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Original Article

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Choice Stepping Reaction Time under Unstable Conditions in Healthy Young and Older Adults: A Reliability and Comparison Study

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Purpose: We aimed to analyze the reliability of the test for choice stepping reaction time (CSRT) under an unstable surface and determine whether there were differences in CSRT between support surface conditions (stable vs. unstable conditions) and between age groups (young adults vs. community-dwelling older adults).
Methods: Twenty healthy community-dwelling older adults and twenty young adults performed the stepping task under an unstable condition over two visits. The mean of the two trials measured for each visit was used for the analysis. The test-retest reliability was analyzed using intra-class correlation coefficient (ICC) with a 95% confidence interval, standard error of measurement (SEM), and minimal detectable change (MDC). Differences in CSRT between support surface conditions and age groups were analyzed using the independent t-test with Bonferroni correction.
Results: Excellent consistency was observed for ICC >0.90 in both groups. Moreover, the SEM and MDC values of the CSRT in older and young adults were 0.03 and 0.09 and 0.01 and 0.04, respectively. There was a significant difference in the CSRT between the age groups under stable ($p<0.001$) and unstable conditions ($p<0.001$).
Conclusion: The findings demonstrated that the test for CSRT under an unstable condition had reliable results in both groups. Although older adults demonstrated longer reaction times than younger adults in all surface conditions, increasing the balance control demand by implementing a choice stepping task concomitant with a balance task had no influence on the reaction time in both age groups.

Keywords: Postural balance, Reaction time, Reproducibility of results

INTRODUCTION

Falls are a major health burden in older adults.[1,2] 30% older adults aged >65 years have at least one fall injury per year.[3] Two types of factors influence the occurrence of falls in older adults—external risk factors, such as unpredictable environment (e.g., obstacles and slippery surfaces), and internal factors, including physical and cognitive performance.[4] Older adults with a history of falls have a long reaction time owing to low concentration,[5-7] low sensitivity to external stimuli, and decreased balance due to reduced strength in the lower extremities.[8-11]

The stepping strategy is an important movement that can prevent secondary injuries by avoiding falls.[12-14] Older adults experienced multiple falls shows slower lower limb movements due to a slower protective response when their balance is out of control than non-multiple fallers.[14] Therefore, the execution of correct, rapid, and well-stepping tasks has been incorporated as balance training for fall prevention.[15] This balance training using a stepping task has been performed under both conditions—on unstable and stable surfaces. Balance training under unstable conditions is especially superior for static and dynamic balance than that under stable conditions.[16-19] In addition, increasing the difficulty level of the balance task and age has been demonstrated to be more demanding for balance control.[20,21]

In terms of the test for evaluating fall risk, choice stepping reaction time (CSRT) was developed and CSRT test has verified as an important predictor of fall risks in older adults.[4] The test procedure is as follows: when the stepping target is illuminated in a random order, the subject steps onto the

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illuminated target as quickly as possible.[4] The faster the reaction, the shorter the reaction time. CSRT has been widely used in the several populations to evaluate the risk the falls including geriatric groups as well as patients with Parkinson's disease, multiple sclerosis, and cancer survivors with chemotherapy-induced peripheral neuropathy.[4,14,22-24] Task performance has been primarily evaluated on a firm support surface in a relatively predictable and self-paced environment.[25] However, limited studies have evaluated the potential of an unstable support surface in the evaluation of stepping task performance. Recently, only one study compared the performance time considering age-related differences, fall history (non-faller and faller older adults), and support surface conditions (with foam and without foam) during the Four-square step test.[26] This study demonstrated that modified test with foam is more accurate than that without foam for identifying non-faller and faller older adults.[26] It is known that balance testing on a compliant support surface improves the accuracy of the test for identifying fall history.[27] Considering the principles of the clinical test of sensory interaction and balance,[23] this condition may be more demanding in terms of using the visual and vestibular systems for balance, but less demanding in terms of using the somatosensory system.

This study was designed to analyze the test-retest reliability of the evaluation of CSRT under an unstable condition and determine whether there are differences in CSRT between support surface conditions (stable vs. unstable conditions) and between healthy age groups (young adults vs. community-dwelling older adults).

METHODS

1. Subjects

This cross-sectional study included community-dwelling older adults who visited senior citizen centers and young adults who attending university. Informed consent was obtained from participants after they were provided an explanation of the study aims and procedures. Inclusion and exclusion criteria were applied to participants who agreed to voluntarily participate. The study protocol was approved by the institutional review board of Konyang University (approval no. KYU-2018-136).

All participants were healthy and >65 years of age. Participants with a Mini-Mental State Examination-Korean version score of >24 and those who could walk >10 m regardless of the use of an assistive tool were selected. Participants with serious damage to visual or auditory sensation, those who could not understand the instructions provided by the researcher, those who had musculoskeletal diseases such as fracture or dislocation during recent 1 year, those who experienced a fall during recent 1 year, and those who were diagnosed with neurological disease were excluded.

Young adults aged 19-39 years without musculoskeletal disorders or exercise restrictions that could affect the study results were also selected.

2. Procedures

We collected data on demographic characteristics—age, weight, height, assistive tool for walking, for community-dwelling older adults and age, weight, and height for young adults. To investigate the test-retest performance of the stepping task under an unstable condition in both groups, the test was performed on the first day and again on the next day, and CSRT was recorded each day. The CSRT test on the stable condition was performed only on the first day.

CSRT was defined as the stepping task performance in an unstable condition. The FITLIGHT® SYSTEM (FLB10004DC, FITLIGHT Corp., Canada) was used to measure the CSRT in an unstable condition. In this performance test, a foam (Airex Balance Pad, Airex AG, Switzerland) was used as an unstable support surface with dimensions of 20.5 (width)×16.6 (depth)×3 (height) inches. All targets were placed inside a 0.3 m square mat to resolve the height difference due to the thickness of foam. In addition to measure measuring CSRT on stable support surface, the participants were asked to perform the stepping task on a firm surface of the same height as the square mat. The experimental settings for the test are presented in Figure 1.

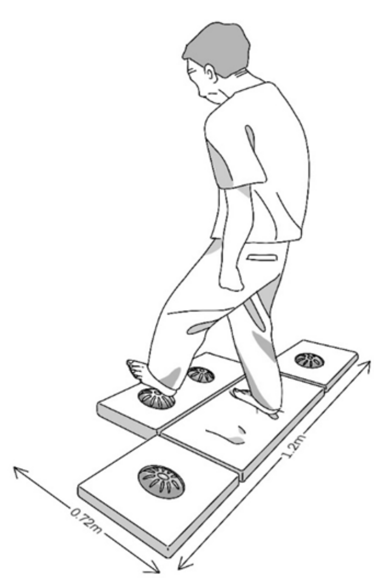

Figure 1. Experimental setting of choice stepping reaction time test under an unstable condition.

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An evaluation protocol consisting of four choice stepping targets was produced using the software of FITLIGHT system. The order in which the stepping target was turned on was randomized for all participants, and the target stimulus was presented in a sequential mode. The number of times each target was turned on was unified five times. Considering the return time, the interval of the next target stimulus was set at 2 seconds.[28]

Before initiating the test, a practice trial was performed to aid the participants' understanding. Participants were given approximately 5 seconds to stand on an unstable support surface. The program was run for approximately 2-5 seconds after the start signal. They were also instructed to use only the left front and side sensors for the left leg and only the right front and lateral sensors for the right leg. Each target was provided with a visual stimulus, which was completely turned off by touching the target with the foot, and auditory feedback was provided. Subsequently, participants returned to their place. Cases where the light was not turned off due to inaccurate stepping were defined as errors. These errors were computed using the FITLIGHT software.

All participants performed two sets of 20 stepping targets per set. A break time of 1 min was provided between the sets. The reaction time was recorded in 1/1,000-seconds units. The examiner was positioned within a distance of 1 m from the participant to prepare for falls during the measurement.

3. Data analysis

All materials were analyzed using SPSS ver. 18.0 (IBM SPSS Statistics, IBM, USA). Frequency and descriptive analyses were used to assess the general characteristics of all participants and data regarding the performance of stepping task (e.g., CSRT, mean total performance time, and number of total target errors over two visits). The number of errors for each participant collected through the software was summed and the total number of errors in each group over two visits was presented as the result. Demographic characteristics were compared using the independent t-test and chi-squared test or Fisher's exact test.

The test-retest reliability of visuomotor stepping task performance in both groups was evaluated based on the relative reliability of intra-class correlation coefficient (ICC) with a 95% confidence interval (CI). The ICC (3,1) model was selected based on a flowchart showing the selection process used in a previous study that proposed an ICC guideline.[29] The ICC was interpreted as excellent (>0.75), moderate to good (0.4-0.75), and poor (<0.4).[30,31]

For absolute reliability, the standard error of measurement (SEM) was calculated using an equation reported in a previous study.[31] We also calculated the minimal detectable change (MDC) at the 95% level, which indicates the smallest change in an individual using the following equation: $SEM \times 1.96 \times \sqrt{2}$. Bland-Altman plots with 95% CIs were used to examine the relationship between the differences and the magnitude of the two repeated measurements.[32]

Differences in CSRT between support surface conditions within each group were analyzed using an independent t-test. Differences in CSRT between age groups in same support surface condition were analyzed using the nonparametric analysis of covariance, including covariates (height and body mass index). The significance level was set at 0.0125 using Bonferroni correction (0.05/4). The dependent variable had a normal distribution but did not meet homoscedasticity. Therefore, a univariate analysis was not performed.

RESULTS

1. Participant characteristics

Forty participants (20 community-dwelling older adults and 20 young adults) were recruited in this study. The demographic characteristics of community-dwelling older adults and young adults are presented in Table 1.

2. Reliability of CSRT of stepping task under unstable condition

The reliability results of CSRT on an unstable support surface for both age groups are shown in Table 2. The ICC (3,1) value obtained from the first and second tests of the visuomotor stepping task under the unstable condition in community-dwelling older adults was 0.935 (95% CI, 0.837-0.974) and that in young adults was .920 (95% CI, 0.799-0.968). In both age groups, the relative reliability was excellent. The SEM values of CSRT in older and young adults were low (range: 0.03-0.01 seconds) and MDC values were 0.09 and 0.04, respectively. Bland-Altman plots are shown in Figure 2.

3. Comparison of reaction time according to age and support surface condition

Figure 3 presents the mean (standard deviation) CSRT for each age group and support surface condition. There were significant differences in the CSRT between age groups under the stable ($p<0.001$, $t=5.432$) and unstable conditions ($p<0.001$, $t=4.730$). However, there were no significant differences in the CSRT between support surface conditions in either age group (young adults: $p=0.756$, $t=-0.313$ and older adults: $p=0.086$, $t=-1.760$).

Table 1. Demographic characteristics of older and young adults

Variable	Older adults (n=20)	Young adults (n=20)	p value
Sex (m/f)	12/8	10/10	0.751
Age (yr)	80.2±4.4	24.3±2.9	<0.001***
Height (cm)	159.6±9.4	166.9±8.4	0.014*
Weight (kg)	60.9±8.6	59.7±12.8	0.717
BMI (kg/m²)	24.0±3.5	21.2±2.7	0.007**
Aids (none/cane)	3/17	NA	NA

BMI: body mass index, NA: not applicable.
*p<0.05, **p<0.01, ***p<0.001.

Table 2. Reliability for choice stepping reaction time under an unstable condition in the age groups

Variable	Age groups	
	Older adults (n=20)	Young adults (n=20)
Total performance time (s)	63.32±4.39	53.49±1.87
Total target error (n)	3	0
Choice stepping reaction time (s)		
Mean trials at visit 1	1.151±0.230	0.663±0.084
Mean trials at visit 2	1.095±0.182	0.637±0.098
$ICC_{3,1}$ (95% CI)	0.935 (0.837-0.974)	0.920 (0.799-0.968)
SEM	0.03	0.01
MDC_{95}	0.09	0.04

ICC: intra-class coefficient, CI: confidence interval, SEM: standard error of measurement, MDC: minimal detectable change.

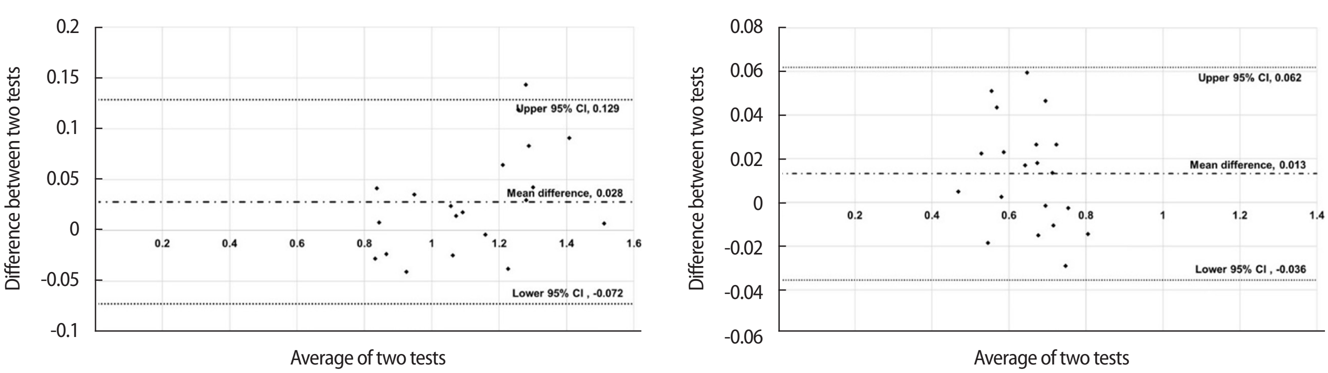

Figure 2. Bland-Altman plots in older adults (left side) and young adults (right side).

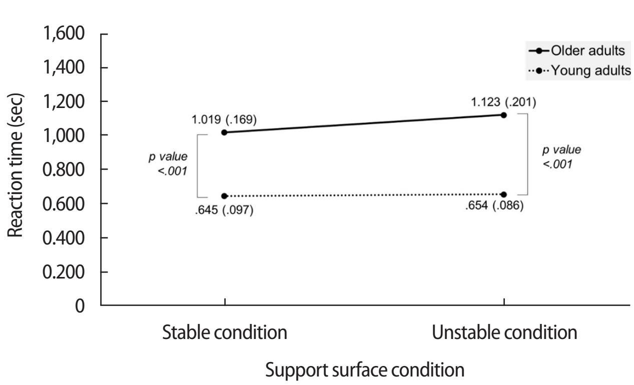

Figure 3. Comparison of mean (standard deviation) choice stepping reaction time according to age and support surface condition.

DISCUSSION

To evaluate the complexity of tasks and age-related changes, we compared the task performance of young adults with that of healthy community-dwelling older adults in terms of the attentional load of motor tasks, such as postural balance with additional balance demands. Also, in this study, we examined the test-retest reliability of CSRT under an unstable condition. Between-group comparisons revealed that the CSRT was significantly longer under both support surface conditions in older adults than in young adults. However, the CSRT in each age group was not signifi-

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cantly different between the support surface conditions, but it was longer under the unstable condition than under the stable condition in both age groups. In our findings of reliability, excellent consistency was demonstrated in community-dwelling older adults (ICC = 0.935, 95% CI, 0.837-0.974) and young adults (ICC = 0.920, 95% CI, 0.799-0.968). Moreover, the SEM and MDC values of the CSRT under the unstable condition in older and young adults were 0.03 and 0.09 and 0.01 and 0.04, respectively. SEM and MDC values provide a clinical reference for clinicians to evaluate the smallest performance change of an individual and not measurement error or bias.

Some results were consistent with those a previous study that examined the effects of a low-obstacle task on the CSRT.[33] The authors found a significantly greater increase in step transfer time under the CSRT test coupled with a stepping obstacle task than that under the CSRT test as a single-task condition in young adults, healthy older adults, and non-fallers. In our study, the CSRT under an unstable condition in both young and older adults showed no significant increase compared to that under a stable condition. No previous study has implemented the CSRT test on foam; therefore, comparison is limited for our findings. A previous study compared the performance time of the Four step square test between young adults, non-faller older adults, and faller older adults, without foam (stable condition) and with foam (unstable condition).[26] The total performance time of non-faller older adults (mean 68.5 years) was significantly longer than that of young adults (mean 27.4 years) in both support surface conditions (with and without foam).[26] Furthermore, the total performance time with foam was significantly longer than that without foam in non-faller older adults.[26] A possible explanation could be that disturbance of proprioceptive information by an unstable surface like foam increases the attentional demands for improved postural control.[34] A recent study found that when applying vibrations to the achilles tendon during inhibitory stepping tasks, active older adults demonstrated the same stepping time with or without vibrations.[35] Similarly,[35] our findings indicated that the older adults who participated in our study were active and had cortical-proprioceptive processing as effective as that of young adults, regardless of the additional balance control task.

Our findings of test-retest reliability of CSRT under an unstable condition showed similar reliability to that of the CSRT under an non-slippery condition (ICC = 0.84, 95% CI, 0.69-.93) reported in a previous study evaluating the CSRT in 27 older people and verifying its high consistency.[36] This study, all SEMs of the CSRT in both age groups were within 10% of the average reaction time, indicating reliable results.[37] In addition, with increasing age and complexity of the balance task, more attention was paid to balance control in previous studies.[20,21] Based on the above findings, it was acknowledged that young adults performed better than community-dwelling older adults, showing a shorter CSRT and total performance times with excellent accuracy for stepping targets in both support surface conditions. Moreover, despite the increasing complexity of the balancing task, community-dwelling older adults was not statistically significant compared to that of stable condition (inter-condition difference = -0.104 seconds).

This study has some limitations. Since only older adults without a history of falls within 1 year were targeted, our findings could not be generalized to other populations such as patients with disease or older adults with a recent fall history. In addition, it could not determine whether the CSRT test under an unstable condition can distinguish fallers from non-fallers. Further studies should include more specific populations, such as older adults with dementia and sarcopenia, and compare visuomotor stepping task performance according to the frequency of fall in individuals. The number of participants in our study was smaller than that in previous studies. Therefore, it is necessary to evaluate a greater number of older people to generalize the results. Backward stepping and step length adoption according to lower extremity length of each participant were not considered. However, the FITLIGHT SYSTEM used to measure CSRT can be freely arranged, and it has the advantage of being positioned at various angles.

In conclusion, our findings proved that the test for CSRT on an unstable surface was very reliable in community-dwelling older and young adults. In addition, the SEM and MDC values of this test provide an essential guide for clinical decision making in community-dwelling older adults. This study examined that although both younger and older adults exhibited longer CSRTs under the unstable surface compared to the stable surface, implementing a choice stepping task concomitant with a balance task (standing on a foam) has no significant influence on reaction time in both older and young adults. We found the significant differences of CSRTs between age groups in both support surface conditions. Overall, our study found that although increasing the complexity of motor responses by implementing a CSRT test concomitant to a balance task, unstable support surface had not an influence on reaction time of both older and young adults.

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