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Reliability and Validity of the Revised Successive-Choice Step Reaction Test in Elderly Women

Kaoru Fujitani[1], Shin-ichi Demura[1], Yuko Asakura[2], Shunsuke Yamaji[3], Hiroki Aoki[4,*], Sohee Shin[5], Narihito Taima[6]

[1]Kanazawa University, Ishikawa, Japan
[2]Kaga Swim Club, Ishikawa, Japan
[3]Fukui University, Fukui, Japan
[4]National Institute of Technology, Fukui College, General Course, Fukui, Japan
[5]University of Ulsan, Ulsan, Korea
[6]Osaka University of Pharmaceutical Sciences, Osaka, Japan
*Corresponding author: aoki@fukui-nct.ac.jp

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Abstract Falls occur unexpectedly in elderly individuals. Even when they pay close attention, they have difficulty avoiding falls. Therefore, these individuals must make fall-avoidance movements instantly-namely, quick one-step forward reactions (compensatory steps) when falls occur. This study examined the reliability and validity of a newly developed step reaction test for elderly women. The subjects included 22 young elderly women (65-74 years old) and 28 older elderly women (75-90 years old) with exercise habits, 22 young elderly women and 20 older elderly women without exercise habits, and 23 young women. Subjects stood in the middle of eight test sheets and then stepped rapidly onto the sheet indicated at random on the computer screen. A sum of the time from stimulus presentation to step landing on each sheet was used as an evaluation variable (movement time). The reliability of the test was high (intraclass correlation coefficient: 0.84-0.97). The results of one-way analysis of variance and multiple comparison tests showed that mean movement time increased in the order young subjects, young elderly subjects, older elderly subjects with exercise habits, and older elderly subjects without exercise habits. In addition, a significant decrease in movement time with age was found in elderly subjects without exercise habits (r = 0.65) but not in elderly subjects with exercise habits. In conclusion, the new step reaction test showed high reliability and validity.

Keywords: *medical aspects of sports, elderly women, fall prevention*

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1. Introduction

Falls in the elderly cause serious injuries such as fractures, and fractures of the lower limbs often leave patients bedridden [1]. Women reportedly have a higher rate of injuries such as fractures and bruises than men [2].In addition, the fall experience itself limits the degree and range of subsequent daily life activities, regardless of whether any direct injuries resulted from the fall [3,4]. Therefore, elderly individuals must avoid falls as much as possible, because they decrease vital functions and inhibit the quality of life. Falling is defined as the unexpected movement of the body to the ground or a lower surface regardless of an individual's intention.

According to Nevitt and Cumming [5], falls in the elderly often occur indoors. Michelson et al. [6] also reported that the elderly frequently fall in places such as bedrooms, living rooms, and kitchens, where they conduct many necessary daily activities and encounter multiple obstacles. Because these rooms present a high risk for falls, the elderly are careful to avoid falls. Nevertheless, many falls occur by stumbling or slipping. Because falls occur unexpectedly, they are often difficult to avoid even when the elderly are vigilant. Therefore, to avoid falls, the elderly must be able to execute instant fall-avoidance movement as soon as the fall begins as well as pay adequate attention to avoid falls.

A fall-avoidance movement occurs when an individual about to fall takes an immediate step to prevent a fall. Maki et al. [7] reported that taking a compensatory step to block a fall is useful for individuals who cannot use their ankle and hip joints to control body sway in response to sudden disturbances, such as slips and trips. A compensatory step is a quick reaction to a sudden disturbance that helps block a fall by spreading the base of support [8]. To help elderly individuals avoid falls, it is crucial to develop a test (the step reaction test) to understand fall avoidance movements, and accurately evaluate the ability to react to unpredictable and sudden disturbances. Tests for compensatory stepping have been developed [9,10]. However, they cannot properly evaluate fall-avoidance movements that occur instantaneously when an individual is about to fall because subjects know the direction of their steps in advance.

To evaluate the agility of open-skill sports athletes, Uchida et al. [11] developed a successive-choice reaction time test that used a personal computer to direct subjects to step randomly and continuously. Because participants in this test are not given the step directions in advance, participants must recognize the direction of the stimulus shown on the computer screen and instantly step to the indicated position. These randomly presented step directions are intended to simulate unpredictable sudden disturbance movements, and subjects must respond with agility. The movement required to complete this test content is similar to fall-avoidance movement. However, it will be problematic to use elderly subjects in a test developed for athletes. For this purpose, the test must be revised to allow the elderly to participate safely. In addition to the test's reliability, its validity must be examined to confirm whether the test appropriately evaluates fall-avoidance abilities in elderly individuals. Generally, various physical functions decrease with age, and physical fitness factors related to fall are weaker in the elderly than in the young. Hence, the elderly are assumed to have inferior fall avoidance abilities to the young. In addition, the modified step reaction test for the elderly requires quick decision making and reactive movement as well as adequate postural control during movement. Neurological function contributes to the achievement of these movements. Because neurological function notably declines in the elderly, the older elderly (over 75 years old) have weaker fall avoidance ability than the younger elderly (65-74 years old). However, declines in physical fitness and the incidence of falls [12] can be improved by regular exercise. Therefore, it is assumed that the elderly who exercise regularly have superior fall and risk avoidance abilities and physical fitness to those who do not. Thus, while fall avoidance ability decreases with age, regular exercise inhibits this decrease. Hence, the difference validity of the revised step reaction test must be able to examine age differences or the presence or absence of regular exercise.

This study aimed to examine the reliability and difference validity of the revised step reaction test from the perspectives of age differences and regular exercise using elderly and young women.

2. Methods

2.1. Participants

We hypothesized that fall avoidance ability, as evaluated by the revised step reaction test, is weakest in the older elderly (over 75 years old), then in the young elderly (65-74 years old), and strongest in the young (Hypotheses 1). However, it is stronger among the elderly who exercise regularly than those who do not (Hypotheses 2).

We examined difference validity of the revised step reaction test by verifying the above hypotheses. To verify hypotheses 1, we recruited young women (G1: n=23, age 22.0 ± 1.4), young elderly women who did not exercise regularly (G2: n=22, age 69.5 ± 3.2), and older elderly women who did not exercise regularly (G3: n=20, age 78.1 ± 3.9).

In addition, to examine hypotheses 2, we recruited young elderly women who exercised (G4: n=23, age 69.1 ± 3.2), as well as older elderly women who exercised regularly (G5: n=28, age 81.3 ± 4.2). These four groups, along with G2 and G3, were used as subjects in hypotheses 2.

Gardner et al. [13,14] reported that a significant reduction in the incidence of falls was observed in elderly subjects who exercised for 15–60 min at a frequency of 1-3 times per week. In this study, regular exercise for elderly subjects was defined as follows: more than 30 min of exercise one or more times per week for more than three consecutive months. This exercise could include yoga, tai chi, gymnastics, table tennis, badminton, swimming, ballroom dancing, and walking. The elderly women in the study exercised an average of 1.1 hours 2.4 times per week.

In addition, no significant age difference was found between those who did or did not exercise within the young and older elderly groups. The purpose and procedure of the experiment were explained fully to all subjects and written consent was obtained before measurements were taken. This study was approved by the Ethics Committee on Human Experimentation of the Faculty of Human Science, Kanazawa University (approval number: 2012-04).

2.2. Procedure

Nine step sheets (step measurement system; Takei Equipment, Niigata, Japan) and a laptop computer (FM; V-BIBLO MG55R, Fujitsu, Tokyo, Japan) were used to conduct the step reaction test in this study.

The step sheets sent a digital signal to the laptop to record when the subject stepped on them. The successive-choice reaction test for athletes uses a 30-cm distance between step sheets. However, successive steps of that length are dangerous for elderly subjects. Hence, in the revised step reaction test, the sheets were placed only 2cm apart to allow the subjects to step safely.

The laptop computer displayed images corresponding to the array of the step sheets. The upper and lower frames on the display corresponded to sheets on the front and back of the floor, respectively.

A video displaying a continuous stream of stimuli was used in the step reaction test. In the video, a red target moved through nine frames (eight total moves). Adapting the procedures of Uchida et al. [11], we employed five target movement patterns to prevent subjects from predicting the direction of subsequent steps (Table 2). Based on the results of a preliminary test, a step tempo of 40 beats/min with a stipulated tempo developed by Shin and Demura [12] was used in the study.

The display was placed 1m front of the subject at eye level. Subjects stood in the center of the step sheets and watched the display. They were instructed to step quickly onto the sheet indicated in the screen. After one or two practice steps, the subjects conducted 1 trial for each target movement pattern (a total of 5 patterns were conducted).

The order of the patterns was random. The test was restarted whenever a subject stepped onto a sheet other than that indicated on the screen or stumbled or fell during a trial. The subjects conducted two trials of this test (5 patterns × 2 trials).

2.3. Evaluation Parameters

In each of the above trials, the total time required to step on each of the eight sheets after stimulus presentation was calculated, and a mean of the 5 patterns was used as a parameter (step reaction time). The average step reaction time between the two trials was used as a representative value. We interpreted lower values to indicate superior fall avoidance ability.

2.4. Statistical Analyses

The reliability of the step reaction test was examined by the intraclass correlation coefficient (ICC). To examine difference validity, we examined the differences in mean step reaction time among the 3 age groups (G1~G3, Hypotheses 1) using one-way analysis of variance (one-way ANOVA) and examined the differences among the 4 groups of elderly participants of different ages and exercise habits (G2~G5, Hypotheses 2) using two-way ANOVA (age × exercise habit). A post hoc test was conducted using Tukey's honestly significant difference method. The relationship between age and step reaction time in the elderly who did and did not exercise regularly was examined by Pearson's correlation coefficient. The significance level in this study was set at $p < 0.05$.

3. Results

Table 1 shows ICCs of the step reaction test. The ICCs were 0.84~0.97 for each elderly group and 0.75 for the young group.

In this study, we assumed that fall avoidance ability decreases with age, but the decrease would be smaller in the eldrly who exercised than in those who did not. We thus examined difference validity from the following 2 prospectives.

Table 2 shows the basic stastics for step reaction time and the results of one-way ANOVA for the 3 age groups (G1~G3). A significant difference was found in step reaction times. The results of the multiple comparison tests showed increasing reaction times from G1 and G2 to G3, with a large effect size (0.56 ~ 0.89).

Table 3 shows the basic statistics of the step reaction time in the 4 groups of elderly of different ages and exercise habits (G2~G5) and the result of two-way ANOVA. A significant interaction was found, and the results of a multiple comparison test showed that reaction times in older elderly groups were shorter in those who exercised than in those who did not, and the elderly groups who did not exercise, it was shorter in the young elderly than in the older eldery.

Table 1. Iccs of the step reaction test in each group

				ICC
The elderly	The young elderly	With exercise habit	(n=22)	0.87
		Without exercise habit	(n=22)	0.97
	The older elderly	With exercise habit	(n=28)	0.84
		Without exercise habit	(n=20)	0.88
The young			(n=23)	0.75

Table 2. Basic stastics of step reaction time in 3 different age groups of different age and the results of one-way ANOVA

	The young (G1:n=23)		The young elderly Without exercise habit (G2:n=22)		the older elderly Without exercise habit (G3:n=20)		F-value	POST-Hoc(HSD)
	Mean	SD	Mean	SD	Mean	SD		
Step reaction time	5.83	0.42	7.46	0.83	8.31	0.59	86.53 *	The young< The young elderly<the older elderly

*: $p < 0.05$

Table 3. Basic stastics of the step time in 4 elderly groups with different age and exercise habit and the result of tow-way ANOVA

	With exercise habit			Without exercise habit			F-value		P-value	POST-Hoc(HSD)
	n	Mean	SD	n	Mean	SD				
The young elderly	22	7.18	0.52	22	7.46	0.81	F1	12.02	0.001 *	the older elderly: With exercise habit< Without exercise habit
The older elderly	28	7.25	0.55	20	8.31	0.58	F2	25.07	0.000 *	Without exercise habit: he young elderly< With exercise habit
							F3	8.55	0.004 *	

F1: age F2: exercise habit F3: interaction
*: $p < 0.05$

Figure 2 and Figure 3 show Pearson's correlation coefficient between age and step reaction time in elderly groups who did and did not exercise. The coefficients were significant with moderate levels in the elderly who did not exercise (r = 0.65), but not significant in the elderly who did exercise (r = 0.22).

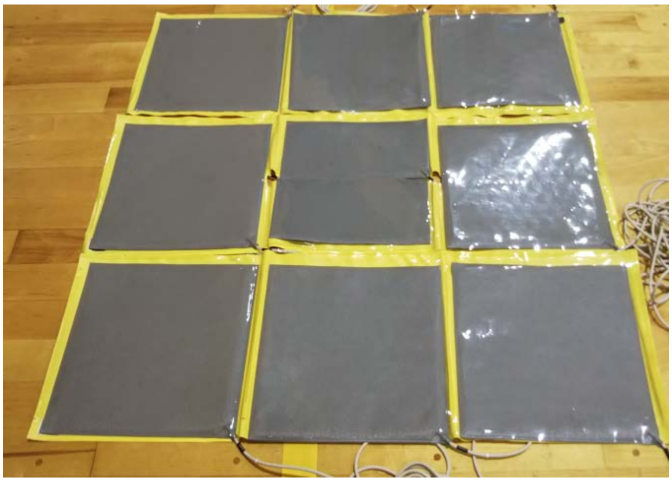

Figure 1. Arrangement of step sheets

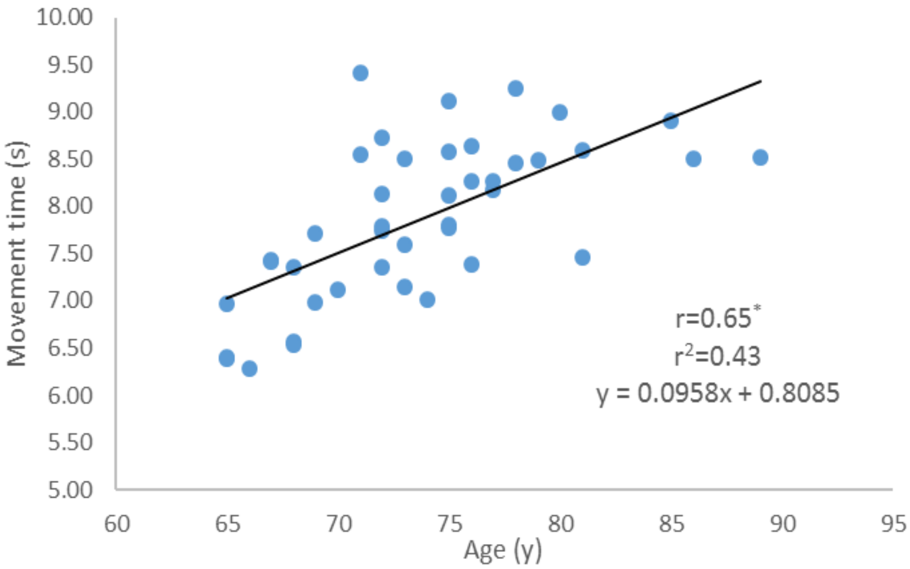

Figure 2. Correlation between age and movement time in the elderly without exercise habits

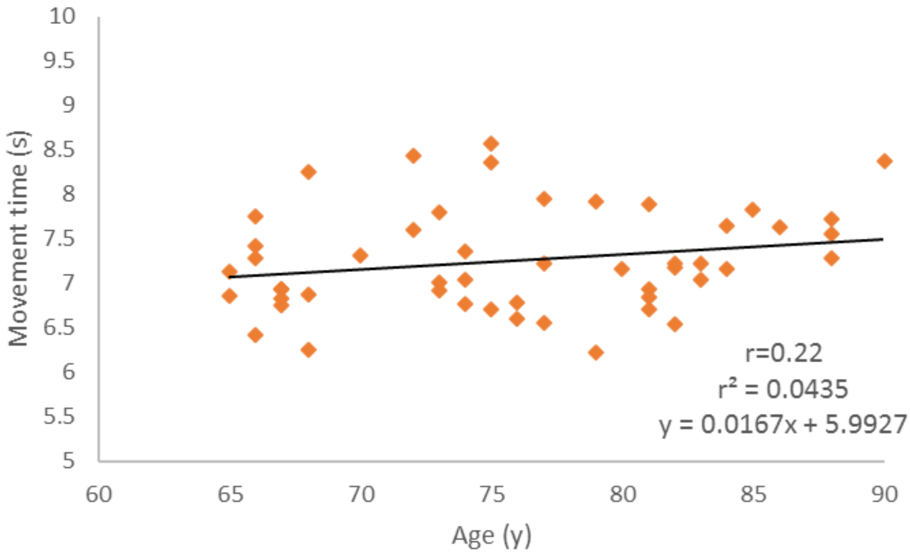

Figure 3. Correlation between age and movement time in the elderly with exercise habits

4. Discussion

We modified the successive choice reaction test developed by Uchida et al. [11] by adjusting the distance between step sheets to allow the test to be performed safely by elderly subjects. However, high reliability is a prerequisite for the practical use of the test. ICCs of the revised step reaction test for the elderly were 0.75 in the young and over 0.84 in the elderly. The ICC level in the young is equal to or greater than that reported by Uchida et al [11]. In addition, all ICCs met the criteria for a sufficient reliability level (ICC = 0.60~0.82) as proposed by Jackson et al. [15]. Because the revised test with short step sheet intervals has high reliability, it allows stable measured values to be obtained from the elderly while protecting their safety.

Step reaction time is shorter in the young than in the elderly and shorter in the young elderly than in the older elderly. The step reaction test requires participants to react to a continuous stream of stimuli (the instructions for directions of movement) and to step quickly to the correct position. Hence, among the various physical fitness factors, agility, lower limb muscle strength, and balance ability, among other factors, are closely related to test performance. Because physical fitness generally decreases with age, step reaction time may have been shorter in the young group, whose physical fitness is stronger than that of the older groups. In addition, physical fitness elements such as the speed of whole body reaction, lower limb muscle strength, balance ability, and so on markedly decrease in the older elderly people. Hence, the step reaction times were shorter in the young elderly than in the older elderly.

In this study, we assumed that fall avoidance ability evaluated by the revised step reaction test is superior in younger people, and hypothesized that it is weakest in the older elderly (over 75 years old), stronger in the young elderly (65-74 years old), and strongest in the young. Because our findings supported this hypothesis, we conclude that the revised step reaction test can distinguish the fall avoidance abilities of different age groups. Only in the older elderly groups were significant differences found in step reaction time between those who did and did not exercise regularly. Thus, exercise can help the elderly slow the decrease in physical fitness [16]. However, physical fitness for the elderly who did not decreased with age. Kimura et al. [17] reported that the elderly who do not exercise are weaker in physical fitness areas such as agility, balance ability, and muscle power than those who do exercise. A significant reduction in the incidence of falls has also been observed in elderly subjects who exercised for 15–60 min at a frequency of 1–3 times per week [13,14]. This suggests that it is possible for the elderly to decrease their incidence of falls and improve their physical fitness through regular exercise. We hypothesized that the elderly who exercise have superior fall avoidance ability to those who do not exercise. However, this hypothesis was confirmed only for those over 75 years old. The mean age of the young elderly group (65~74 years old) in this study, both those who did and did not exercise, was under 70 years old, as much as 10 years younger than that of the older elderly group (with exercise habit: 81.3 years old, without exercise habit: 78.1 years old). As previously noted, physical fitness skills related to the step reaction test markedly decreased in the older elderly. The average life span of Japanese women is 87.1 years old. The young elderly have appreciably higher levels of physical fitness than the older elderly considering the improvement in the physical fitness of the elderly in recent years. The benefits of exercise were greater in the elderly with low physical fitness than in those with high physical fitness [18]. This suggests that the presence or absence of an exercise habit has only a small effect on the physical fitness of young elderly without markedly degraded physical fitness. This would account for why no differences were found between the young elderly who did or did not exercise.

On the other hand, the type or intensity of exercise also affects decreasing physical fitness. This study defined regular exercise as over 30 min of exercise one or more times per week for more than three consecutive months but did not specify the intensity of this exercise. In case of young elderly persons, it may be necessary to define regular exercise with a stricter standard that accounts for the type, frequency, and intensity of exercise. In examining the relationship between age and step reaction time for all young and older elderly persons, step reaction time decreased with age in the elderly who did not exercise regularly ($r = 0.65$, $P < 0.05$), but not in those who did not ($r = 0.22$ $P > 0.05$). This result confirms that regular exercise correlates to step reaction time in the elderly, consistent with the findings of Demura [8]. Physical fitness in the elderly who do not exercise decreases with age. The reduced decline in fall avoidance ability caused by regular exercise may emerge with age and be more noticeable in the older elderly with inferior physical fitness than in the young elderly.

This study recruited the elderly women. There are sex-related differences in the physical fitness levels of the elderly [19], and the average life span is shorter in men than in women. Therefore, patterns in physical fitness decline in the elderly may differ by sex. Future investigations will be needed to examine the revised step reaction among elderly men, along with examining a more stringent definition of regular exercise.

5. Conclusion

We confirmed that the reliability of the revised step reaction test to evaluate fall avoidance abilities in the elderly is high for all age groups, and test performance showed differences by age and exercise habit among the older elderly. In conclusion, the revised step reaction test has high reliability and difference validity from the perspectives of age differences and exercise habits in the older elderly.

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