Predicting the probability of falls in community-dwelling elderly individuals using the trail walking test

By

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Running head: Predictive validity of Trail Walking Test

Key words: fall, elderly, Trail Walking Test, predictor, complex-task condition

ABSTRACT

Background: Falling is a common problem in the growing elderly population. Multitasking or engaging in two or more activities at the same time is common in daily living.

Objective: To determine the usefulness of the trail walking test (TWT) for predicting a fall in community-dwelling elderly individuals.

Methods: A prospective design was employed in this study. One hundred seventy-one community-dwelling elderly individuals (mean age, 80.5 ± 5.6 y) participated in this study. TWT was devised to evaluate the risk of falling. The following tests were performed: TWT, trail making test (TMT), timed up and go test (TUG), functional reach (FR) test, one leg standing (OLS) test, and 10-m walking time test. Test-retest reliability was assessed by repeating TWT within 2 weeks of the first trial, and there was a 1 year follow-up. Stepwise logistic regression analysis was used to analyze whether TWT, TMT, TUG, FR, OLS, or 10-m walking tests predicted falling.

Results: The test-retest reliability of TWT was high (ICC = 0.945, $p < 0.001$). After the 1 year follow-up, 59 subjects (34.5%) reported a fall. The stepwise logistic regression analysis demonstrated that only TWT was significantly related to falling (odds ratio (OR) 1.160; 95% confidence interval (CI) 1.107 - 1.214; $p<0.001$). In total, 77.8% of cases were correctly classified.

Conclusion: When reliability and validity were considered, the TWT was most useful for assessing the risk of fall.

INTRODUCTION

It is estimated that 32% of community-dwelling elderly individuals aged 75 and older will fall at least once during a 1-year interval, and that 24% of these individuals will sustain serious injuries [1-2]. The medical costs related to falls are substantial; fall-related injuries in individuals aged 60 years and more cost 981 million pounds per year [3]. Thus, falling is a common problem in the growing elderly population.

Previous reports has identified a myriad of risk factors associated with elderly falls including age-related changes to gait pattern [4], deficits in the musculoskeletal system [5], proprioception [6], and vestibular system, all of which will have a detrimental effect on locomotion. Most falls occur during locomotion and therefore, unsurprisingly, previous research has focused on identifying age-related differences in locomotor performance [7]. Several performance balance measures, such as the timed up and go (TUG) [8], one-leg stand (OLS) [9], functional reach (FR) [10], and Tinetti balance [11] are available for evaluating community-dwelling older people. However, the useful predicted of falls used as golden standard does not exist.

Nevitt et al. reported that the rate of falling indoors is high [12]. It is necessary to be cautious and pay attention to various objects when there are two or more obstacles indoors. In recent years, it was reported that a decrease in physical function during complex-task conditions is a factor related to falling in elderly individuals [13, 14]. Multitasking or engaging in two or more activities at the same time is common in daily living, and real-life situations are performed in a complex-task environment. It is reported that, complex-task condition when self-induced falls occur during walking, rising from a chair, or stumbling on a rug or inappropriately placed furniture or telephone cord, situations that may occur in daily life [7]. The majority falls in the elderly occur during common daily activities, such as walking or changing position [1] or from tripping or tangling of the feet. Recent evidence suggests that an impaired ability to allocate attention to balance during complex-task situations is a powerful predictor of fall [8]. It is necessary to distribute suitable attention to complex-tasks simultaneously in a complex-task environment. Such an attention function decreases due to aging in the elderly [15].

However, not all reports show that the results of falling are due to a decrease in motor function under a complex-task condition [13, 14, 16-18]. Recent reviews have reported that there is no clear basis for using the intervention under dual-task condition method for preventing a fall [19]. Negative findings on a neuropsychological function test may be caused by inappropriate task design. For example, when combining a motor and cognitive task, if the difficulty of a cognitive task is very high or very low, the attention given to the cognitive task may not be appropriately distributed. In such a case, even if the assessment includes a dual-task situation, the distribution of attention to the motor task may be equivalent to a single-task condition. In addition, even if motor performance is part of a dual-task situation, attention to the motor task may not decrease. Moreover, even if maximum effort is devoted to a cognitive task, it is possible to execute a motor task such as walking [20].

However, tasks imposed in real life may need to be finished completely. For example, when the task "please stop" is given, it is necessary to "stop" completely. However, completion to perfection is not required for a cognitive or dual task including walking. Alexander et al. reported that their development of this ambulatory version of the trail marking test [21]. However, the ambulatory version of the trail marking test which has low difficulty for community-dwelling older adults. Therefore, we considered the trail walking test (TWT) as an improved version of the ambulatory version of the trail marking test [22]. TWT is a walking from numbered flags in ascending or descending order. A cognitive function (visual search function, short-term memory, etc.) and motor function (locomotion, turning, etc.) are simultaneously required to successfully execute TWT.

The purpose of this study was to examine whether TWT would be useful for predicting falls in community-dwelling elderly individuals.

METHODS

Participants

Participants were recruited by means of an advertisement in the local press. An initial interview screened participants based on the following criteria: age 65 years or older, community-dwelling, have visited a primary care physician within the previous three years, a sum score on the Mini-Mental State Examination [23] of 24 or greater, independent ambulators (could use a cane), willingness to participate in group exercise classes for at least six months, access to transportation, minimal hearing and vision impairments, and no regular exercise in the previous 12 months.

The exclusion criteria, as checked by the interview were severe cardiac, pulmonary or musculoskeletal disorders, pathologies associated with increased risk of falls (i.e., Parkinson's disease or stroke), osteoporosis, and the use of psychotropic drugs. Written informed consent was obtained from each of the remaining 171 community-dwelling elderly individuals (mean age, 80.5 ± 5.6 y) who were included in the trial in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

Cognitive status measures

Executive function was assessed using TMT, a well-established psychomotor test originally developed as part of the Army Individual Test Battery [22]. TMT has been widely used in clinical evaluations to assess deficits in executive cognitive function. Part A of TMT is a visual-scanning task; the participant is required to draw lines sequentially connecting consecutively numbered circles (No. 1 to 25) randomly arranged on a page as quickly as possible.

Trail walking test

In the TWT environment, flags are installed randomly at each of the 15 positions in a 25 m^2 area (5m × 5m). The positions on which the flags were placed are shown in Figure 1. The participants were asked to sequentially pass from No. 1 to 15 (Fig 1). A 30-cm diameter circle was drawn on each flag. Passage occurred by stepping on the circle. The height of the flag was 30 cm. The tester ordered, "Please move to No. 15 as quickly and correctly as possible." The trials were timed using a stopwatch to the nearest 0.01 s following a standard procedure. TWT was performed only once. Test-retest reliability was assessed by repeating TWT within 2 weeks of the first trial. The flag positions were the same as those in the first trial.

Physical performance measures

Physical functions were assessed using the timed up and go (TUG) [6], functional reach (FR) [24], one-leg stand (OLS), and 10-m walking time (10 m walking) tests [25].

All test measures were completed prior to randomization. Before commencing the study, all staff members received training in correct protocols for administering all assessment measures included in the study from the author (M.Y.). If a walking aid was normally used at home, then this aid was used during the TUG and 10-m walking.

In TUG, participants were asked to stand up from a standard chair with a seat height of 40 cm, walk a distance of 3 m at a normal pace, turn, walk back to the chair, and sit down. The time recorded in the two trials was averaged to obtain the TUG score.

In FR, each participant was positioned next to a wall with one arm raised at 90° and fingers extended. A yardstick was mounted on the wall at shoulder height. The distance that a participant could reach while extending forward from an initial upright posture to the maximal anterior leaning posture without moving or lifting the feet was visually measured in cm as the third finger tip position against the mounted yardstick. The distances measured in the two trials were averaged to obtain the FR score.

In OLS, participants were instructed to start from a position with a comfortable base as support, with eyes open and arms by the side of the trunk. They were then instructed to stand unassisted on any one leg. OLS was tested in seconds from the time one foot was lifted from the floor to when it touched the ground or the standing leg.

In ST walking, participants walked 15 m at their comfortable speed, and the time to complete the 10-m mark in between this walk was recorded using a stopwatch. The time recorded in the two trials was averaged as the ST walking score.

One year follow-up

Information on incident falls during the 1 year follow-up was collected monthly by phone. A fall is defined as an event that resulted in a person unintentionally coming to rest on the ground, floor, or other lower level with or without loss of consciousness or injury [26]. Falls resulting from extraordinary environmental factors (e.g., traffic accidents and falls while riding a bicycle) were excluded. Falls were recorded in fall diaries that participants were asked to mail to the research assistants every month. All participants who had fallen were interviewed during these calls using a structured questionnaire about the fall event and its consequences.

Statistical analysis

Test-retest reliability was assessed by the intraclass correlation coefficient (ICC 1.1) between TWT at the test and retest 2 weeks later, using an analysis of variance.

The relationship between TWT and cognitive and physical performance was investigated with the Pearson correlation coefficient. The t test was used to compare the results of TWT, TMT, TUG, FR, OLS, and 10 m walking tests between fall and non-fall groups.

Stepwise logistic regression analysis was used to analyze whether TWT, TMT, TUG, FR, OLS, or 10-m walking tests predicted falling.

Data was registered and analyzed using the Statistical Package for Social Science (Windows version 11.0). A p value <0.05 was considered statistically significant for the analyses.

RESULTS

Test-retest reliability

The test-retest reliability of TWT was high (ICC = 0.945; 95% confidence interval [CI], 0.95–0.99; $p < 0.001$).

Correlation analysis

Table 1 shows the Pearson correlation coefficients between TWT, TMT, TUG, FR, OLS, and the 10-m walking tests that predicted falling. TWT was correlated with TMT ($r = 0.562$, $p < 0.001$) and TUG ($r = 0.243$, $p = 0.001$). The relationship between TWT and OLS, FR, or 10-m walking tests was not significant (Table 1).

Predictive analysis

After a 1 year follow-up, 59 subjects (34.5%) reported a fall (Table 2). There was no significant difference between groups for age, height, weight, BMI, gender, MMSE, independent ADL, walking aids, and medication ($p > 0.05$). Individuals in the fall group had significantly higher mean values in TWT ($p < 0.001$), TMT ($p < 0.001$), and TUG ($p = 0.003$) compared with those in the non-fall group. There was no significant difference between the two groups for other measures (Table 2).

The stepwise regression model identified TWT as significantly related to falls (odds ratio (OR) 1.160; 95% confidence interval (CI) 1.107 - 1.214; $p<0.001$); however, the other measures were not significantly related. The adapted regression model was able to correctly classify 77.8% of the cases ($R^2 = 0.488$, $p < 0.001$). The specificity was 83.9% and sensitivity was 66.1%.

DISCUSSION

This study showed that approximately 35% of community–dwelling adults 65 years of age or older fall at least once a year. This falling rate was consistent with a previous report [2, 27]. The results of this study indicated that TWT appears to be a reliable measurement because ICC of TWT was high. The results of TWT were moderately correlated with those of TMT and TUG. Therefore, TWT may be considered a measurement that is related to dynamic balancing ability and attention.

Podsiadlo et al. reported that TUG is useful for evaluating the risk of falling [8], and some studies have linked cognitive impairment and falls or fall-related injuries [2, 28, 29]. Furthermore, the paper-and-pencil TMT evaluates visual scanning and mental flexibility, and predicts major fall injuries [30]. Previous work has shown that elderly individuals living in a community with a history of falling have significantly slower TMT times than elderly non-fallers [31]. Based on these reports, we would expect that TWT might be able to predict the risk of falling in the elderly. Furthermore, the ones who had a fall during the 1 year follow-up period required an extended time period to undergo TWT. This result showed that TWT was a predictor for falling. TWT requires that the subject perform a movement while distributing attention to a number. Not only must attention be focused on a flag but it is also necessary to use short-term memory for the flag position to reach the next target. In addition, fundamental motor functions, such as locomotion and turning, are needed for TWT. The combination of such central nervous system and motor function is indispensable for everyday life; if the ability to execute multiple functions decreases, the risk of falling increases. Some researchers have reported that TUG [8, 32] and FR tests [10] are useful for assess fall risk. However, in the elderly, various functions including motor, cognitive, visual performance, and hearing functions may be decreasing in a complex manner. TWT was most closely correlated to falls in the logistic regression analysis, and TUG and FR were not extracted as significant relevant factors. Therefore, when predicting falls, it is more useful to use multiple-function assessments such as TWT. Moreover, the result of TWT is obtained by a simple time measurement, and even if it is assessed by an individual without professional expertise, the measurement is easily made. These considerations suggested the possibility that TWT shows high generality as a risk assessment for falls.

There are several potential limitations these results. Firstly, the sample size was small. Secondly, the participants were probably more motivated and showed greater interest in health issues and the risk of falls than the general population of older adults. Thirdly, the TWT was analyzed by repeated attempts. An important point was that a group of pre-frail elderly individuals participated in this study because it was considered necessary to clarify the risks of falling in this group. Therefore, it was meaningful to have predicted the risk of falls in the pre-frail elderly individuals using TWT. Future research should include a fall prevention interventional study. Performance under complex-task conditions may be improved by training with TWT, and this type of training may be helpful for preventing falls.

CONCLUSION

This study examined the usefulness of TWT, an assessment we devised that is related to TUG and TMT. TWT may therefore be useful for predicting the risk of falling in the elderly.

ACKNOWLEDGEMENTS

The authors acknowledge Dr. Toshiro Sakata and Mr. Toshiaki Uehara for their major contribution to the data collection.

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Table 1 Correlation between TWT, TMT, OLS, FR, TUG, or 10m walking

measures	TWT	TMT	OLS	FR	TUG	10m walking
TWT	1.00	0.56 **	0.06	-0.09	0.24 **	0.08
TMT		1.00	-0.10	-0.11	0.06 **	-0.03
OLS			1.00	-0.09	-0.09	0.11
FR				1.00	0.17 *	-0.15 *
TUG					1.00	0.76 **
10m walking						1.00

** Correlation significant at p<0.01

* Correlation significant at p<0.05

TWT, trail walking test

TMT, trail making test part-A

OLS, one leg standing

FR, functional reach

TUG, timed up and go test

10m walking, 10m walking time

Table 2 Subjects characteristics and physical performance between faller and non-faller

characteristic		faller (n=59) average (SD)	non-faller (n=112) average (SD)	p-value
age	(years)	79.5 (6.2)	81.4 (4.9)	0.334
age distribution				
70-74	(n)	10 (16.9%)	21 (18.8%)	
75-79	(n)	15 (25.4%)	20 (17.9%)	
80-84	(n)	20 (33.9%)	27 (24.1%)	
85-89	(n)	14 (23.7%)	44 (39.3%)	
height	(cm)	147.1 (7.1)	147.1 (6.9)	0.982
weight	(kg)	52.1 (10.2)	50.3 (7.1)	0.972
BMI		23.5 (3.4)	24.0 (3.9)	0.426
women	(n)	40 (67.8%)	94 (83.9%)	0.581
MMSE	(point)	27.9 (2.3)	28.1 (2.0)	0.762
independent ADL		59 (100%)	112 (100%)	
walking aids	(n)	5 (8.5%)	13 (11.6%)	0.609
medication	(n)	2.7 (2.2)	2.9 (2.3)	0.777
TWT	(s)	78.2 (8.2)	61.5 (11.9)	<0.001
TMT	(s)	91.0 (33.7)	66.1 (37.6)	<0.001
OLS	(s)	6.3 (5.5)	5.5 (5.4)	0.335
FR	(cm)	24.5 (5.7)	24.4 (5.7)	0.987
TUG	(s)	13.1 (2.1)	12.0 (2.7)	0.003
10m walking	(s)	11.7 (2.8)	11.2 (2.6)	0.260

BMI, body mass index

MMSE, mini mental state examination

Independent ADL, independent activities of daily living

TWT, trail walking test

TMT, trail making test part-A

OLS, one leg standing

FR, functional reach

TUG, timed up and go test

10m walking, 10m walking time

FIGURE

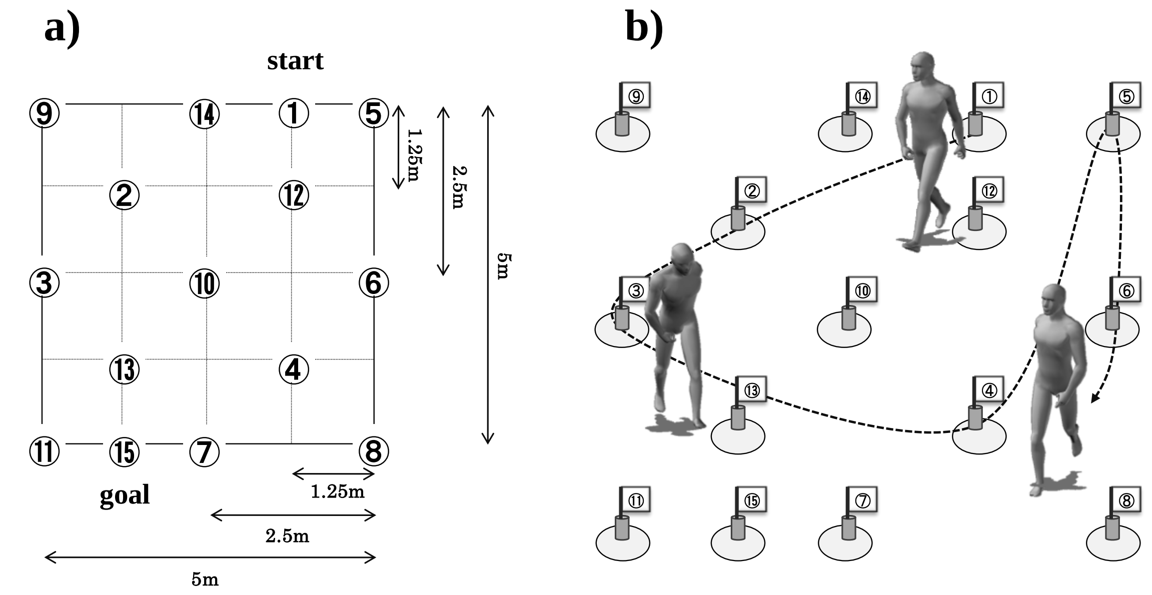
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FIGURE LEGENDS

Figure 1 Schema of Trail Walking Test

a) The participants were asked to sequentially pass from No. 1 to 15. The tester ordered, “Please move to No. 15 as quickly and correctly as possible.” The trials were timed using a stopwatch to the nearest 0.01 s following a standard procedure.

b) The image schema of task excursion