Paper

Effectiveness of Sit-to-stand Tests for Evaluating Physical Functioning and Fall Risk in Community-dwelling Elderly

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This study aimed to examine the effectiveness of sit-to-stand (STS) tests for evaluating physical functioning and fall risk in community-dwelling elderly. 157 healthy elderly females living in the community who could stand without support (age, 76.1 ± 5.8 years, 63–87 years; height, 147.2 ± 5.9 cm; body mass, 49.2 ± 7.3 kg) participated in the following three STS tests: the five-repetition STS time (5RST) with maximal effort; ground reaction force (maximal rate of ground reaction force development; RFD) during single STS with maximum effort; and peak and mean center of gravity transferring velocity (CGTp and CGTm, respectively) during single STS with maximum effort. All subjects could perform the both single tests (RFD, CGTp, and CGTm), but 18 subjects could not perform the 5RST. The odds ratio (OR) for fall experience was not significant for any of the STS tests (OR = 1.00–1.01, p > 0.425). Significant ORs were observed for fall risk in 5RST (OR = 1.03, p < 0.001) and for activities of daily living score in 5RST and RFD (OR = 1.03 and 1.02, respectively; p = 0.001 and 0.046, respectively). In conclusion, the 5RST with a relatively high degree of difficulty may be necessary to evaluate fall and primary nursing care risks in the elderly with high physical function who live independently in the community. However, repetition number may be required to adjust to evaluate fall and primary nursing care risk of the elderly with inferior physical fitness.

Key words : sit-to-stand movement, physical function test, community dwelling elderly

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1. Introduction

Many physical function tests, such as the functional reach test (Duncan et al., 1990), 10-meter walking speed (Bohannon 1997), Timed Up & Go test (Podsiadlo and Richardson, 1991) and 30-second chair-stand test (Jones et al., 1999) have been proposed to prevent fall and primary nursing care of the elderly. Practical considerations, such as safety, facility, portability, and cost are important for these tests because they are generally used to evaluate large populations of the elderly. For example, the timed up and go test proposed by Podsiadlo and Richardson (1991) measures the time to complete a series of movement tasks such as sit-to-stand (STS) and gait for evaluating transferring, sitting, and standing abilities in the elderly. The 30-s STS test proposed by Jones et al. (1999) and Nakatani et al. (2002), measures the number of STS movements completed within 30 s to evaluate sitting and standing abilities. Both tests utilize daily living activities as the movement task and use only simple measurement tools such as a tape measure, chair, and a stopwatch. Therefore, they are practical physical function tests for the elderly.

Physical function tests for the elderly have often been used to predict fall risks based on current physical functioning levels or to confirm the effect of exercise intervention for preventing falls and the need for primary nursing care. These tests are used in the elderly who have sufficient physical functioning and can live independently. However, these elderly people include those who use assistive devices such as a cane or walking frame or those who suffer from movement disorders such as arthropathy; therefore, the safety and facility of the test are very important. Test difficulty is often lowered for use in the elderly with widely variable physical functioning. Recently, a five-repetition STS test, which utilizes fewer repetitions of the STS movement, was used more often than the 30-s STS test proposed by Jones et al. (1999) and Nakatani et al. (2002) Thus, it may be necessary revise the test so that it can be performed by the elderly with varied physical functioning.

However, the abovementioned field tests may not adequately evaluate individual differences in groups with wide variations in physical functioning levels, from active elderly with very high physical functioning to the elderly who can live independently but are at high risk for falls and require primary nursing care. Thus, tests that can be performed by most elderly individuals with high physical functioning (ceiling effect) may not be achievable by most of the latter population of elderly (floor effect). Moreover, even if the repetition number of the STS test is reduced, many elderly people who use assistive devices or suffer from movement disorders may have difficulty repeating the STS movement many times. Recently, tests that measure accurately with fewer repetitions of movements, shorter times to complete, and lower physical burden have been proposed. Fleming et al. (1991), Lindemann et al. (2003), and Nakatani and Ue (2004) used ground reaction force and Yamada and Demura (2009) used transferring velocity during one STS movement in attempt to evaluate a fall risk and/or primary nursing care risk similar to the past STS tests with repetition. However, it has not been clarified whether either STS test is useful for evaluating fall and primary nursing care risks in the elderly, with widely varied functional characteristics.

Our study aimed to examine whether any STS test is effective for evaluating physical functioning and fall risk in community-dwelling elderly.

2. Methods

2.1. Subjects

We included 157 elderly females living in the community (mean age, 76.1 ± 5.8 years; range, 63–87 years; height, 147.2 ± 5.9 cm; body mass, 49.2 ± 7.3 kg) who were participating in primary care prevention services sponsored by their local government. Subjects underwent medical checkups before the experiment and were adjudged capable of participating in the study. Written informed consent was obtained from all subjects after the study purpose and protocol were fully explained. Thirty-six subjects had experienced one or more falls (fallers: age, 78.1 ± 5.2 years; height, 146.7 ± 5.4 cm; body mass, 49.3 ± 5.8 kg) and 121 subjects had not experienced falls (nonfallers: age, 75.6 ± 5.9 years; height, 147.3 ± 6.0 cm; body mass, 49.1 ± 7.7kg). The study protocol was approved by the Ethics Committee on Human Experimentation of the Faculty of Education, Kanazawa University, Japan (authorization number: 19-18).

2.2. Procedure

Before participating in the STS tests, the subjects answered the activities of daily living (ADL) questionnaire of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the fall risk questionnaire of the Tokyo Metropolitan Institute of Gerontology (TMIG). The order of each STS test was counterbalanced, and sufficient rest was provided between the STS tests and trials. Only one trial of the five-repetition STS test was conducted in consideration of the physical burden on the subjects. The other STS tests were conducted twice. In addition, chair seat height affects the subject's physical burden during STS movement (Janssen et al., 2002). Because lower leg length differs among the subjects, the burden differs among the subjects when conducting STS movements using a chair with the same height (Yamada and Demura, 2004). Therefore, the chair seat height was adjusted according to the knee height of each subject.

2.3. Center of gravity transferring velocity during a single STS movement with maximal effort

Center of gravity transferring velocity during STS movements was measured according to the method of Yamada and Demura (2009). Subjects were instructed to adopt the appropriate sitting posture during measurement. Subjects maintained both lower limbs (with bare feet) shoulder-width apart, with the trunk in neutral, ankles at a 90º, and arms crossed over the chest. The STS movements were performed as quickly as possible from a sitting posture after the instructor's signal. The center-of-gravity transferring velocity during STS movements was measured by FiTROdyne Premium (Fitronic s.r.o., Slovakia). This device can measure the length of a cord pulled from or returned to the bobbin over time and incorporates a built-in rotary encoder. Subjects wore a belt at the level of the iliac crest. The cord was fixed at this position on the belt, and the length that the cord moved was measured against time for each STS movement. The center of gravity is located in the abdomen during sitting but transfers to and stabilizes at the lumbar spine during movement. Iliac crest transfer velocity measured from the distance traveled by the cord length against time is assumed to reflect the center of gravity transferring velocity during STS movements. Data were uploaded to a personal computer every 0.01 s.

2.4. Ground reaction force during a single STS movement with maximal effort

Ground reaction force during STS movement was measured according to the method of Fleming et al. (1991), Lindemann et al. (2003), and Nakatani and Ue (2004). Sitting posture and movement were the same as for the measurement of center of gravity transferring velocity during STS movement. Ground reaction force during STS movement was measured by T.K.K. 5809 (Takei Scientific Instruments Co., Ltd.). This device can measure vertical ground reaction force obtained from a force plate with time. The force plate was located at sole of the foot with each subject in the sitting position. Data were uploaded to a personal computer every 0.005 s.

2.5. Five-repetition STS time

Five-repetition STS time (5RST) with maximal effort was measured according to the method of Bohannon (2011). Sitting posture and movement were the same as in the abovementioned STS tests. Subjects repeated the STS movement five times as quickly as possible in the sitting posture after the instructor's signal. Subjects were instructed to extend the hip and knee joints completely in the standing phase. The time from the instructor's signal to the sitting posture after completing five STS movements was measured.

2.6. Parameters

ADL and fall risk scores were calculated based on ADL and TMIG questionnaires. Subjects with more or less than 24 ADL points were judged to be at low or high primary nursing care risk, respectively, based on the implementation guidelines of a new physical fitness test of the MEXT (MEXT, 1999). Moreover, subjects with more or less than 5 fall-risk points were judged to be high or low in fall risk, respectively, based on the criteria proposed by the Health Assessment Study Committee (2000). Peak (CGTp) and mean (CGTm) movement velocities from start to finish were calculated from the time-course data of the center of gravity transferring velocity during STS movement (Yamada and Demura, 2009). The peak value of the differentiated ground reaction force during STS movement was calculated as the maximal rate of ground reaction force development (RFD), according to previous studies (Fleming et al., 1991; Lindemann et al., 2003; Nakatani and Ue 2004), and 5RST was used for the analysis. The mean values of two trials were used for analysis of all parameters except for 5RST.

2.7. Statistical analysis

Pearson product–moment correlation coefficients were calculated to examine the relationships between each STS test. Logistic regression analysis using fall experience, fall risk, and ADL scores for dependent variables; height, body mass, and age for covariates; and measured values of each STS test for the independent variable was performed to examine the usefulness of evaluating fall and primary nursing care risks of each STS movement. In addition, the percentile rank of each item was used for logistic regression analysis. P values of < 0.05 indicated statistical significance.

3. Results

Table 1 shows the number of subjects who performed each STS movement test. All subjects completed CGTp, CGTm, and RFD measurements during single STS movements. However, the 5RST could not be measured for18 subjects (11.4%). Therefore, the data from 157 measurements were used for analyzing CGTp, CGTm, and RFD, and data from139 measurements were used for analyzing 5RST. Table 2 shows correlations among the STS tests. All correlations were significant. RFD moderately correlated with CGTp ($r = 0.46$, $p < 0.05$) and CGTm ($r = 0.43$, $p < 0.05$), and the 5RST had low correlation with CGTp ($r = -0.31$, $p < 0.05$), CGTm ($r = -0.33$, $p < 0.05$), and RFD ($r = -0.28$, $p < 0.05$). Because the correlation between CGTp and CGTm was very high, only CGTp was used for subsequent analysis considering multicollinearity. Table 3 shows the results of logistic regression analysis using fall experience for the dependent variable; height, body mass, and age for the covariates; and measured values of each STS test for the independent variables. No significant OR was found in any STS test. Table 4 shows the result of logistic regression analysis using fall risk for the dependent variable; height, body mass, and age for covariates; and each STS test for the independent variables. A significant OR of 1.03 ($p < 0.001$) was found only for 5RST but not for the other STS tests. Table 5 shows the results of logistic regression analysis using ADL score for the dependent variable; height, body mass, and age for covariates; and each STS test for the independent variables. Significant ORs were found in 5RST and RFD being 1.03 ($p = 0.001$) in the former and 1.02 ($p = 0.046$) in the latter.

4. Discussion

The elderly living independently in the community vary from those who are highly active to those who use assistive devices such as canes or walkers and those with movement disorders, such as arthropathy. Existing field tests may not adequately evaluate physical functioning because of this large variation among individuals. Furthermore, there are many issues relating to portability and cost of measurements using technical devices. A practical test employing an exercise task with a lighter physical burden is desirable for evaluating all subjects when targeting an elderly population with high variability in physical function levels.

The present results show that the relationships among the three STS tests are less than moderate (Table 2; $|r| = 0.28–0.46$). This suggests that, although subjects were performed the same exercise task, the functional findings may not be the same among the three STS tests. The center of gravity transferring velocity during STS movement proposed by Yamada and Demura (2009) evaluates litheness and speed during the STS movement. RFD during STS movements proposed by Fleming et al. (1991), Lindemann et al. (2003), and Nakatani and Ue (2004) may evaluate the strength of digging foot into the floor exerted vertically during STS movements. The 5RST proposed by Bohannon (2011) also evaluates the sitting phase in addition to movement speed during the standing phase. Therefore, even the same STS tests can differ in purpose and content. These differences may have affected the relationships among the results of the 3 STS tests.

All STS tests showed low relationships with fall experience (Table 3; OR = 0.09–1.14, $p > 0.243$). Speechley

Table 1. The number of possible/impssible subjects of each STS movement test.

	Possible subjects n	Impossible subjects n
Center of gravity transferring velocity during STS movement	157	0
Rate of ground reaction force development during STS movement	157	0
Five-repetition STS movement time with maximal effort	139	18

Table 2. Correlations among each STS test

			A	B	C
Center of gravity transferring velocity during STS movement	CGTp	A			
	CGTm	B	0.91*		
Rate of ground reaction force development during STS movement		C	0.46*	0.43*	
Five-repetition STS movement time with maximal effort		D	−0.31*	−0.33*	−0.28*

* p < 0.05

and Tinetti (1991) measured fall history, environmental causes of falls, degree of injury after a fall, cognitive function, depression, physical function (gait and balance), medical history, and physical complaints and disorders to classify the types of falls. They reported that 17% of active elderly and 52% of frail elderly experienced a fall during their 1-year follow-up. The falls of active elderly occurred particularly during displacement movements, particularly on the stairs. Moreover, they reported that the active elderly frequently encountered fall triggers because of their higher activity level. In addition, Freiberger and Menz (2006) reviewed 12 months of data to clarify the fall scenes, times, causes, injuries, and medical treatments associated with falls in 293 physically active elderly. During the study period, there were 322 falls; the typical fall occurred outside home during leisure activities, at midday or in the afternoon. The elderly in this study were living independently and also were participating in primary care prevention services sponsored by their local government. Furthermore, fall incidence of the present elderly in the past year was 22.9%, which is similar to that of the vigorous elderly studied by Speechley and Tinetti (1991). We speculate that the physical function of the present subjects is higher than that for frail elderly subjects, with higher risk of falling or needing primary nursing care. Therefore, as in the previous studies cited above, the relationship between fall experience and STS tests might be low because of our subjects' higher physical activity levels and also their resultant greater risk of exposure to possible accidents. On the other hand, a significant relationship was found only in 5RST with fall risk (OR = 1.03, $p < 0.001$; Table 4) and in 5RST and RFD with primary nursing care risk (OR = 1.03 and 1.02, respectively; $p = 0.001$ and 0.046, respectively; Table 5). Santos et al. (2011) measured fall experience for 91 physically active elderly and 96 physically inactive elderly using the Berg Balance Scale (BBS) to validate it. As a result, the cutoff value for screening the physically inactive elderly with/without fall experience was 49 points, and its

Table 3. The results of logistic regression analysis using fall experience for the dependent variable; height, body mass, and age for the covariates; and measured values of each STS test for the independent variables.

	Odds ratio	95%CI lower	95%CI upper	*p*
Age	1.02	1.00	1.04	*0.073*
Height	1.00	0.98	1.02	*0.842*
Body-mass	0.99	0.97	1.01	*0.262*
5RST	1.01	0.99	1.02	*0.425*
RFD	1.00	0.99	1.02	*0.624*
CGTp	1.00	0.98	1.02	*0.924*

95%CI, 95% confidence interval

Table 4. The result of logistic regression analysis using fall risk for the dependent variable; height, body mass, and age for covariates; and measured values of each STS test for the independent variables.

	Odds ratio	95%CI lower	95%CI upper	*p*
Age	1.01	0.99	1.02	*0.405*
Height	1.00	0.99	1.02	*0.767*
Body-mass	0.99	0.98	1.01	*0.380*
5RST	1.03	1.01	1.05	*0.000*
RFD	1.00	0.99	1.02	*0.856*
CGTp	1.00	0.98	1.02	*0.864*

95%CI, 95% confidence interval

Table 5. The results of logistic regression analysis using ADL score for the dependent variable; height, body mass, and age for covariates; and measured values of each STS test for the independent variables.

	Odds ratio	95%CI lower	95%CI upper	*p*
Age	1.01	1.00	1.03	*0.107*
Height	1.01	0.99	1.03	*0.250*
Body-mass	0.98	0.96	0.99	*0.006*
5RST	1.03	1.01	1.04	*0.001*
RFD	1.02	1.00	1.03	*0.046*
CGTp	1.02	1.00	1.03	*0.066*

95%CI, 95% confidence interval

sensitivity and specificity were very high (sensitivity: 91%, specificity: 92%). However, they reported that the physically active elderly had low sensitivity (0%–15%) and their specificity ranged from 82% to 100%. Therefore, because fall risk due to decreased physical activity increases in inactive people, screening their fall experience may be possible. However, for active elderly people, it may be not highly possible to judge that even if they had a low fall risk, they have high fall risk. This problem in measurement occurred because the exercise task conducted for those elderly with high physical functioning had a low degree of difficulty. Therefore, test sensitivity is low because individual variation is small. The relationships between fall and primary nursing care risks might also be low because the elderly in our study had relatively high physical function (as stated above), and they could easily achieve a single STS. Hence, a relatively high-level exercise task, such as 5RST, should be imposed on them.

However, the ORs of 5RST and RFD, which show a relationship with fall and primary nursing care risks, were significant but not high (OR = 1.02–1.03). Seino et al. (2010) measured 20 physical function items containing 5RST for 483 community-dwelling elderly to clarify the fall-related factors, focusing on the intervention of fall prevention, and conducted logistic regression analysis using fall experience for the dependent variable. They reported that “climbing 10 steps” and “tandem walk” were selected as items with a high relationship with fall risk (OR = 2.75 and 1.05, respectively), but 5RST was not selected. Kawabata and Hiura (2008) used the 30-s chair stand test (CS-30) for 135 elderly to examine the validity of the test for fall prediction and conducted logistic regression analysis using fall experience for the dependent variables. They reported the OR of CS-30 to be 23.3. An average record of CS-30 ranges from 14 to 25, considering the age of the subjects of this study (Nakatani et al., 2002), and a larger number of STS movements were imposed on the elderly compared with those in 5RST. Repetition is restricted when the elderly only have lower physical function; therefore, although STS was used as a movement task in both tests, the results obtained by Kawabata and Hiura (2008) and Seino et al. (2010) differed markedly. Screening of fall and primary nursing care risks may be difficult if the repetition number is set above a certain limit when the elderly can live independently and are also participating in primary care prevention services sponsored by their local government. However, 18 of 157 subjects (11.5%) had difficulty performing the 5RST (Table 1). The primary reasons for this failure were pain related to osteoarthritis and rheumatism and/or accompanying joint replacement. Because these subjects lived independently, they could barely perform the STS movement one time but could not repeat it. It is inferred that more elderly have difficulty in performing the 5RST because the elderly living in the community generally have lower physical functioning than the present elderly. Therefore, considering their physical burden and validity of screening, the optimum number of repetitions is required to be adjusted for the elderly.

5. Conclusion

Five RST with relatively high degrees of difficulty may be necessary to evaluate the fall and primary nursing care risks of elderly persons with high physical functioning who live independently in the community. However, adjustment of the number of test repetitions may be required to evaluate the fall and primary nursing care risks of the elderly with inferior physical fitness.

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