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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

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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

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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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