M., Guralnik, J.M., 2003. Physical performance measures in the clinical setting. J. Am. Geriatr. Soc. 51, 314–322.
Studenski, S.A., Perera, S., Patel, K., Rosano, C., Faulkner, K., Inzitari, M., Brach, J., Chandler, J., Cawthon, P., Connor, E.B., Nevitt, M., Visser, M., Kritchevsky, S., Badinelli, S., Harris, T., Newman, A.B., Cauley, J., Ferrucci, L., Guralnik, J., 2011. Gait speed and survival in older adults. J. Am. Med. Assoc. 305, 50–58.
Tanaka, K., Shigematsu, R., Nakagaichi, M., Kim, H., Takeshima, N., 2000. The relationship between functional fitness and coronary heart disease risk factors in older Japanese adults. J. Aging Phys. Act. 7, 162–174.
Tsutsui, T., Muramatsu, N., 2007. Japan's universal long-term care system reform of 2005: containing costs and realizing a vision. J. Am. Geriatr. Soc. 55, 1458–1463.
Ware Jr., J.E., Sherboume, C.D., 1992. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med. Care 30, 473–483.

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Comparison of a combination of upper extremity performance measures and usual gait speed alone for discriminating upper extremity functional limitation and disability in older women

Satoshi Seino [a,b,*], Noriko Yabushita [a], Mi-ji Kim [c], Miyuki Nemoto [a], Songee Jung [a], Yosuke Osuka [a], Yoshiro Okubo [a], Tomoaki Matsuo [a], Kiyoji Tanaka [a]

[a] *Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8577, Japan*
[b] *The Japan Society for the Promotion of Science, 8 Ichiban, Chiyoda, Tokyo 102-8472, Japan*
[c] *The Research Team for Promotion Independence of the Elderly, Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology, 35-2 Sakae, Itabashi, Tokyo 173-0015, Japan*

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ABSTRACT

Although usual gait speed (UGS) is considered an indicator of overall well-being, it is unclear whether upper extremity performance (UEP) measures provide a similar, additive contribution to functional status. We aimed to identify whether combining UEP measures can more accurately discriminate upper extremity functional limitation (UE limitation) and disability compared to UGS. We conducted a cross-sectional analysis on data from 322 community-dwelling older women, aged 65–96 years. Trained testers assessed UGS, and hand-grip strength (GRIP), functional reach (FR), back scratch, manipulating pegs (PEG), and moving beans with chopsticks as UEP measures. We assessed three functional statuses: UE limitation, activities of daily living (ADLs) and instrumental ADLs (IADLs) disabilities using self-reported questionnaires. Areas under the receiver operating characteristic curves (AUCs) were used to compare the discriminating power of UGS, with the individual and combined UEP measures for each status. Among UEP measures, only GRIP (AUC = 0.68 for UE limitation, 0.81 for IADLs disability, and 0.84 for ADLs disability) could accurately discriminate each status as well as UGS (AUC = 0.65, 0.83, and 0.91, respectively). Furthermore, UGS alone could discriminate UE limitation almost as well as the combination of GRIP, PEG, and FR (AUC = 0.70). Combining other UEP measures did not help discriminate further. There were few advantages to combining UEP measures, and UGS or GRIP alone may suffice for assessing UE limitation and disability. However, the UGS should be the test of first choice, certainly more than GRIP, in routine assessment of functional limitation and disability, including UE limitation.
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1. Introduction

Numerous studies have demonstrated that poor lower extremity performance (LEP) not only correlates cross-sectionally with functional status (e.g., functional limitation and disability), but also predicts them prospectively (Guralnik et al., 1994, 1995, 2000; Shinkai et al., 2000; Cesari et al., 2005; Kim et al., 2010). In particular, gait speed, chair rising, and balance tests, which are included in the short physical performance battery (SPPB) (Guralnik et al., 1994), have been studied to determine the added value of each additional LEP measure in predicting adverse health-related outcomes. Furthermore, UGS has been considered to be the most important predictor of adverse health-related outcomes among LEP measures (Cesari et al., 2009).

Thus, LEP measures, particularly UGS, are largely representative of a person's general health condition, but UEP is also likely to be tightly associated with a person's functional status because of the following: (1) physical functioning can be divided into three components, upper extremity, basic lower extremity, and advanced lower extremity functions (Haley et al., 2002); and (2) several common ADLs, such as dressing, eating, and personal hygiene are mostly upper extremity-related tasks. Notably, the vast majority of women also engage in upper extremity-related IADLs tasks (e.g., cooking, housekeeping, and doing the laundry). Indeed, Hazuda et al. (2005) have shown that their UEP battery of testing makes an independent contribution beyond the SPPB in explaining disability and dependence.

Although several UEP measures are widely used in older adults, it is unclear whether any or all of them provide a similar, additive contribution to our determination of functional status. Compared to one measure alone, combining several UEP measures may

* Corresponding author at: Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8577, Japan.
Tel.: +81 29 853 5600x8365; fax: +81 29 853 2986.
E-mail address: se-no@stat.taiiku.tsukuba.ac.jp (S. Seino).

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capture more manifestations of disability, however, it has yet to be determined which, if any, combination of UEP measures is most efficient at detecting functional limitation and disability.

The purpose of this study was to identify whether a combination of UEP measures is better at detecting UE limitation and disability compared to one measure alone, and if so, which combination of UEP measures is most accurate. To verify the value of UEP measures, we compared the discriminating power of each UEP measure alone and in different combinations with the commonly used UGS test, which is well established as a measure of general health (Cesari et al., 2005).

2. Methods

2.1. Participants

A total of 343 community-dwelling older Japanese women participated in this study in 2010. The participants were recruited from the towns of Ibaraki, Chiba, and Fukushima, Japan, as part of a nursing care prevention program or day-care service. Almost all of participants were recruited through local advertisements and flyers. The eligibility criteria were as follows: (1) they must be community dwellers aged 65 years or older; and (2) participants must be able to understand the instructions of performance tests and questionnaires. Participants who required assistance or were too functionally limited to perform the tests safely and participants with missing data of UEP measures were excluded. The remaining 322 participants included in this study ranged in age from 65 to 96 years. All participants provided written informed consent. This study was conducted in accordance with the guidelines proposed in the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of the University of Tsukuba, Japan.

2.2. Measurements

2.2.1. UGS

Participants were instructed to stand with their feet behind and just touching a starting line marked with tape at 0 m and, on receiving the tester's command, to start walking at their normal pace along a 7 m course. The actual walking speed was measured over 5 m starting with the first footfall past the 1 m mark and ending with the first footfall after the 6 m mark. Participants performed two trials with results averaged to the nearest 0.01 m/s (Shinkai et al., 2000). The reliability of UGS was excellent, with an intraclass correlation coefficient (ICC) of 0.97.

2.2.2. UEP measures

UEP components for performing ADLs included upper body strength, flexibility, and dexterity. We selected the following performance tests as indicators for these components: hand-grip strength (GRIP), functional reach (FR), back scratch (BS), manipulating pegs in a pegboard (PEG), and moving beans with chopsticks (BEAN). In selecting these items for assessing UEP, we referred to test selection criteria (Rikli and Jones, 1999) and studies by Hazuda et al. (2005), Tanaka et al. (1995), Shigematsu and Tanaka (2000), Syddall et al. (2003), Rikli and Jones (1999), and others. Participants could complete the 5 tests within 20 min and were not fatigued.

GRIP. We measured GRIP using a hand-held dynamometer (GRIP-D, T.K.K 5401; Takei Scientific Instruments, Tokyo, Japan). Participants were in a standing position with their arms hanging naturally at their sides. They were instructed and verbally encouraged to squeeze the hand-grip as hard as they could. Grip size was adjusted to a comfortable level for the participant. Participants performed two trials with each hand alternately, and the results were average to the nearest 0.1 kg. The reliability of the GRIP was excellent, with an ICC of 0.95.

FR. According to the measuring method devised by Duncan et al. (1992), participants stood with their feet together, their bodies perpendicular to and with one shoulder adjacent to, but not touching, a wall which had a measuring yardstick affixed to it horizontally. They raised their arms in front of them to a horizontal position with their tips of the middle fingers positioned at the zero end of the measuring yardstick. They reached forward as far as possible, bending as necessary but keeping their arms straight and horizontal and their feet in the starting position. The distance from beginning position to ending position as measured at the tips of the middle fingers was the FR value. We measured FR two times and recorded the average to the nearest 1 cm. Although the FR test was originally developed as a measure of dynamic balance, it involves movement of the upper extremities and is required for many upper body tasks (Hazuda et al., 2005). The reliability of FR was excellent, with an ICC of 0.95.

BS. Participants were asked to place the preferred hand behind the same-side shoulder, palm toward back and fingers extended, reaching down the middle of the back as far as possible (elbow pointed up) in a standing position. They placed the other hand behind the back, palm out, reaching up as far as possible in an attempt to touch or overlap the extended middle fingers of both hands. We measured the distance between (or the overlap of) the middle fingers behind the back two times and recorded the average to the nearest 1 cm. If their middle fingers could not touch, we recorded the value as minus. If their middle fingers could overlap, we recorded the value as plus. The participants were not allowed to grab fingers together and pull (Rikli and Jones, 1999). The reliability of the BS was considered acceptable, with an ICC of 0.88.

PEG. For this test, we used a pegboard (hand working test instrument, T.K.K 1306; Takei Scientific Instruments, Tokyo, Japan) consisting of 48 pegs arranged in a six by eight matrix on the side of the board distal to where the participants stood. With the board situated close to and at the midline of the body, participants were instructed to manipulate the pegs as fast as possible, one by one, using both hands, from the far side of the board to the near side. We recorded the number of pegs relocated within 30 s during 1 trial (Shigematsu and Tanaka, 2000). We evaluated this test's reliability using 22 of the participants; we considered it acceptable, with an ICC of 0.88. Shigematsu and Tanaka (2000) demonstrated an ICC with the PEG test of 0.82.

BEAN. The participants used chopsticks to transfer as many beans as possible (approximately 0.8 cm in diameter) from one dish (2.0 cm in depth, 20.0 cm in diameter) to another (3.5 cm in depth, 6.0 cm in diameter) within 30 s. The dishes were 20 cm apart. We recorded the number of beans correctly transferred during one 30 s trial (Shigematsu and Tanaka, 2000). This evaluation was modified from a previous study by Kim and Tanaka (1995) in which pincers rather than chopsticks were used. Shigematsu and Tanaka (2000) arrived at an ICC of BEAN of 0.84, which was considered acceptable.

2.2.3. UE limitation and disability status

From a self-reported questionnaire, we determined a participant's UE limitation using a severity of UE limitation scale (Simonsick et al., 2001), which assesses the degree of difficulty in performing three primarily upper extremity actions (i.e., using fingers to grasp or handle something, lifting and carrying 10 lbs, and raising arms up over the head). Response categories were no difficulty, a little difficulty, some difficulty, a lot of difficulty, and unable to do. Participants who reported any difficulty with these three activities were rated as having UE limitation.

Disability status was assessed using IADLs (Lawton and Brody, 1969) and ADLs (Mahoney and Barthel, 1965) scales. The IADLs include the ability to use the telephone, shop, prepare food, perform housekeeping chores, do laundry, use a mode of transportation, maintain responsibility for own medications, and handle finances. The ADLs include aspects of eating, moving from

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bed to chair, grooming, toilet use, bathing, ambulation, negotiating stairs, dressing, emptying bowels and bladder. IADLs and ADLs disabilities were defined as a participant being unable to perform or needing human help with one or more IADL or ADL tasks, respectively (Lawton and Brody, 1969).

2.2.4. Potential confounders

Several potential confounders were included in our analyses: age; body mass index (BMI), defined as body weight divided by height squared (kg/m^2); frequency of weekly outings; clinical conditions (history of stroke, hypertension, diabetes mellitus, heart disease, respiratory disease, and dyslipidemia); and joint pain (presence of shoulder pain, low-back pain, or knee pain). All of these were computed on the basis of self-report questions.

2.3. Statistical analyses

We used descriptive statistics to characterize the study participants and performed multiple logistic regression analyses to evaluate whether UGS and each UEP measure alone were significantly associated with UE limitation, IADLs disability, or ADLs disability. Cesari et al. (2005) demonstrated that the prognostic value of UGS for identifying people at high risk of health-related outcomes was 1.0 m/s. In our analyses, we used the 1.0 m/s cut-off value to dichotomize UGS into high- and low-performance groups. GRIP, FR, BS, PEG, and BEAN were dichotomized using the same percentile (21.7%) as the chosen UGS cut-off value. By choosing this same threshold to identify individuals at a low-performance level, we determined equal distributions of the performance measures of interest, consequently allowing fair comparisons (Cesari et al., 2009). We calculated the odds ratio (OR) and 95% confidence interval (95% CI) for each functional status (i.e., UE limitation, IADLs disability, and ADLs disability) according to our two categories after adjusting for potential confounders: the high-performance category, which we considered a reference group; and the low-performance category. We also performed these analyses considering continuous variables for each UEP measure. The continuous variables of performance measures were rescaled to standardized score (i.e., average per standard deviation).

To compare the discriminating power of an individual UEP measure and their combination for each status, we conducted receiver operating characteristic (ROC) analyses. We compared the areas under the ROC curves (AUCs) using the DeLong method (DeLong et al., 1988) implemented in the statistical software Analyse-It for Microsoft Excel. An AUC between 0.7 and 0.8 is considered acceptable discrimination, between 0.8 and 0.9 is considered excellent discrimination, and greater than 0.9 is considered outstanding discrimination (Hosmer and Lemeshow, 2000).

We used an alpha level of 0.05 to determine statistical significance, and all statistical analyses were performed using SPSS statistics Version 18.0 (SPSS Inc., Chicago, IL, USA).

3. Results

Table 1 summarizes descriptive details of the study participants. Mean age ± standard deviation of the study participants was 75.6 ± 6.7 (range 65–96). The numbers of participants reporting UE limitation, IADLs disability, and ADLs disability were 117 (37.6%), 68 (22.4%), and 40 (12.5%), respectively.

Table 2 presents ORs and 95% CIs for UE limitation, IADLs disability, and ADLs disability according to performance measures results with adjustments for potential confounders. In the sample participants, the 1.0 m/s cut-off value for UGS corresponded to the 21.7th percentile. We used the same percentile to identify the cut-off values for GRIP (low-performance group < 16.8 kg), FR (low-performance group < 20.1 cm), BS (low-performance group < −15.0 cm), PEG (low-performance group < 34 pegs), and BEAN (low-performance group < 7 beans). The UGS was consistently associated with each functional status as both categorical and continuous variables. When looking at individual UEP measures, only GRIP and PEG tests were consistently associated with each status as both categorical and continuous variables. Although BS was significantly associated with IADLs and ADLs disabilities as both categorical and continuous variables, it was not associated with UE limitation. As a categorical variable, FR was significantly associated with each status, whereas, as a continuous variable, it was not associated with IADLs disability. BEAN was not significantly associated with any status as either a categorical or a continuous variable.

Table 1
Characteristics of the study participants (n = 322).

Characteristics	Mean ± SD or n (%)
Age (years) (n = 322)	75.6 ± 6.7
Height (cm) (n = 322)	146.9 ± 6.4
Weight (kg) (n = 322)	50.6 ± 7.8
BMI (kg/m^2) (n = 322)	23.5 ± 3.4
Frequency of weekly outings (days/wk) (n = 314)	6.1 ± 1.8
Conditions, n (%)	
Stroke (n = 316)	10(3.5)
Hypertension (n = 317)	148(46.7)
Diabetes mellitus (n = 317)	17(5.4)
Heart disease (n = 317)	34(11.0)
Respiratory disease (n = 317)	13(4.1)
Dyslipidemia (n = 317)	58(18.3)
Shoulder pain (n = 318)	32(10.1)
Low back pain (n = 318)	90(28.3)
Knee pain (n = 318)	100(31.4)
UGS (m/s) (n = 317)	1.23 ± 0.32
UEP measures (n = 322)	
GRIP (kg)	20.1 ± 4.6
FR (cm)	24.8 ± 7.1
BS (cm)	−6.7 ± 11.0
PEG, number of pegs	38.4 ± 7.0
BEAN, number of beans	9.2 ± 3.6
Self-reported functional status, n (%)	
UE limitation (n = 311)	117(37.6)
IADLs disability (n = 304)	68(22.4)
ADLs disability (n = 319)	40(12.5)

SD, standard deviation; BMI, body mass index; UGS, usual gait speed; GRIP, hand-grip strength; FR, functional reach; BS, back scratch; PEG manipulating pegs; BESN, moving beans with chopsticks; UE limitation, upper extremity functional limitation; IADLs, instrumental activities of daily living; ADLs, activities of daily living.

Through multiple logistic regression analyses, we set up the following 4 combination patterns of UEP measures: (1) GRIP + PEG, which was consistently associated with each status as both categorical and continuous variables, (2) GRIP + PEG + FR, (3) GRIP + PEG + BS and (4) GRIP + PEG + FR + BS. Each combination was represented by simple addition of the standardized score of individual measures. Since BEAN was not associated with any status, we did not include it in the combination patterns.

Table 3 shows the AUC and 95% CI for UGS, each individual UEP measure, and combinations of UEP measures for each status. All ROC curves were significantly different from a diagonal line (AUC = 0.5) that indicates zero discriminating ability of the tests. Among the individual measures, GRIP had the greatest AUC for UE limitation (0.68), and UGS had the greatest AUCs for IADLs and ADLs disabilities (0.83 and 0.91, respectively). Only GRIP's AUCs were not significantly different from the AUCs of UGS for any status. The AUC for PEG alone was nearly equal to that for GRIP alone. The AUCs of FR and BS were consistently lower than any other measures alone or in combination.

For the UE limitation, we did not detect any significant differences between the AUCs of UGS (0.65) and the individual UEP measures. The AUCs of GRIP + PEG (0.69) and GRIP + PEG + FR (0.70) for UE limitation were significantly greater than UGS alone, but the 4–5% difference between AUCs was not substantial.

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Table 2
Adjusted odds ratio for each status according to performance measures results ($n = 322$).

Performance measures	Cases/participants (%)			Adjusted odds ratio (95% confidence interval)		
	UE limitation 117/311 (37.6)	IADLs disability 68/304 (22.4)	ADLs disability 40/319 (12.5%)	UE limitation	IADLs disability	ADLs disability
UGS						
>=1 m/s (high-performance)	77/242 (31.8)	28/235 (11.9)	6/245 (2.4)	1 (reference)	1 (reference)	1 (reference)
<1 m/s (low-performance)	38/64 (59.4)	38/64 (59.4)	32/69 (46.4)	2.20 (1.10–4.40)*	3.00 (1.30–6.89)*	21.60 (6.70–69.65)***
Continuous				0.65 (0.46–0.91)*	0.36 (0.21–0.60)***	0.09 (0.04–0.21)***
GRIP						
>=16.8 kg (high-performance)	74/246 (30.1)	32/242 (13.2)	13/251 (5.2)	1 (reference)	1 (reference)	1 (reference)
<16.8 kg (low-performance)	43/65 (66.2)	36/62 (58.1)	27/68 (39.7)	2.94 (1.45–5.96)**	3.20 (1.39–7.36)**	6.18 (2.38–16.04)***
Continuous				0.54 (0.39–0.75)***	0.40 (0.25–0.65)***	0.28 (0.16–0.49)***
FR						
>=20.1 cm (high-performance)	78/244 (32.0)	32/238 (13.4)	17/249 (6.8)	1 (reference)	1 (reference)	1 (reference)
< 20.1 cm (low-performance)	39/67 (58.2)	36/66 (54.5)	23/70 (32.9)	1.99 (1.03–3.84)*	2.93 (1.35–6.34)**	2.92 (1.20–7.09)**
Continuous				0.64 (0.45–0.87)**	0.69 (0.46–1.03)	0.63 (0.40–0.97)*
BS						
>=−15.0 cm (high-performance)	83/247 (33.6)	41/244 (16.8)	19/253 (7.5)	1 (reference)	1 (reference)	1 (reference)
<−15.0 cm (low-performance)	34/64 (53.1)	27/60 (45.0)	21/66 (31.8)	1.55 (0.81–2.97)	2.66 (1.11–6.35)*	4.40 (1.73–11.24)**
Continuous				0.79 (0.59–1.05)	0.54 (0.35–0.83)**	0.38 (0.24–0.61)***
PEG						
>=34 pegs (high-performance)	80/251 (31.9)	36/247 (14.6)	15/256 (5.9)	1 (reference)	1 (reference)	1 (reference)
<34 pegs (low-performance)	37/60 (61.7)	32/57 (56.1)	25/63 (39.7)	2.78 (1.39–5.58)**	2.61 (1.12–6.06)*	4.14 (1.63–10.55)**
Continuous				0.35 (0.21–0.58)***	0.40 (0.24–0.65)***	0.35 (0.21–0.58)***
BEAN						
>=7 beans (high-performance)	77/235 (32.8)	41/231 (17.7)	22/243 (9.1)	1 (reference)	1 (reference)	1 (reference)
<7 beans (low-performance)	40/76 (52.6)	27/73 (37.0)	18/76 (23.7)	1.88 (0.95–3.34)	1.84 (0.80–4.23)	2.37 (0.99–5.63)
Continuous				0.80 (0.61–1.04)	0.68 (0.44–1.04)	0.65 (0.40–1.06)

UE limitation, upper extremity functional limitation; IADLs, instrumental activities of daily living; ADLs, activities of daily living; UGS, usual gait speed; GRIP, hand-grip strength; FR, functional reach; BS, back scratch, PEG manipulating pegs; BESN, moving beans with chopsticks. Odds ratio: adjusted for age, body mass index, frequency of weekly outings, stroke, hypertension, diabetes mellitus, heart disease, respiratory disease, dyslipidemia, shoulder pain, low back pain, knee pain. The continuous variables of performance measures were rescaled to standardized score (i.e., average per standard deviation).

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

For the IADLs disability, we did not detect a difference between the AUCs of UGS (0.83), GRIP (0.81) and PEG (0.83), however, all three were significantly higher than the AUCs of FR and BS (0.73 and 0.68, respectively). Although the AUC of GRIP + PEG (0.86) was significantly greater than the AUC of GRIP alone, the difference was only 5%.

For the ADLs disability, the AUCs of the individual UEP measures, with the exception of GRIP, were significantly lower than the AUC of UGS (0.91). When we increased the number of combined UEP measures, the differences were not significant between the AUC for any combination compared to the AUCs of UGS, GRIP (0.84), or PEG (0.81).

4. Discussion

Among UEP measures, only GRIP could accurately discriminate each status as well as UGS. Interestingly, despite UGS being a test of lower extremity function, this single test could discriminate UE limitation as well as the GRIP test. Moreover, even when we added PEG and then FR in combination with GRIP, there was only a 4–5% difference in their AUCs for UE limitation compared with UGS alone. Adding any other UEP measure to the GRIP + PEG combination did not increase the discriminating power for each status. Therefore, our study suggests that combining UEP measures has few advantages, and the implementation of UGS should be

Table 3
AUCs for each status according to each performance measure alone and combinations of UEP ($n = 322$).

Performance measures	AUC* (95% confidence interval)		
	UE limitation	IADLs disability	ADLs disability
UGS	0.65 (0.58–0.71)	0.83 (0.78–0.89)	0.91 (0.85–0.97)
UEP measures			
GRIP	0.68 (0.62–0.74)	0.81 (0.75–0.88)	0.84 (0.77–0.92)
PEG	0.66 (0.60–0.73)	0.83 (0.77–0.89)	0.81 (0.73–0.90)[a]
FR	0.63 (0.57–0.70)	0.73 (0.66–0.81)[a,b,c]	0.78 (0.70–0.87)[a]
BS	0.59 (0.53–0.66)[b]	0.68 (0.60–0.75)[a,b,c]	0.77 (0.70–0.85)[a]
Combinations of UEP measures			
GRIP + PEG	0.69 (0.63–0.75)[a,c,d,e]	0.86 (0.80–0.91)[b,d,e]	0.86 (0.78–0.93)[d]
GRIP + PEG + FR	0.70 (0.64–0.76)[a,c,d,e]	0.85 (0.80–0.91)[d,e]	0.87 (0.81–0.94)[d]
GRIP + PEG + BS	0.65 (0.59–0.72)[e]	0.81 (0.75–0.87)[d,e]	0.87 (0.82–0.93)[d,e]
GRIP + PEG + FR + BS	0.67 (0.61–0.73)[e]	0.83 (0.77–0.88)[d,e]	0.88 (0.83–0.94)[d,e]

AUC, area under the receiver operating characteristic curve; UGS, usual gait speed; UEP, upper extremity performance; GRIP, hand-grip strength; PEG manipulating pegs; FR, functional reach; BS, back scratch; UE limitation, upper extremity functional limitation; IADLs, instrumental activities of daily living; ADLs, activities of daily living.

[a] $p < 0.05$ vs UGS.
[b] $p < 0.05$ vs GRIP.
[c] $p < 0.05$ vs PEG.
[d] $p < 0.05$ vs FR.
[e] $p < 0.05$ vs BS.
* Range 0.5–1.0. Degree of discrimination: 0.7–0.8 acceptable, 0.8–0.9 excellent, 0.9–1.0 outstanding.

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encouraged in routine assessment of functional limitation and disability, including assessment of UE limitation.

Although we should consider a statistically significant difference as meaningful when comparing AUCs, Guralnik et al. (2000) have concluded that a 3–5% difference between AUCs is negligible. Furthermore, since the 95% confidence intervals largely overlapped in our study, we consider the 4–5% difference in the AUCs between UGS alone and GRIP + PEG or GRIP + PEG + FR to be insubstantial. Onder et al. (2005) demonstrated that LEP measures, particularly UGS, showed a greater predictive ability than UEP measures for incident disability outcomes including upper extremity disability. Therefore, the UGS is considered a general measure of health and physical performance, and not just a specific indicator of localized poor function.

This is consistent with our findings, and we also showed that when combining UEP measures, the discriminating power for UE limitation did not increase meaningfully compared to UGS alone. These results would discourage the use of PEG, FR, BS, and BEAN in clinical practice and reinforce using UGS as the preferred performance measure, even more than a combination of UEP measure for assessing physical function.

Guralnik et al. (2000) showed that UGS alone, which is part of the SPPB, performed almost as well as the full SPPB in predicting incident disability. Onder et al. (2005) also demonstrated that UGS is nearly as good as their lower-extremity summary performance score in predicting incident disability. Moreover, Viccaro et al. (2011) recently evaluated the predictive ability of UGS and timed up-and-go for adverse-health outcomes. The UGS and timed up-and-go predicted outcomes equally well, but combining the two measures did not add to the predictive ability. These results also showed that, even when combining LEP measures, predictive ability does not substantially increase over UGS alone. The performance measure (e.g., GRIP and UGS), which has the strongest impact on discerning disablement, may include the vast majority of information generally obtained through the other performance measures.

In the present study, only GRIP could discriminate each functional status almost as well as UGS among individual UEP measures. There are several explanations for this. Numerous studies have consistently demonstrated that GRIP is an independent predictor of frailty (Sayer et al., 2006), disability (Rantanen et al., 1999), and cause-specific and total mortality (Rantanen et al., 2003). Thus, GRIP is also considered representative of a person's general health condition. On the other hand, Onder et al. (2005) showed that GRIP is a very specific predictor of future incident progressive upper extremity disability. Rantanen et al. (1999) also found that the GRIP test performed in middle age predicts functional limitation in terms of UE tasks 25 years later in old age. As shown by these studies, GRIP may be clinically meaningful as an indicator for both disablement and primary upper extremity function (using fingers to grasp or manipulate).

Although the importance of both UGS and GRIP as screening measures is confirmed, UGS may have greater value than GRIP. As shown in the present study, UGS can discriminate UE limitation almost as well as combined UEP measures. On the other hand, our previous study results (Seino et al., 2011) demonstrated that the discriminating power of GRIP for mobility limitation was 15% lower than the discriminating power of combined LEP measures in older women, indicating that the difference in discriminating power between the two methods was substantial. Moreover, a systematic review and meta-analysis (Cooper et al., 2011) showed that associations between physical performance measures and all-cause mortality in community-dwelling older adults. The summary hazard ratios for mortality, when comparing the best 25% with the worst 25% of performance measures, were 2.87 for UGS (five studies, 14,692 participants), and 1.67 for GRIP (14 studies, 53,476 participants). These studies indicate that the UGS is certainly more important than GRIP in the routine assessment of older adults.

There were several limitations in this study. First, population studies of older adults may sometimes be affected by a selection bias, because relatively healthier people tend to participate. Second, this study was a cross-sectional study, which does not allow evaluation of the predictive ability of the UEP measures and the combinations we studied. Moreover, we could not obtain more direct and clinically meaningful results (e.g., hazard ratio) in terms of the strength of the different combinations of UEP measures because our study design and the small sample size of participants did not permit this. Further research is needed to confirm the predictive validity of our findings in longitudinal studies. Third, although we were able to adjust our analyses for health information with this study, there could be unmeasured confounders for which we could not adjust. Finally, although we reinforced the importance of UGS and GRIP as performance measures, exercise interventions may have a differential impact on different regions and should be monitored with appropriate regional measures.

In conclusion, the results of the present study showed that, in our attempt to refine our ability to discern UE limitation and disability, the advantages of combining UEP measures were less than we expected. Our results suggest that UGS alone or GRIP alone have similar utility, and they may be adequate for assessing UE limitation and disability. In particular, UGS should be considered the first choice of performance measures, certainly more than GRIP, in routine assessment of functional limitation and disability among older women because the UGS test can discriminate UE limitation almost as well as a combination of different UEP measures.

Conflict of interest statement

None.

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References

Cesari, M., Kritchevsky, S.B., Penninx, B.W., Nicklas, B.J., Simonsick, E.M., Newman, A.B., Tylavsky, F.A., Brach, J.S., Satterfield, S., Bauer, D.C., Visser, M., Rubin, S.M., Harris, T.B., Pahor, M., 2005. Prognostic value of usual gait speed in well-functioning older people-results from the Health, Aging and Body Composition Study. J. Am. Geriatr. Soc. 53, 1675–1680.

Cesari, M., Kritchevsky, S.B., Newman, A.B., Simonsick, E.M., Harris, T.B., Penninx, B.W., Brach, J.S., Tylavsky, F.A., Satterfield, S., Bauer, D.C., Rubin, S.M., Visser, M., Pahor, M., Health, Aging and Body Composition Study, 2009. Added value of physical performance measures in predicting adverse health-related events: results from the Health, Aging and Body Composition Study. J. Am. Geriatr. Soc. 57, 251–259.

Cooper, R., Kuh, D., Hardy, R., Mortality Review Group; FALCon and HALCyon Study Teams, 2011. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. Br. Med. J..

DeLong, E.R., DeLong, D.M., Clarke-Pearson, D.L., 1988. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 44, 837–845.

Duncan, P.W., Studenski, S., Chandler, J., Prescott, B., 1992. Functional reach: predictive validity in a sample of elderly male veterans. J. Gerontol. 47, M93–M98.

Guralnik, J.M., Simonsick, E.M., Ferrucci, L., Glynn, R.J., Berkman, L.F., Blazer, D.G., Scherr, P.A., Wallace, R.B., 1994. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J. Gerontol. 49, M85–M94.

Guralnik, J.M., Ferrucci, L., Simonsick, E.M., Salive, M.E., Wallace, R.B., 1995. Lower extremity function in persons over the age of 70 years as a predictor of subsequent disability. N. Engl. J. Med. 332, 556–561.

Guralnik, J.M., Ferrucci, L., Pieper, C.F., Leveille, S.G., Markides, K.S., Ostir, G.V., Studenski, S., Berkman, L.F., Wallace, R.B., 2000. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J. Gerontol. A Biol. Sci. Med. Sci. 55A, M221–M231.

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