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Original Article

Short physical performance battery for middle-aged and older adult cardiovascular disease patients: implication for strength tests and lower extremity morphological evaluation

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Abstract. [Purpose] To examine if the SPPB is higher with healthy subjects than outpatients, which was higher than inpatients and if the SPPB can be validated assessment tool for strength tests and lower extremity morphological evaluation in cardiovascular disease patients. [Subjects and Methods] Twenty-four middle aged and older adults with cardiovascular disease were recruited from inpatient and outpatient facilities and assigned to separate experimental groups. Twelve age-matched healthy volunteers were assigned to a control group. SPPB test was used to assess balance and functional motilities. The test outcomes were compared with level of care (inpatient vs. outpatient), physical characteristics, strength and lower extremity morphology. [Results] Total SPPB scores, strength tests (knee extensor muscle strength), and lower extremity morphological evaluation (muscle thickness of anterior and posterior mid-thigh and posterior lower-leg) were greater in healthy subjects and outpatients groups compared with inpatients. To predict total Short Physical Performance Battery scores, the predicted knee extension and anterior mid-thigh muscle thickness were calculated. [Conclusion] The SPPB is an effective tool as the strength tests and lower extremity morphological evaluation for middle-aged and older adult cardiovascular disease patients. Notably, high knee extensor muscle strength and quadriceps femoris muscle thickness are positively associated with high SPPB scores.

Key words: SPPB, Muscle thickness, Quadriceps femoris

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INTRODUCTION

Cardiovascular disease (CVD) is a major contributor to the global burden of diseases[1, 2]. In addition, CVD (heart failure and stroke, etc.) often causes disuse muscle atrophy in the acute and subacute phase, which increases the likelihood of wheelchair or bedridden state in the chronic phase[3–5]. Consequently, the progression of muscle atrophy in lower extremity function may render a high need for medical and nursing care.

The Short Physical Performance Battery (SPPB)—a brief performance battery based on a timed short distance walk, repeated chair stands, and a set of balance tests—is a validated assessment tool for measuring lower extremity function that is widely used in both clinical and research settings[6, 7]. The popularity of this instrument stems, in part, from its relative ease of

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use, perceived potential for implementation in clinical practice, and good association with physical activity levels and general walking disability in a variety of patients or older adults. It has also been found to predict mortality, hospitalization rate, and a variety of comorbid disease conditions[7]. Although the SPPB is an effective assessment tool for lower extremity function, it is unclear the SPPB can be used to evaluate mobility capability for cardiovascular disease patients including inpatients and outpatients. Previous studies demonstrated that gait speed was associated with survival in older adults and which was faster with healthy older adults than outpatients, which was faster than inpatients[8, 9]. Thus, the purpose of this study was to examine two hypotheses: that the SPPB would be higher with healthy older adults than outpatients, which was higher than inpatients; and that the SPPB can be validated assessment tool for strength tests and lower extremity morphological evaluation in middle-aged and older adult cardiovascular disease patients.

SUBJECTS AND METHODS

Thirty-six middle-aged and older adults, aged 49 to 89 years, with cardiovascular diseases [outpatients (OUT-Pt) and inpatients (IN-Pt)] and healthy subjects (Ctrl) volunteered to participate in the study and were selected according to the exclusion criteria (history of anemia, cerebrovascular disease and arthroscopic joint surgery). In addition, volunteers who suffered from a chronic disease such as severe orthopedic disorders, peripheral vascular disease, or cognitive dysfunction were excluded from the study. All participants had undergone complete chemistry and hematologic evaluation and were informed of the risks associated with involvement in the study and signed an informed consent document before participation. All participants were recruited through study notices in area and oral communications in the university hospital. The principles of the World Medical Association Declaration of Helsinki and the American College of Sports Medicine Guidelines for Use of Human Subjects were adopted in this study. The study was approved by the Ethics Committee of the University. Analyses of ultrasound images and all measurements data were performed by the same author, who was blinded to the group assignments. The author has been specialized in the research of exercise physiology by use of ultrasound images, strength tests and lower extremity morphological evaluation more than 15 years.

Participants performed the SPPB according to the National Institute on Aging protocol. The tests were performed in the following sequence: a) standing balance tests, b) gait test, and c) chair stand test. The standing balance portion requires participants to maintain, for 10 seconds each, stances with their feet placed side by side, semi-tandem, and in tandem. The scores ranged from 0 to 4 (maximum performance). The gait test measured the time needed to walk 4 m at a typical pace. The chair stand required participants to rise from a steel chair, 0.40 m height and 0.30 m depth, with their arms across their chest, five times. Categorical scores, range: 0–4, for both the gait and the chair stand tests were based on timed quartiles established previously in a large population. Individuals who were unable to complete either the 4 m gait task or the 5 repetitions chair stand test received a score of 0. The sum of the three components comprised the final SPPB score, with a possible range from 0 to 12. A score of 12 indicated the highest degree of lower extremity function[6, 10].

Maximum voluntary isometric contraction (MVIC) of the handgrip was determined using a factory-calibrated hand dynamometer (TKK 5401, TAKEI Scientific Instruments Co., Ltd., Tokyo, Japan). All subjects were instructed to maintain an upright standing position, arms at their side, holding the dynamometer in the right hand with the arm at a right angle and the elbow held at the side of the body. The size of the dynamometer handle was set so that it felt comfortable to the subject while squeezing the grip. Each subject underwent 2 trials, and the best value of 2 trials was used for analysis.

MVIC of the knee extensors was determined using a digital handheld dynamometer (μTas MT-1, ANIMA Co., Ltd., Tokyo, Japan)[11]. The dynamometer pad is 55 × 55 mm, and its front side is curved to fit the shape of the area of the extremity to be measured. Subjects were seated in a hard chair with their knees flexed 90° and their arms on their thighs. The dynamometer was placed perpendicular to the leg just above the malleoli. During all tests, the dynamometer was kept stable by the examiner using both hands and the subject's leg was fixed by a belt to keep the knee flexed at 90°. Subjects were told to push against the dynamometer by attempting to straighten their leg. They were asked to build force gradually to a maximum voluntary effort. Each subject was given 2 trials with an interval of at least 2 min between the trials. The highest score was adopted for the individual data.

Percent body fat and fat-free mass were measured using leg-to-leg bioelectrical impedance analysis (Reactance Technology, Inner Scan, TANITA, Tokyo, Japan). The measurements were carried out while the subjects stood with their elbows extended and relaxed.

After thigh and lower leg length measurements using anatomic landmarks, all measurement sites were marked with a marker pen and then mid-thigh, at 50% between the lateral condyle of the femur and the greater trochanter, and lower-leg, at 30% proximal between the lateral malleolus of the fibula and the lateral condyle of the tibia, girths and were measured using a tape measure on the right side of the body[12]. Ultrasound evaluation of muscle thickness (MTH) was performed by using a real-time linear electronic scanner with a 10.0-MHz scanning head (5.5 cm length probe, ProSound C3CV, Hitachi Aloka System, Tokyo, Japan). The scanning head was coated with a water-soluble transmission gel to provide acoustic contact without depressing the dermal surface. The subcutaneous adipose tissue-muscle interface and the muscle-bone interface were identified from the ultrasonic image. The perpendicular distance from the adipose tissue-muscle interface to the muscle-bone interface was considered to represent MTH. Briefly, the measurements were carried out while the subjects stood with their elbows extended and relaxed[12].

Table 1. The physical characteristics and clinical data

	IN-Pt	OUT-Pt	Ctrl
Male (n)	7	7	7
Female (n)	5	5	5
Age (years)	71.8 (11.6)	70.3 (8.1)	70.0 (6.7)
Height (cm)	160 (14)	162 (10)	164 (9)
Weight (kg)	59.8 (14.0)	60.9 (10.0)	58.9 (7.1)
Body mass index (kg/m^2)	23.6 (6.5)	23.3 (3.0)	22.0 (1.4)
% body fat	30.1 (17.5)	24.0 (7.6)	23.1 (6.4)
Systolic BP (mmHg)	113 (24)	133 (19)	137 (19) $^{\#}$
Diastolic BP (mmHg)	64 (14)	71 (11)	82 (12) $^{\#\#}$
Resting heart rate (bpm)	79 (12)	71 (12)	73 (8)
BNP (pg/ml)	177 (170) *	62 (46)	-
Hospital admission (within 10 years)			
Number	2.9 (2.2)	2.0 (1.9)	0
Duration (days)	49.3 (53.5)	23.1 (24.2)	0
Specific diseases (n)			
Vascular diseases	3	6	0
Ischemic heart diseases	6	10	0
Valvular diseases	0	3	0
Congestive heart failure	7	1	0
Hypertension	6	9	0
Others	3	2	0

Data are given as mean (standard deviation). BNP: brain natriuretic peptide; BP: blood pressure. Others, myocarditis, deep vein thrombosis, etc. *$p<0.05$, IN-Pt vs. OUT-Pt. $^{\#\#}p<0.01$, $^{\#}p<0.05$, IN-Pt vs. Ctrl

Results are expressed as mean ± standard deviation for all variables. All data were analyzed using JMP software v.12.0 for Mac (SAS Institute Inc., Tokyo, Japan). Pearson product correlations of tandem, or Chair stand, or gait or total SPPB scores and variable factors were also statistically quantified. When the data were not normally distributed, non-parametric statistical analysis, Wilcoxon signed rank test, was used to identify differences in IN-Pt vs. OUT-Pt vs. Ctrl groups. A stepwise multiple-regression analysis (method of increasing and decreasing the variables, criterion was set at $p<0.05$) was performed to develop a prediction equation for SPPB scores using age, height, weight, BMI, %BF, systolic and diastolic blood pressures, resting heart rate, handgrip, knee extension, fat free-mass, mid-thigh and lower-leg girths, and anterior mid-thigh, posterior mid-thigh, and posterior lower-leg MTHs as independent variables. Consequently, the predicted variables, coefficients and intercept coefficients were automatically picked out by the JMP software. Statistical significance was set at $p<0.05$. The sample size was estimated from a priori power analysis to detect the correlation (power of 0.80, an α of 0.05, two-tailed, and $\rho=0.5$) with the reference[13]. Consequently, it was determined that a minimum of 29 participants was required.

RESULTS

The physical characteristics and clinical data are shown in Table 1. There were no significant differences among three conditions in physical characteristics except for systolic and diastolic blood pressures. Total SPPB scores, strength tests, and morphological assessments were greater in the Ctrl and the OUT-Pt groups compared with the IN-Pt group (Table 2). Pearson's correlation coefficients between SPPB scores and variable factors are shown in Table 3.

To predict tandem stand, the predicted age and posterior mid-thigh muscle thickness were calculated (tandem stand=1.80 × posterior mid-thigh muscle thickness − 0.10 × age + 5.43) (n=36, $R^2=0.331$, $p<0.05$). To predict chair stand, the predicted fat free-mass, knee extension and anterior mid-thigh muscle thickness were calculated (chair stand=0.21 × fat-free mass − 3.21 × anterior mid-thigh muscle thickness − 0.25 × knee extension MVIC + 22.34] ($R^2=0.776$, $p<0.01$). To predict gait test, the predicted posterior lower-leg muscle thickness was only calculated (gait test= −1.51 × posterior lower-leg muscle thickness + 13.59) ($R^2=0.340$, $p<0.01$). To predict total SPPB scores, the predicted knee extension and anterior mid-thigh muscle thickness were calculated (total SPPB scores=0.05 × knee extension MVIC + 1.15 ×anterior mid-thigh muscle thickness + 4.60) ($R^2=0.630$, $p<0.05$).

Table 2. Short physical performance battery (SPPB), strength tests, and morphological assessments

	IN-Pt	OUT-Pt	Ctrl
SPPB (raw data)			
Side-by-side stand (sec)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
Semi-tandem stand (sec)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
Tandem stand (sec)	7.1 (3.6)	8.3 (3.1)	10.0 (0.0) ##
Gait test (sec/4m)	5.4 (3.2)	3.8 (0.6) *	3.4 (0.3) ##
Chair stand test (sec/5rep)	16.0 (5.0)	10.0 (1.7) **	7.4 (1.7) ##, §§
SPPB score			
Side-by-side stand	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Semi-tandem stand	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Tandem stand	1.3 (0.8)	1.6 (0.8)	2.0 (0.0) ##
Gait test	3.5 (1.0)	3.9 (0.3)	4.0 (0.0)
Chair stand test	2.2 (1.3)	3.7 (0.5) **	4.0 (0.0) ##, §
Total SPPB	9.0 (2.4)	11.2 (1.0) *	12.0 (0.0) ##, §§
Strength test			
Handgrip (kg)	24.1 (9.8)	28.6 (8.6)	29.3 (7.2)
Knee extension (kg)	19.7 (9.9)	34.9 (10.3) **	37.4 (6.3) ##
Morphological assessment			
Fat free-mass (kg)	40.9 (11.4)	46.2 (8.4)	43.5 (10.2)
Mid-thigh girth (cm)	43.8 (8.1)	46.3 (3.3)	45.0 (6.2)
Lower-leg girth (cm)	33.1 (5.2)	35.3 (2.4)	34.2 (4.1)
Anterior mid-thigh MTH (cm)	3.13 (0.89)	4.28 (0.74) **	4.34 (0.60) ##
Posterior mid-thigh MTH (cm)	5.06 (0.78)	6.05 (0.51) **	5.55 (0.81) #
Posterior lower-leg MTH (cm)	5.59 (0.82)	6.52 (0.61) **	6.46 (0.50) ##

N=36. Data are given as mean (standard deviation). MTH: muscle thickness. **p<0.01, *p<0.05, IN-Pt vs. OUT-Pt. ##p<0.01, #p<0.05, IN-Pt vs. Ctrl. §§p<0.01, §p<0.05, OUT-Pt vs. Ctrl

Table 3. Pearson's correlation coefficients between SPPB scores and variable factors

	Pearson's correlation			
	Tandem	Chair stand	Gait	Total SPPB scores
Strength test				
Handgrip	0.432 **	−0.527 **	−0.523 **	0.562 **
Knee extension	0.382 *	−0.717 **	−0.491 **	0.690 **
Morphological assessment				
Fat free-mass	0.369 *	−0.386 *	−0.429 **	0.366 *
Mid-thigh girth	0.233	−0.548 **	−0.364 *	0.464 **
Lower-leg girth	0.264	−0.598 **	−0.409 *	0.436 **
Anterior mid-thigh MTH	0.463 **	−0.802 **	−0.569 **	0.759 **
Posterior mid-thigh MTH	0.488 **	−0.472 **	−0.465 **	0.563 **
Posterior lower-leg MTH	0.437 **	−0.670 **	−0.583 **	0.655 **

N=36. Data are given as mean (standard deviation). MTH: muscle thickness. **p<0.01, *p<0.05

DISCUSSION

The main findings of this study were as follows. First, total SPPB scores were greater with Ctrl group than OUT-Pt group, which was higher than IN-Pt group. Second, knee extension strength and anterior mid-thigh muscle thickness can predict total SPPB scores in middle-aged and older adult cardiovascular disease patients.

The SPPB assessment was established as a disability evaluation for older adults, healthy elderly and some disability conditions[6, 14–16]. A previous study reported that impaired mobility was reflected by a total SPPB score of less than 10[14].

In addition, total SPPB scores of 4–6 were 4.2 to 4.9 times more likely to have disability in the activities of daily living or mobility-related disability at 4 years. On the other hand, those with total SPPB scores of 7–9 were 1.6 to 1.8 times more likely to become disabled[17]. In this study, the average of total SPPB scores in IN-Pt group was 9.0 and scores of 4–6 were only in 2 patients. In addition, there was no patient with a score of 0–3. However, a stepwise multiple-regression analysis could be applied to the predictor knee extension and anterior mid-thigh muscle thickness to predict total SPPB scores. These results suggested that the total SPPB scores could be evaluated by the strength tests and morphological assessment in knee extensor muscles for middle-aged and older adult cardiovascular disease patients, even if severely impaired mobility patients were very few within the group.

In this study, the scores in side-by-side, semi-tandem stand and gait test were similar among the three groups. In contrast, the chair stand test (4 out of 12 score) makes up a large part of total SPPB scores compared with tandem stand (2 out of 12 score), suggesting that the differences of total SPPB scores were mainly dependent on the chair stand test. It is well known that knee extension muscle size and strength play an important role in the chair stand performance for older adults[18, 19]. Additionally, knee extension muscle size and strength were higher correlation coefficients with chair stand test, compared with balance and gait tests in this study. Thus, it appears that the total SPPB scores were largely affected by muscle strength and size of the quadriceps femoris.

The limitation of this study was very difficult to evaluate the function and morphological assessment within the same hospital admission for IN-Pt group or the same hospital visit for the OUT-Pt group. Additional research into these issues is needed.

In conclusion, the SPPB is an effective tool as the strength tests and lower extremity morphological evaluation for middle-aged and older adult cardiovascular disease patients. Notably, high knee extensor muscle strength and quadriceps femoris muscle thickness are positively associated with high SPPB scores.

Conflicts of interest

The authors have no conflicts of interest to declare.

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