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Correlation between the Sensory Organization Test and the Functional Reach Test in Balance Evaluation of Elderly Individuals

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Abstract. [Purpose] The purposes of this study were to investigate the age-related differences in balance ability of elderly individuals and to verify the clinical usefulness of the Functional Reach Test (FRT) in comparison with the Sensory Organization Test (SOT) for balance evaluation of this subject group. [Subjects] The subjects were 46 community-dwelling elderly people aged over 65 years old. [Methods] Balance was measured using the FRT and the six sub-equilibrium sessions and composite equilibrium score of the SOT. Pearson's correlation coefficient was used to evaluate the relationships among these balance measures. [Results] The <75 years old group showed significantly better balance ability than the ≥75 years old group. Significant positive correlations were found between the FRT and both the eyes-closed sway-surface (EC/SS) section (r=0.79) and the composite equilibrium score (r=0.55) of the SOT. [Conclusion] It is possible to use the FRT as a quantitative measure of balance for elderly individuals rather than the SOT, which is more expensive and complicated to evaluate.
Key words: Balance, Elderly, Functional reach test

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INTRODUCTION

The balance needed for postural control is described as balance ability, and it requires consistent control of muscles and joints to maintain the center of gravity (COG) within a base of support (BOS) while performing daily activities[1)]. Although balance is considered a simple and natural process through which the COG is maintained within the BOS, it is accompanied by a complex process that includes coordinated activation of various systems, such as the sensory system, motor system, central nervous system (CNS), and biomechanical system[2, 3)]. The sensory system involved in balance consists of visual, vestibular, and somatosensory signals, all of which need to be well coordinated[4)]. Vision allows recognition of the orientation of the head and eyes with regard to the surrounding environment, and the visual signal, supported by the rest of the sensory system, provides information on the location of each segment of the body and the joints, and on the status of the BOS. The vestibular system provides information about acceleration, which includes gravity and head movements with respect to inertia. The CNS recognizes information regarding movement from the sensory system and incorporates it. Additionally, the CNS plays an important role in initiating the appropriate reaction of the musculoskeletal system[5)]. Therefore, balance evaluation based on measurement of various aspects of balance is more useful than simpler methods because balance is affected by complex interaction of a variety of factors[6–9)].

A balance measure used for elderly individuals should have demonstrated reliability and validity. Additionally, it should be sensitive enough to verify balance improvement when used to monitor treatment procedures. Furthermore, it should be easily applicable to clinical needs[10)]. The Functional Reach Test (FRT) and the Sensory Organization Test (SOT) are commonly used to study and evaluate balance among the elderly population[11–14)]. The SOT was invented to evaluate static balance, i.e., the ability to stand without sway, and it consists of six sub-items. Although the SOT has advantages in that it provides quantitative and objective data on balance ability that can be processed by a computerized program, it requires expensive devices and procedures, and it is a laboratory evaluation tool that cannot easily be used elsewhere. Moreover, it has additional limitations, such as the fact that it is not good for evaluating dynamic balance during activity and functional movement[12, 15)].

The FRT is known as an evaluation tool that is able to measure dynamic anteroposterior balance. It measures the maximal distance of a subject's reach while maintaining the standing position on a fixed BOS[16)]. The FRT is widely used in the clinic because it does not require special measuring instruments, have high testing costs, or a long testing time. Moreover, the FRT can be used to evaluate balance in elderly individuals easily, simply, and safely[15)]. Due to the lack of research on the FRT, particularly among the elderly population of Korea, only a few studies have provided measurements using FRT that could be used as a standard for verifying the efficiency and validity of the FRT. Such data are needed to confirm the correlation between the FRT and other balance test tools with objective and quantitative measures such as the SOT.

Therefore, the purposes of this study were to investigate differences in the balance ability of elderly individuals (older than 65 years) by age and to verify the FRT is suitable for evaluating balance in this population by comparing the FRT with sub-sessions of the SOT, which is known for its objective and quantitative measuring method.

SUBJECTS AND METHODS

Subjects

This study was conducted with an elderly cohort consisting of people older than 65 years recruited from among community-dwelling volunteers. Subjects who meet the criteria included 46 people ranging in age from 65 to 83 years old. The subjects sufficiently understood the study procedure and submitted consent forms indicating their voluntary participation.

The exclusion criteria included active neuromuscular and musculoskeletal diseases such as vestibular disorders, arthritis, dizziness, Parkinson's disease, major depressive/affective disorder, cognitive disorder, impaired sensory function, and orthostatic hypotension. None of the subjects required constant support from a walker or more sophisticated aid to assist in ambulation. Initially, 51 subjects were recruited for this study, but five subjects were excluded from data analysis because they fell under the exclusion criteria.

Methods

To ensure safety, an assistant was asked to stand close to the subjects during the FRT. The subjects were asked to reach one arm forward in the standing position, while the other arm remained extended horizontally, with the shoulder flexed at 90 degrees. The point of measurement was the metacarpo–phalangeal joint of the third finger. The distance from the initial point to the endpoint, which was the farthest length that the subjects could reach with their arm, was measured. Both posterior translation of the hip joint and flexion of the knee were restricted to increase the reliability and validity of the FRT. Distance measurements were recorded with a yardstick attached to the wall. The mean of three trials was used for data analysis. A previous study with 128 people aged 20–80 years demonstrated a test–retest reliability of ICC=0.92, and the ICC was 0.98 for inter-tester reliability[16].

The SOT was developed to comprehensively evaluate the sensory system involved in balance[5]. The NeuroCom Balance Master system (NeuroCom International, Inc., Clackamas, OR, USA) was used for the SOT. SOT equipment included a safety supporting frame to prevent subjects' falling, a force plate, a visual surround, a computer monitor suspended at the same (eye) level of the visual surround, a computer system, and the SOT computer software program, which controls the equipment and provides test results. The SOT force plate consists of left and right sides, each measuring 23 × 46 cm, that are connected by a pin joint and four built-in pressure sensors that detect anteroposterior pressure of weight transfer through the sole. Thus, the force plate is measuring the excessive weight pressure force in the anteroposterior direction during the SOT. Loss of balance is determined when a subject's sway exceeds the limits of stability (8.5° anteriorly and 4° posteriorly), requiring a support by the examiner to prevent a loss of balance, fall or injury, at least once during the SOT[5]. Subjects were asked to stand comfortably on the force plate to measure pressure, and their feet were adjusted to match an established line (short: 76–140 cm, medium: 141–165 cm, large: 166–203 cm) that was drawn in accordance with the posture on the force plate. For safety, the subject was instructed to wear a harness and not to change the position of his or her feet from that which was originally set during the test. The SOT is composed of six sub-items, dependent on sensory conditions. Measurement of static balance was repeated three times for 20 s in each section. The six sub-sections of the SOT were conducted in a standard order from the first to the sixth condition[5]. The six conditions are as follows: (1) normal vision and support surface (EO); (2) eyes closed and normal support surface (EC); (3) sway-referenced vision and normal support surface (SV); (4) normal vision and sway-referenced support surface (EO/SS); (5) eyes closed and sway-referenced support surface (EC/SS); and (6) sway-referenced vision and support surface (SV/SS). Two trials were conducted for the first and second conditions and three trials for the other conditions. The mean of the six conditions was used as the composite equilibrium score in the data analysis. A 100% composite score means well-maintained balance without disturbance; a score of 0% means falling due to instability of equilibrium[5]. Good test-retest reliability was reported for the SOT composite equilibrium score, ICC=0.98, and the concurrent validity was, ICC=0.72, in a previous study[17]. The subjects were divided into groups by age to investigate age-related differences in balance ability. One group was <75 years old, and the other group was ≥75 years old. The independent t-test was used to determine differences in general characteristics and balance ability between the two groups. Pearson's product-moment correlation coefficient was used to investigate the relationships between equilibrium scores of the SOT and the FRT. The data were analyzed using SPSS (version 18.0). Significance was accepted at $p<0.05$.

RESULTS

The subjects' general characteristics are shown in Table 1. Among the 46 subjects, 25 (54.3%) were <75 years, and 21 (45.6%) were ≥75 years. There were 11 men (44.0%) and 14 women (56.0%) in the <75 years group and 11 men (52.3%) and 10 women (47.7%) in the ≥75 years group. There were no significant differences in height or weight between the two groups.

The average FRT score was 24.16 cm in the <75 years old group and 19.38 cm in the ≥75 years old group. Thus, the younger elderly group showed significantly better balance ability than the older group ($p<0.01$) (Table 2). Additionally, comparing the equilibrium scores of the SOT between the

Table 1. Descriptive characteristics of the elderly subjects

Characteristics	Younger than 75 (n=25)		75 or Older (n=21)	
	Mean ± SD	Range	Mean ± SD	Range
Age (y)	68.86 ± 2.80	65–74	78.00 ± 2.15**	75–83
Height (cm)	156.76 ± 6.75	146–168	155.25 ± 4.78	148–164
Weight (kg)	60.78 ± 7.79	45–79	60.50 ± 7.02	51–81

(n=46) Abbreviations: SD, Standard deviation. Comparison between groups (independent t-test).** $p<0.01$

Table 2. Comparison of sub-sessions of the SOT and FRT by age of the elderly cohort

Characteristics	Younger than 75 (n=25)		75 or Older (n=21)	
	Mean ± SD	Range	Mean ± SD	Range
FRT (cm)	24.16 ± 3.05	15–29	19.38 ± 4.75**	11–27
EO (%)	90.88 ± 3.11	84–95	90.52 ± 1.74	87–93
EC (%)	90.32 ± 3.58	85–97	89.33 ± 1.77	85–93
SV (%)	80.64 ± 4.32	72–88	78.54 ± 4.01	70–84
EO/SS (%)	74.12 ± 3.67	66–79	73.05 ± 4.10	62–80
EC/SS (%)	71.53 ± 6.75	50–80	61.11 ± 8.33**	42–74
SV/SS (%)	71.67 ± 4.25	60–78	61.45 ± 4.88**	52–70
Comp (%)	73.84 ± 3.15	67–79	70.52 ± 6.15*	59–79

(N=46) Abbreviations: SOT, sensory organization test; FRT, functional reach test; EO, eyes open; EC, eyes closed; SV, sway vision; SS, sway surface; Comp, composite equilibrium score; SD, standard deviation. Comparison between groups (independent t-test). * $p<0.05$, ** $p<0.01$

Table 3. Correlations between FRT and each equilibrium score of SOT for the elderly cohort

	EC	SV	EO/SS	EC/SS	SV/SS	Comp	FRT
EO	0.49**	0.15	–0.00	0.05	–0.03	–0.17	0.06
EC		–0.10	–0.06	–0.00	0.04	–0.09	0.08
SV			0.33*	0.39**	0.36*	0.20	0.28
EO/SS				0.62**	0.48**	0.41**	0.49**
EC/SS					0.79**	0.70**	0.79**
SV/SS						0.66**	0.72**
Comp							0.55**

Abbreviations: SOT, sensory organization test; FRT, functional reach test; EO, eyes open; EC, eyes closed; SV, sway vision; SS, sway surface; Comp, composite equilibrium score. Data presented are Pearson correlation coefficients. * $p<0.05$, ** $p<0.01$.

two groups, the younger elderly group showed significantly higher balance abilities for the EC/SS, SV/SS, and composite equilibrium scores of the SOT ($p<0.05$). On the other hand, there were no significant differences in balance ability between the two groups for EO, EC, SV, or EO/SS of the SOT ($p>0.05$) (Table 2).

The correlations between each equilibrium score of the SOT and the FRT score are shown in Table 3. The correlation was positive and significant between the FRT score and the composite equilibrium score of the SOT ($r=0.55$, $p<0.01$), and the correlation between FRT and EC/SS was significantly higher than those of the other equilibrium scores of the SOT ($r=0.79$, $p<0.05$). There were no significant correlations between FRT and the static-balance equilibrium scores, such as the EO, EC, or SV sessions of the SOT ($p>0.05$). Comparing the SOT sub-tests, there were no significant correlations between EO and any other equilibrium score of the SOT except EC ($p>0.05$). In the comparison of SV and the other sub-tests of the SOT, there were statistically significant correlations with some sub-tests of the SOT ($p<0.05$), but they were weak (SV and EO/SS, $r=0.33$; SV and EC/SS, $r=0.39$; SV and SV/SS, $r=0.36$); there was no significant correlation between SV and the other sub-tests of the SOT ($p>0.05$). EO/SS was significantly correlated with SV, EC/

SS, SV/SS, and the composite equilibrium score ($p<0.05$), and the composite equilibrium score was significantly correlated with EO/SS, EC/SS, and SV/SS ($p<0.01$) (Table 3).

DISCUSSION

The purposes of this study were to investigate differences in balance ability by age in the elderly population over 65 years old, to verify the correlation of the FRT with the six equilibrium sub-scores and composite equilibrium score of the SOT, which is known as an objective and quantitative measure of balance ability, and to determine whether the FRT is a clinically acceptable balance assessment tool for the elderly population. This study found significant correlations between the FRT and each equilibrium score of the SOT, thereby confirming that the FRT is suitable for clinical balance tests in elderly individuals.

In this study, the mean FRT was 24.16 ± 3.05 cm in the <75 years elderly group and 19.38 ± 4.75 cm in the ≥75 years group, indicating that younger elderly subjects could reach significantly farther than older subjects ($p<0.01$). Winter et al.[18] suggested that ankle strategy was the main contributor to changes in FRT, and that it reflected the ability to control anteroposterior direction in standing posture. In this study, even though subjects' level of physical activity was not measured, the reason that the younger elderly group had significantly greater FRT measurements was presumed to be that physical activity and general health levels decrease with advancing age in elderly people[2]. Endo et al.[19] reported a correlation between toe plantar flexor isometric muscle strength and functional toe length in a functional reach task, which was defined as the "maximum distance that the subject could move the center of ground reaction force forward of the first metatarsophalangeal joint" in a subject cohort of 20 young healthy adults, mean age 22.7 years, and 20 healthy elderly individuals, mean age 73.2 years. That study found a positive correlation between FRT and toe plantar flexor strength ($r=0.84$, $p<0.01$), indicating that the stronger the toe plantar flexor strength is the higher the performance of the FRT became, which is consistent with the results of the present study. Duncan et al.[16] reported that FRT below 17.5 cm marked the functional limitation of balance. However, in the present study, the group ≥75 years of age had an average functional reach of 19.38 cm, which is longer than the 17.5 cm identified by Duncan as the functional limitation of balance. This may be because our participants had not history of falls, and they were healthy community-dwelling elderly individuals who were able to walk without assistive devices, despite their age. In this study, the correlation between height and FRT was not significant ($r=0.11$, $p>0.05$). This result differs from those of previous studies that have reported a significant correlation between height and FRT scores[16, 19, 20]. This difference in results may arise from differences between the previous studies and the present study in general characteristics of the subjects, or from the study design, such as sample size, subject age, or health status.

In the comparison of the FRT with the various sub-tests of the SOT, the FRT and EC/SS, which measures anteroposterior movement according to force plate sway while subjects eyes are closed, was significantly high ($r=0.79$, $p<0.01$). Although there are no previous studies with which to compare with this result, Daubney and Culham[10] reported that ankle plantarflexor and dorsiflexor strengths were good predictors of performance in the FRT. In this study, EC/SS of the SOT may mostly reflect ankle strength, which controls sway movement on the force plate without visual information during the SOT. The highest correlation was between the FRT and EC/SS ($r=0.79$). Other equilibrium sections of the SOT, such as EO, EC, and SV, showed no significant correlation with FRT ($p>0.05$). The reason for this may be that the EO, EC, and SV sections of the SOT are generally used to measure static balance in the standing posture, whereas the FRT measures dynamic balance during forward movement. Although there was a significant correlation between the FRT and the composite equilibrium score, which is the average of all six sub-tests of the SOT ($r=0.55$, $p<0.05$), the EC/SS equilibrium score was likely the biggest contributor to the FRT score ($R^2=0.62$).

Among the equilibrium sub-tests of the SOT, EO and EC, which are easy to perform, were significantly correlated ($r=0.49$, $p<0.01$), but the other sections of the SOT, which are difficult to perform, such as EO/SS, EC/SS, and SV/SS, were not significantly correlated with the easier sections, EO and EC ($p>0.05$) (Table 3). The correlations of EO/SS, EC/SS, and SV/SS with the composite equilibrium score were significant ($p<0.05$). From these results, it is reasonable to conclude that using the high-level equilibrium sections of the SOT would be useful for balance tests of healthy elderly individuals who have not history of falls, and the low level equilibrium sections of the SOT, such as EO, EC, and SV, would be useful for balance tests of elderly individuals who have decreased balance ability and a history of frequent falls.

Recently, considerable interest has focused on maintaining the quality of life in elderly individuals because of the rapid increase in the elderly population in Korea[21]. Falls are thought to be one important factor detracting from quality of life of elderly individuals. One-third of community-dwelling elderly people who are over 65 years old have experienced a fall at least once in a given year[22, 23]. Elderly individuals who have experienced a fall worry about recurring falls and experience fear while performing physical and social activities; they also feel less confident at performing independent daily activities[24]. Therefore, it is important for elderly individuals to maintain their balance ability through postural control, so that they can perform safe daily activities.

Although assessment tools for balance of the elderly population need to be easy and simple to perform, as well as reliable and valid, it is impossible to perfectly evaluate all aspects of elderly individuals' balance because there are many variables that affect the balance ability of elderly individuals. Therefore, physical therapists are required to be fully aware of the benefits and limitations of each assessment tool. Additionally, they should consider the characteristics of the subjects, testing time, scoring methods, the validity and reliability of the tools, and the training level of the tester prior to choosing assessment tools. Bogle Thorbahn and Newton[25] suggested that both clinical and laboratory measures should be considered together for ideal balance evaluation. The laboratory balance measures can be used to obtain quantitative and precise measurements, but these tools require a lot of testing time and cost. On the other hand, clinical balance measures are simpler and easier testing procedures; however, they cannot measure data exactly and in detail[24]. According to the results of the present study, the FRT can be used widely in clinics as a balance assessment tool for elderly individuals, as the benefits are sufficient to outweigh the disadvantages. Although the FRT has become a standard clinical test for assessing an elderly individual's potential risk for falling that has high reliability, and a high degree of construct validity[16, 26], the test has some limitations. One limitation of the FRT is that it is affected by the subject's characteristics such as age and height[16]. Another limitation is that it measures the limit of balance in the forward direction only. It is clear that the FRT does not deal with lateral stability that seems to be a critical item in the assessment of individuals' risk of falling.

There were some limitations to this study. First, this study was conducted with subjects who had not history of falls, because of the difficulty of selecting suitable subjects, making the sample size too small to generalize to all elderly individuals. Second, other assessment tools that are widely known as balance measures for the elderly population were not tested. Therefore, further studies are needed to investigate the validity and effectiveness of the FRT for elderly individuals who have a history falls and to identify correlations between the FRT and other balance assessment tools, such as the Berg Balance scale and the Timed "Up & Go" test.

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