An Approach to Assessment of the Fall Risk for the Elderly by Probe Reaction Time during Walking

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Abstract. [Purpose] This study examined physical and cognitive factors associated with falls by the elderly. The authors hypothesized that, elderly people who experienced at least one fall in the past 12 months would show delayed probe reaction time (P-RT) during walking compared with elderly people with no history of falls. [Subjects] The subjects were 101 elderly people (27 males, 74 females), and the subjects were divided into two groups: a Fall group and a No-fall group. [Methods] We evaluated the probe reaction time, Trail Marking Test Part-A (TMT-A), Timed Up and Go Test (TUG), walking speeds at a self-determined pace, and the gait cycle time. [Results] The Fall group showed longer P-RT, TMT-A, TUG times and slower walking speeds than the No-fall group and its coefficient of variation (CV) of the time for a gait cycle was increased. In logistic regression analysis with fall as the dependent variable, the probe reaction time was identified as an significant factor, and the cut-off value of the probe reaction time was 406 ms as evaluated by the Receiver-Operating-Characteristic (ROC) curve. [Conclusion] It was found that probe reaction time is both reliable and useful for the evaluation of the fall risk for the elderly.

Key words: Probe reaction time, Elderly, Falls

INTRODUCTION

Many falls suddenly happen during daily activities. One of the major problems associated with aging is an increased vulnerability to falls. One out of 3 elderly people is likely to fall once or more times a year. The frequency of falls is even higher among elderly people in hospitals. Fractures are associated with falls, often causing victims to become bedridden. On the other hand, even if there is no fracture, the experience of falls leads to anxiety and fear of falling again, and this can lead to ‘disuse syndrome’\(^1\). Thus, the prevention of falls is an important issue for an aging society. The risk of falls should be examined frequently in assessing older people’s mobility. Moreover, 50% of falls occur during walking, 14% during descending and ascending stairs, and 8% during standing up from a chair or the floor\(^2\). Many researchers have attempted to identify risk factors for falls, and have developed strategies for fall prevention. Risk of falls has been assessed by using items such as vision, muscle strength, reaction time, distal sensory perception, balance ability, autonomic nervous system function etc\(^3\). However, these items can only be measured in laboratories, and most of these measurements are difficult to use in clinical practice because of the restrictions of equipment and the environment for testing. In previous studies of older people, we have found that there are a lot of assessments of physical functions, and very few studies have directly examined the
cognitive functions. Several studies have used the simple reaction time and the choice reaction time as indicators of the cognitive functions to examine fall. However, there were many flaws with these studies, the participation rates were low, or expensive equipment was necessary.

Reaction time is thought to influence the ability to balance. One of the risks of falls is the long reaction time. It is thought in psychology that there is a limitation in the capacity to process information from the environment. For instance, when a movement task is going on, and another task is applied concurrently. Work requiring performance of two tasks at the same time is known as a dual task. If the main task is comparatively simple, a comparatively large amount of attention can be allocated to the second task. This makes it possible to perform the second task comparatively quickly, and it is interpreted that a lot of attention resources are allocated to the second task. So, if the second task (simple reaction time) is demanded during movement task enforcement and the reaction time to the dual task is relatively short, it implies that the main task is performed automatically. This study method is called the probe reaction time (P-RT).

This method is recommended in movement-related research when trying to identify the attention required for performing the main task. Measuring phonatory reaction time is particularly recommended as a second task, it sensitively recognizes a slight change in attention demand in voluntary movement. Another advantage of the probe reaction time is that it can be used ever with heavily handicapped subjects, because the probe reaction time can be measured at subjects’ preferred exercise pace. In this study, we report on a trial tool which is portable, easy to use and useful for the evaluation of the risk of falls, and discuss the relationship between probe reaction time when walking at a self-determined velocity and subjects’ risk of falls.

METHODS

The subjects were 101 community-dwelling elderly people (66.3 ± 5.2 years; 27 males, 74 females). All subjects were able to perform daily life independently. Subject characteristics are detailed in Table 1. All subjects were screened before the start of the study by filling out a medical history questionnaire. The questionnaire addressed whether the subjects had a history of cardiopulmonary, musculoskeletal, somatosensory, or neurological disorders or severe visual and vestibular loss. If so, they were excluded from the study. All subjects gave their informed consent to participate in the study. The subjects were divided into two groups, a Fall group who had experienced at least one fall in the past 12 months, and a No-fall group with no history of falls; the fall rate was 23.8%. Falls are defined as “an event in which a person’s body came to rest unintentionally on the ground or another lower level, not as a result of a major intrinsic event or an overwhelming hazard.”

To examine the reliability of P-RT, 11 subjects (2 males and 9 females; M_age = 65.2 yr, SD_age = 6.7 yr; M_height = 161 cm, SD_height = 7.4 cm; M_weight = 65.3 kg, SD_weight = 9.4 kg) were elected at random from among the subjects. Four subjects who had experienced at least one fall in the past 12 months were among the 11 subjects. The retest was implemented on the next day. We evaluated the simple reaction time when standing on the floor, the P-RT, the 10 m walking speeds at a self-determined velocity, the gait cycle time and the coefficient of variation (CV) of the time for a gait cycle. The interrater reliability interclass correlation coefficient (ICC) was calculated.

A physical therapist conducted the clinical examination, which included the Timed “Up & Go” Test (TUG), hand-grip strength, the 10 m walking speed at a self-determined velocity, and the gait cycle time and the coefficient of variation (CV) of the time for a gait cycle. The Trail-Marking Test Part-A (TMT-A) was performed to indicate overall attention ability.

The simple reaction time was measured continuously 10 times in total when standing on the floor. To measure the probe reaction time, the subjects were asked to walk at a
self-determined velocity on the floor. The task was to measure the simple phonatory reaction time to an auditory stimulus.

A digital audio player/recorder (Rio•Japan) was used as the auditory stimulator. The recording device contained a digital audio player/recorder (Rio•Japan), too. The auditory stimulus file was prepared on a computer in advance. The file contained a series of 16 warning signal “sets” and stimulus auditory signals (50 ms). It was compiled using personal computer overtone opinion processing software, DigionSound5 (Digion). The file was input to a digital audio player/recorder, and the digital audio player/recorder was connected to a portable speaker, for the auditory cue box. The interval between the warning signal and the auditory stimulus was completely randomized in the range 2–5 seconds.

An auditory cue box was attached to the abdominal region of the subjects. The subjects were required to respond to an auditory cue by loudly saying the word “Pa” as quickly as possible.

The sound “Pa” was recorded with a digital audio player/recorder hung on each subject’s chest from the neck. To measure the time of the gait cycle, another play/recorder was attached a short distance above the medial malleolus, and it captured the landing sound of the foot. The gait cycle was measured 10 times, and the average value was assumed as a representative value. Prior to the experiment, the subjects were informed what would be done in the experiment, and they made trial exercises to familiarize themselves with it. In the actual experiment, subjects were asked to walk at a self-determined velocity on a flat linear course. The probe reaction time was measured as the time-lapse between the auditory stimulus and the utterance of “Pa”. One minute after a subject had started walking, the auditory stimulus was started and measured continuously for 10 times in total at the subjects’ self-determined walking velocities. Data were input into a personal computer, and the DigionSound5 sound-processing software was used for the analysis.

To measure the 10 m walking speed at a self-determined velocity, subjects were asked to walk at a self-determined velocity. Lines were drawn at the 10 m and 20 m points on a straight line walking track of 30 m, and the time taken 10 m walking between the 10 m and 20 m points was recorded as the 10 m walking time.

In order to determine the reliability of measurement values, the interclass correlation coefficient (ICC) was calculated. To determine differences between the No-fall group and the Fall group, the independent t-test was performed for each measure. To determine the correlation between each item, Pearson’s Correlation Coefficient was used. The logistic regression analysis and the Receiver-Operating-Characteristic (ROC) curve were used to investigate the accrual of the falls and its relation to each factor. The Hosmer & Lemeshow Test judged the adaptability of the logistic regression analysis. The data were analyzed using SPSS Ver. 12.0 for Windows.

## RESULTS

Table 2 shows the values of the test-retest coefficients (ICC). The ICC of the probe reaction time was 0.98, showing a high reproducibility, which was higher than that of the ICC of the simple reaction time.

The Fall group had significantly longer simple reaction time, probe reaction time, TMT-A and TUG shower, 10 m walking velocity than the No-fall group, and its coefficient of variation (CV) of the time for a gait cycle was increased (p<0.01). The hand-grip strength and the gait cycle time showed no significant between the Fall group and No-fall group.
the No-fall group (Table 3).

Table 4 shows the correlations among the items. There was a high correlation between the probe reaction time and the simple reaction time. Moderate correlations were found among the other items.

Logistic regression analysis with fall as the dependent variable of the probe reaction time, TUG, TMT-A, and the coefficient of variation (CV) of the time for a gait cycle was performed. To prevent multicollinearity, we excluded simple reaction time and 10 m walking velocity. Three factors were identified as relevant: the probe reaction time, TMT-A, and the coefficient of variation (CV) of the time for a gait cycle. The statistical result of the Hosmer & Lemeshow Test, $\chi^2=12.0$ (p=0.148) and the null hypothesis were adopted. The odds ratio was obtained, and only the probe reaction time was significant as an independent factor of fall risk; TMT-A and the coefficient of variation (CV) of the time for a gait cycle were not significant (Table 5).

Using falls as a variable of state, the ROC curve of the probe reaction time was calculated (Fig. 1). The area under the curve (AUC) was 76% of the ROC curve. The cut-off value of the ROC curve was 406 ms, and the sensitivity was 92%; the specificity was 60% according to the cross-tabulation of the cut-off value.

**DISCUSSION**

The ICC of the probe reaction time was higher than that of the simple reaction time, and showed a high reproducibility for the elderly. When the reaction time is measured, it affects the arousal level of the brain, and dispersion in the measurements of the reaction time is great (11). Looking at the results of the present research, the dispersion in the probe reaction times during walking was smaller than that of the simple reaction time, and was highly reproducible. This implies that the arousal level of the brain during walking is
more stable than under resting conditions, and the reliability of the probe reaction time measure is high. A significant relationship was presented as for the simple reaction time, the probe reaction time, TMT-A, the coefficient of variation (CV) of the time for a gait cycle, hand-grip strength, TUG, and 10 m walking velocity. We consider that we were able to reliably measure the physical ability and the cognitive ability; thus, the internal consistency was high.

The Fall group had significantly longer the simple reaction time, probe reaction time, TMT-A and TUG times, and slower 10 m walking velocity than the No-fall group, and its coefficient of variation (CV) of the time for a gait cycle was increased. The elderly with risk of falls demonstrated poorer physical ability and lower cognitive functioning.

Falls often occur during walking, and when getting up from a chair or the floor. The probe reaction time during walking was measured in this research. The results of the Fall group show that their response times were slower than those of the No-fall group. It is thought that the longer probe reaction times were due to increased attention demands for walking.

In logistic regression analysis, the probe reaction time, TMT-A and the coefficients of variation (CV) of the time for a gait cycle were identified as of importance, but only P-RT was significant, indicating that probe reaction time is useful for the evaluation of the risk of falls for the elderly.

One example of the dual task impediment is halting at the initiation of conversation during walking. Olsson\textsuperscript{12}) defined that a dual task impediment is “Stop walking when talking”, and he clarified its relationship with the occurrence of falls. The sensitivity of this test is as low as 48%, but the specificity is as high as 95%. This phenomenon is useful from the viewpoint of not overlooking the subjects’ possibility of falling. However, the “Stop walking when talking” test has not been quantified yet. In the present research, the cut-off value of the probe reaction time was 406 ms as derived from the ROC curve, its sensitivity was 92%, and its specificity was 60%. We showed that the detectability of the risk of falls was high, and the quantitative assessment of the risk of falls is possible with the measurement of the probe reaction time.

The TUG as a traditional assessment is useful to examine the risk of falls for the elderly. Shumway-Cook\textsuperscript{13}) said that the cut-off value of TUG was 13.5 seconds, and both the sensitivity and the specificity were 87%. In this research, the subjects were community-dwelling elderly of a relatively young age, and they had high independence of daily activities. The cut-off value of TUG was 8.1 seconds, the sensitivity was 83%, and the specificity was 61%. Moreover, the TUG was excluded as a predictive variable by logistic regression analysis, as it was shown that the probe reaction time had higher sensitivity TUG as an indicator of the risk of falls for the elderly with high physical function.

The gait cycle time showed no difference between the No-fall group and the Fall group. However, the coefficient of variation (CV) of the time for the gait cycle showed a significant

| Table 5. Result of Logistic Regression Analysis with Falls as the Dependent Variable |
|---------------------------------------------|-------------------|-----------------|-----|
| Item                                   | Odds Ratio | 95% CI          | p   |
| Probe Reaction Time                     | 1.006      | 1.001–1.011     | 0.017|
| CV\textsuperscript{a}                   | 1.614      | 0.982–2.651     | 0.059|
| Trail Marking Test Part- A              | 1.003      | 0.999–1.007     | 0.101|
| The Hosmer-Lemeshow Test $\chi^2$       | 12.08      | 0.001–1.011     | 0.017|

Note: Stepwise Way. \textsuperscript{a}CV = The coefficient of variation (CV) of the time for a gait cycle. \textsuperscript{b}CI = Confidence Interval.

![Fig. 1. The Receiver-Operating-Characteristic (ROC) curve of the probe reaction time. The area under the curve (AUC) was 76%, and the cut-off value was 406 ms; the sensitivity was 92% and the specificity was 60%. (Asymptotic significance probability = 0.000)
difference between the No-fall group and the Fall group, and the dispersion time for the gait cycle was larger in the Fall group. For the Fall group it was more difficult to maintain the same rhythm. Increased attention was demanded to maintain the rhythm for walking, lengthening the P-RT. In a similar approach, Kubo14) found that the coefficient of variation of the 10 m walking speed (ten times) showed a significant value (Fall group 9.0% and No-fall group 4.1%) in the Fall group even when there was no significant difference in the optimal walking speed between the Fall group and the No-fall group.

REFERENCES