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Assessment of the Fall Risk for the Elderly by Probe Reaction Time During Rhythmic Stabilization

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Abstract. [Purpose] The purpose of this study was to examine physical factors associated with falls by the elderly. We hypothesized that elderly people who had experienced at least one fall in the past 12 months would show a delayed response in the probe reaction time (P-RT) during rhythmic stabilization (RS) compared with elderly people with no history of falls. [Subjects] The subjects were 81 elderly people (37 males, 44 females) , and the subjects were divided into two groups: a Fall group and a No-fall group. [Methods] The simple reaction time (SRT), the P-RT during RS, the maximal resistance force of RS (Max. RF) , the resistance force of RS during P-RT (RF during P-RT) , the trail marking test part-A (TMT-A), and the timed up and go test (TUG) were evaluated. [Results] The Fall group showed longer SRT and P-RT times than the No-fall group and its RF during P-RT was decreased. In logistic regression analysis with fall as the dependent variable, the P-RT was identified as a significant factor, and the cut-off value of the P-RT was 639 ms as evaluated by the Receiver-Operating-Characteristic (ROC) curve. [Conclusion] We found that P-RT is both reliable and useful for the evaluation of the fall risk of the elderly.

Key words: Probe reaction time, Elderly, Falls

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INTRODUCTION

The improvement of balance function is important in the prevention of falls by the elderly and patients with post-stroke hemiplegia. The rhythmic stabilization (RS) of proprioceptive neuromuscular facilitation (PNF) is a technique which is used to improve balance function. The RS technique uses isometric contraction of antagonistic patterns and results in co-contraction of the antagonists if the isometric contraction is not broken by the physical therapist[1)] . RS may be appropriate for improving short-term trunk muscle endurance and trunk mobility in people with chronic low back pain[2,3)] . RS is effective in the treatment of patients with impairment of motor coordination[4)]. RS is used as a clinical examination technique for slight cerebellar disease[5)] .

Recently, dual tasks have been used to evaluate falls in several studies[6–8)] . For instance, when a movement task is going on, and another task is concurrently applied, simultaneous performance of the two works 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 tasks comparative quickly, and it is interpreted that a lot of attention resources are allocated to the second task. So, if a second task (simple reaction time task) 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) . Measuring phonatory reaction time is particularly recommended as in the above method it sensitively recognizes a slight change in attention demand in voluntary movement[9)] . 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 the probe reaction time during rhythmic stabilization and subjects' risk of falls.

SUBJECTS AND METHODS

The subjects were 81 community-dwelling elderly people (73.4 ± 6.4 years; 37 males, 44 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

Table 1. Subject Characteristics [a]

	No-fall group (n= 56)	Fall group (n= 25)	Overall (n= 81)
Age (y)	73.5 ± 6.7	73.2 ± 5.9	73.4 ± 6.4
Height (cm)	165.8 ± 8.9	162.8 ± 7.7	164.2 ± 8.8
Weight (kg)	64.5 ± 11.7	64.4 ± 9.4	64.5 ± 11.0

Note: values are mean ± standard deviation. [a] No-fall group= elderly people with no history of falls. Fall group= elderly people who had experienced at least one fall in the previous 12 months. There were no significant differences between groups.

at least one fall in the past 12 months, and a No-fall group with no history of falls; the fall rate was 30.9%. A falls is defined as "an event in which a person's body comes to rest unintentionally on the ground or another lower level, not as a result of a major intrinsic event or an overwhelming hazard" [10).

A physical therapist conducted the clinical examination, which included measurements of the simple reaction time (SRT) , the P-RT during RS, the maximal resistance force of RS (Max. RF) , the resistance force of RS during P-RT (RF during P-RT) , the trail marking test part-A (TMT-A)[11) , and the timed up and go test (TUG)[12) .

To examine the reliability of the SRT, the P-RT, and the resistance force. Nine subjects (two males and seven females; 68.6 ± 2.0 yr; 65.8 ± 0.4 kg; 162.3 ± 12.3 cm) were selected at random from among the subjects. Four subjects who had experienced at least one fall in the past 12 months were among the nine subjects. The retest was implemented on the next day. The interrater reliability interclass correlation coefficient (ICC) was calculated.

A digital audio player/recorder (Rio · Japan) was used as the auditory stimulus. The recording device used a digital voice recorder (Panasonic · Japan). The auditory stimulation file was prepared on a computer in advance. A file was edited as a series of 16 warning signal and auditory stimulus (50 ms) 16 sets using personal computer overtone opinion processing software, DigionSound5 (Digion) . The file was input to the digital audio player/recorder, and the digital audio player/recorder was connected both to a digital voice recorder and a headset used a two-socket adaptor, so as to form an auditory cue box. The interval between the warning signal and the auditory stimulus was completely randomized between 2–5 seconds.

The auditory cue box was attached to the abdominal region of the subjects to measure the probe reaction time. The subjects were required to respond to an auditory cue by loudly saying the word "Pa" as quickly as possible. The headset was worm by the subjects. The warning signal, the auditory stimulus and the response sound of the subject were recorded on the digital voice recorder.

The SRT was measured continuously five times in total in a standing position. One minute after a subject started RS, the P-RT was started and measured continuously for five times in total. Prior to the experiment, the subjects were informed what would be done in the experiment, and they performed trials to familiarize themselves with the experimental procedures. Data was input into the personal computer, and the DigionSound5 sound-processing software was used for the analysis. The difference value of RT (ΔRT= P-RT - SRT) was calculated.

To measure the Max. RF and the RF during P-RT, manual contact was alternately given to both shoulders during RS. The RS was executed in four directions on the diagonal line and ten seconds in unidirectional. To measure the resistance force of RS, two hand-held dynamometers (HHD, ANIMA MT-1) was held, one in each hand, by the physical therapist, and the tester function of HHD was used to measure the maximum resistance force. The resistance force was the maximum resistance force at which trunk shake of the subjects did not appear. The mean value of the maximum resistance force of both hands was assumed as the representative value. The difference value of RF (ΔRF= Max. RF - RF during P-RT) was calculated.

In order to determine the reliability of measurements, the interclass correlation coefficient (ICC) was calculated. To determine differences between the Fall group and the No-fall group, the independent t-test was performed for each measure. To determine whether there were differences in SRT and P-RT, and Max. RF and RF during P-RT, two-way analysis of variance were performed. The task condition and the group were assumed to be factors. If there the significant interaction between groups, the paired t-test was performed for each group. To determine the correlation between each item, Pearson's Correlation Coefficient was calculated. 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 and Lemeshow Test was used to judge the suitability of the logistic regression analysis. The data were analyzed using SPSS Ver. 12.0 for Windows.

RESULTS

The ICC (1, 1) of SRT was 0.98, that of P-RT was 0.97, and that of RF during P-RT was 0.99; the Max. RF, 0.97, showed a high reproducibility (Table 2) .

Table 3 shows the results for each of the test items. The Fall group had significantly longer SRT, P-RT and ΔRT than the No-fall group independent t-test ($p<0.01$) , and its RF during P-RT was decreased. In the two-way analysis of variance of RT, there was a significant interaction of group with task ($F(1, 79) = 5.31$, $p<0.05$) ; the pattern of change in RT was different in each group. The paired t-test showed a statistically significant difference between SRT and P-RT; the P-RT response was slower than that of SRT in each group ($p<0.01$) . In two-way analysis of variance of RF, the main effect of task ($F(1, 79) = 80.3$, $p<0.01$) was statistically significant between Max. RF and RF during P-RT; RF during P-RT decreased less than the Max. RF in each group. There was a main effect of group ($F(1, 79) = 4.77$, $p<0.05$) , but no significant interaction ($F(1, 79) = 2.09$, $p>0.05$) .

The Pearson's Correlation Coefficients for P-RT and SRT, the P-RT and ΔRT, and Max. RF and RF during P-RT showed high correlation (Table 4) .

Logistic regression analysis with fall as the dependent variable of SRT, P-RT, ΔRT, TUG, RF during P-RT, and

Table 2. Measurement and ICC [a] (1, 1) of Two Measurements (n=9)

	First measurement	Second measurement	ICC
Simple reaction time (ms)	381.3 ± 159.7	406.0 ± 181.8	0.98**
Probe reaction time (ms)	464.4 ± 183.2	416.0 ± 200.8	0.97**
Max. RF (kg)	4.59 ± 1.13	4.59 ± 1.10	0.97**
RF during P-RT (kg)	3.71 ± 1.01	3.65 ± 0.97	0.99**

Note: values are mean ± standard deviation. ** p<0.01. [a] ICC= interclass correlation coefficient.

Table 3. Comparison of the results of the physical tests of the No-fall group and the Fall group[a]

	No-fall group (n= 56)		Fall group (n= 25)		
Timed up and go test (s)	8.2 ± 2.3		10.5 ± 11.9		
Trail marking test part-A (s)	186.7 ± 87.7		205.0 ± 82.8		
Simple reaction time (ms)	391.9± 109.5	**	473.3 ± 146.4	**	**
Probe reaction time (ms)	452.0 ± 123.6		605.6 ± 265.3		**
ΔRT (ms)	60.1 ± 79.3		132.3 ± 203.6		*
Max. RF (kg)	3.97 ± 1.04	**	3.52 ± 1.26	**	
RF during P-RT (kg)	3.50 ± 1.06		2.85 ± 1.01		*
ΔRF (kg)	0.48 ± 0.46		0.66 ± 0.66		

Note: values are mean ± standard deviation. **p<0.01. [a] ΔRT: P-RT–SRT; Max. RF: the maximal resistance force of RS; RF during P-RT: the resistance force of RS during P-RT; ΔRF: Max. RF–RF during P-RT.

Table 4. Pearson Correlation Coefficients between Measures [a] (n=81)

	TUG	TMT-A	SRT	P-RT	ΔRT	Max. RF	RF during P-RT
TUG	1.00						
TMT-A	0.07	1.00					
SRT	0.24*	0.26*	1.00				
P-RT	0.17	0.24*	0.72**	1.00			
ΔRT	0.01	0.11	0.08	0.75**	1.00		
Max. RF	–0.11	–0.07	–0.30**	–0.13	0.10	1.00	
RF during P-RT	–0.01	–0.12	–0.34**	–0.21	0.03	0.88**	1.00

*:p<0.05, **:p<0.01. [a] TUG= Time Up-and-Go Test; TMT-A: Trail Marking Test Part- A; SRT: Simple Reaction Time; P-RT: Probe Reaction Time; ΔRT: P-RT–SRT; Max. RF: the maximal resistance force of RS; RF during P-RT: the resistance force of RS during P-RT.

Table 5. Result of Logistic Regression Analysis with Falls as the Dependent Variable

Item	Odds Ratio	95% CI [b]	p
Probe Reaction Time	1.005	1.001~1.008	<0.05
RF during P-RT [a]	0.600	0.341~1.056	>0.05
The Hosmer- Lemeshow Test	χ^2= 15.3	p>0.05	

Note: Stepwise Way. [a] RF during P-RT: the resistance force of RS during P-RT. [b] CI= Confidence Interval.

TMT-A was performed. To prevent multicollinearity, we excluded Max. RF. Two factors were identified as relevant: P-RT and RF during P-RT. The statistical result of the Hosmer and Lemeshow Test, χ^2=15.3 (p=0.053) , and the null hypothesis were adopted. The odds ratio was obtained, and only P-RT was significant as an independent factor of fall risk; RF during P-RT was not significant (Table 5). Using falls as a variable of state, the ROC curve of the P-RT was calculated (Fig. 1). The area under the curve (AUC) was 71% of the ROC curve. The cut-off value of the ROC curve was 639 ms, and the sensitivity was 40%; the specificity was 96% according to the cross-tabulation of the cut-off value (Table 6) .

DISCUSSION

The ICCs of SRT, P-RT, RF during P-RT, and Max. RF showed these measures are highly reproducibile for the elderly. Significant relationships were found for P-RT with SRT, P-RT with ΔRT, and Max. RF with RF during P-RT.

The Fall group had significantly longer SRT, P-RT and ΔRT than the No-fall group, and its RF during P-RT was

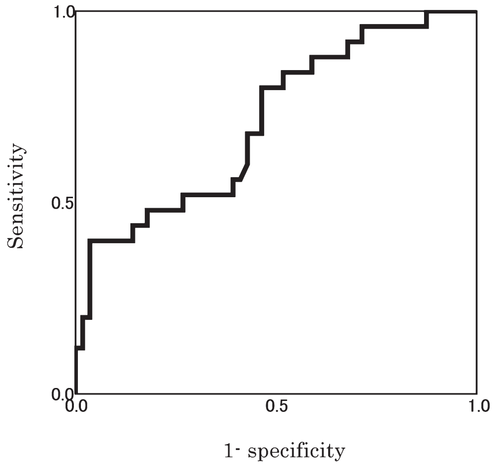

Fig. 1. The Receiver-Operating-Characteristic (ROC) curve of the probe reaction time. The area under the curve (AUC) was 71%, and the cut-off value was 639 ms; the sensitivity was 40% and the specificity was 96%. (Asymptotic significance probability =0.003)

decreased. The elderly with risk of falls demonstrated poorer physical ability.

Falls often occur during walking, and when getting up from a chair or the floor. P-RT during RS 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 RS.

The P-RT response was slower than SRT in both groups. RF during P-RT was decreased in both groups, too. We think that attention to RS was decreased by the dual task. There was a significant interaction of group with task, the pattern of change in reaction time was different in each group, suggesting that attention ability during the dual task decreased in the Fall group compared with the No-fall group.

In logistic regression analysis, P-RT, and RF during P-RT were identified as of importance, but only P-RT was significant. In addition, the positive predictive value was 83 %, the negative predictive value was 78 % and the predictive accuracy was 79 %, greatly exceeding the level of the fall rate, 30.9 %, indicating that P-RT is useful for the evaluation of the risk of falls for the elderly.

One example of the dual task impediment is halting on the initiation of conversation during walking. Olsson[6] defined a dual task impediment as "stop walking when talking", and he clarified its relationship with the occurrence of falls. The sensitivity of this test is 48%, 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 P-RT was 639 ms as derived from the ROC curve; its sensitivity was 40%, and its specificity was 96%. We showed that the quantitative assessment of the risk of falls is possible with measurement of P-RT.

The TUG as a traditional assessment is useful for

Table 6. The cross-table of the cut-off value of the P-RT

	Fall group	No-fall group	Sum total
≥639 ms	10	2	12
<639 ms	15	54	69
Sum total	25	56	81

* The sensitivity= 10/25= 0.40. The specificity= 54/56= 0.96. The positive predictive value= 10/12= 0.83. The negative predictive value= 54/69= 0.78. The predictive accuracy= (10+54) /81= 0.79.

examining the risk of falls for the elderly. Shumway-Cook[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 with high independence of daily activities, and the TUG times of the two groups were not significantly different. Moreover, the TUG was excluded as a predictive variable by logistic regression analysis.

In further investigations, it will be necessary to perform an intervention study using the probe reaction time during a rhythmic stabilization task to improve the balance ability of the elderly with fall risk.

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