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Measurements of Stepping Accuracy in a Multitarget Stepping Task as a Potential Indicator of Fall Risk in Elderly Individuals

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Background. Elderly individuals who are at high risk for a fall generally exhibit increased gait variability, a decline in visuomotor control of foot movement, and cognitive impairment, particularly in executive functions. A new walking test, a multitarget stepping task, was developed in the present study to identify elderly individuals with impaired stepping performance on a walkway requiring the involvement of executive functions to find a footfall target.

Methods. Thirty-one high-risk (82.7 ± 6.4 years) and 87 low-risk (80.7 ± 7.9 years) elderly individuals performed the multitarget stepping task on 2 days with a 2-week interval. For the multitarget stepping task, they walked while stepping on squares with an assigned color as a footfall target continuously along the 15 lines while avoiding other colors (distracters). Two types of failure were measured: (a) failure to step precisely on the target (stepping failure) and (b) failure to avoid distracters (avoidance failure). The two groups' performance was compared. A logistic regression analysis was also performed to determine whether the measurements were independently associated with falling.

Results. The high-risk groups showed a significantly higher rate in stepping (64.5 vs 25.3% of participants in the group) and avoidance (54.8 vs 17.2%) failure than the low-risk groups. The test–retest analyses showed good agreement for both measurements. A logistic regression analysis demonstrated that the stepping failure was independently associated with falling (odds ratio = 19.365, 95% confidence interval = 3.28–113.95; $p < .001$).

Conclusions. Measurements of stepping accuracy while performing the multitarget stepping task, particularly precise stepping failure, could contribute to identifying high-risk elderly individuals.

Key Words: Elderly—Fall—MTST.

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ACCIDENTAL falls among elderly individuals are frequently attributed to tripping while walking. Age-related inability to step precisely on the ground (1–7), particularly under challenging conditions (8–11), is likely to cause tripping. Although previous research on stepping behavior in elderly individuals has shown the usefulness of measuring the accuracy of stepping on a ground during gait as a clinical tool to distinguish individuals who are at high risk (HR) for a fall from those who are at low risk (LR), attempts to develop such clinical tests are limited (12). For the current study, we developed a walking test, the multitarget stepping task (MTST). During the test, two types of failure, stepping and avoidance, were measured while the participants walked along a 10-m walkway and stepped on multiple targets. Our objective was to determine whether the indices of stepping accuracy, as well as the time required for performing the task, could be used to identify elderly individuals at risk of falling.

Elderly individuals generally demonstrate increased variability of stride length (1–3). Increased variability in gait has been shown to be associated with a greater risk of falling among elderly participants (1,2). Evidence is increasing that age-related declines in visuomotor control of foot movements are likely to contribute to such stepping variability. When instructed to step precisely on a footfall target, HR elderly individuals showed less accurate and more variable foot placement than younger and LR elderly individuals while stepping on footfall targets (4). Analyses of their gaze behavior showed that the HR elderly individuals looked sooner and longer at imminent stepping targets than younger individuals. This tendency was more pronounced with increased task difficulty (5). The fact that HR elderly individuals looked at targets longer indicates that they require more time to process visual information regarding targets and/or program appropriate motor responses (4–6). Elderly individuals also exhibit impaired visuomotor control of foot movement in a feed-forward manner. When a target was invisible prior to the onset of stepping on that target, the rate of failure to step onto a footfall target was 42% in older participants but less than 10% in younger participants (6). Overall, these findings suggest that an age-related decline in visuomotor control of foot movement is likely to be one of the causes for impaired stepping performance.

Another factor relating to impaired stepping performance during gait is an age-related decline in the cognitive functions, particularly the executive functions (e.g., attention control, working memory, and problem solving) (12–19). Persad et al. (13) showed that, for elderly participants, difficulties with a complex walking task, including stepping precisely on a ground, have been linked to measures of executive function but were independent of other cognitive functions, such as memory and language.

Alexander et al. (12) developed a Walking Trail Making Test (W-TMT) in which a participant walked at a comfortable pace while stepping on multiple targets in a specific order. Participants were instructed to step on targets so that the number printed beside the stepping target would sequentially increase (W-TMT A) or to step on targets so that the number and letter beside the targets would increase in an alternating manner (ie, 1-A-2-B; W-TMT B). They demonstrated that the difference in the time taken to perform the W-TMT B (ie, cognitively high demand with respect to executive function) from the W-TMT A (ie, cognitively moderate) was extraordinarily high in older participants. With these findings, Alexander et al. concluded that elderly individuals have difficulty in performing accurate stepping movements with increased cognitive demands. A recent study by Persad et al. (14) demonstrated that the time taken to perform the W-TMT B diminished significantly in patients with deficits in executive function. This suggests that performing the W-TMT B involves executive function during gait and, therefore, should be effective to identify HR elderly individuals.

To date, attempts to develop a clinical test to measure the accuracy with which elderly individuals step on the ground have been limited. In the W-TMT, only the time taken to perform the task was measured. Given previous findings on the age-related decline in the visuomotor control of foot movement, measurement of the stepping accuracy itself could be an important contributory factor for identifying HR elderly individuals. Moreover, in the W-TMT, multiple targets and distracters were randomly placed. However, to thoroughly analyze the involvement of age-related decline in the spatiotemporal coordination between eye and foot movement into less stepping accuracy in HR elderly individuals, a more structured arrangement of the targets and distracters would be useful.

Considering these issues, we developed a new clinical test, a MTST, to measure the stepping accuracy in a simplified manner and compare the performance between HR and LR elderly individuals. In the MTST, participants walked along a 10-m walkway on which 15 lines of three colored squares were placed. They were instructed to step on an assigned square (the footfall target) continuously along the 15 lines while avoiding the other squares (distracters). As in the W-TMT (12), performing the MTST involved visual scanning of the targets while simultaneously stepping precisely on the target; participants would, thus, perform the MTST with the involvement of their executive functions. We investigated whether HR elderly individuals had significantly higher rates of stepping failure, that is, stepping on the target and avoiding the distracters, than the LR elderly. The participants also performed other standard clinical tests frequently used in clinical setting to identify elderly individuals at HR of falling, that is, a timed-up-and-go (TUG) test (20), a functional reach (FR) test (21), a one-leg standing (OLS) test (22), and a 10-m walking test (10-m walking) (23). Correlation analyses between each measurement collected from the MTST and each of the other standard clinical tests used were conducted to evaluate their associations. We further examined a logistic regression analysis to clarify which of these measurements, including the measurements taken from the MTST, were independently associated with falling.

Methods

Participants

A total of 118 community-dwelling older individuals (mean age, 84.5 ± 6.5years) participated. The exclusion criteria ensured that none of the participants had any indications of the following symptoms: (a) serious visual impairment (cataract, glaucoma, or color blindness), (b) inability to ambulate independently (those requiring the assistance of a walker were excluded), (c) score of less than 7 on the rapid dementia screening test (24), (d) symptomatic cardiovascular disease, (e) neurological and orthopedic disorders, (f) peripheral neuropathy of the lower extremities, or (g) severe arthritis. The participants wore flat-soled footwear while participating in the present study. Written informed consent was obtained from each subject in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

A participant who met the following two criteria was classified as an HR elderly individual: (a) a self-report of the occurrence of at least one fall within the past year and (b) the time required for performing a TUG test was greater than 13.5 seconds (25,26). A fall was defined as any event that led to an unplanned unexpected contact with a supporting surface during walking. Details of the protocols for the TUG test are described later. As a result, 31 HR and 87 LR elderly individuals participated (see Table 1 for participant details). We ensured that there were no significant group

Table 1. Characteristics of Both Groups of Participants

Characteristics	High-Risk Elderly Participants, $n = 31$	Low-Risk Elderly Participants, $n = 87$	p
Age	82.7 ± 6.4	80.7 ± 7.9	.214
Gender distribution (% men)	25.80	26.40	.574
Height (cm)	153.5 ± 10.9	156.8 ± 9.8	.377
Weight (kg)	55.6 ± 12.8	58.1 ± 11.1	.568
Rapid dementia screening test (s)	8.80 ± 1.37	9.21 ± 1.51	.198
Trail Making Test Part A (s)	129.3 ± 43.3	143.6 ± 46.4	.159
Visual acuity score (decimal)	0.65 ± 0.32	0.69 ± 0.33	.550
10 m walking time (s)	21.57 ± 10.65	12.77 ± 3.63	<.001
Number of 10 m walking steps	34.45 ± 13.74	23.02 ± 4.36	<.001
Timed up and go test (s)	20.15 ± 6.26	11.57 ± 3.41	<.001
Functional reach (cm)	14.51 ± 6.31	21.57 ± 7.33	<.001
One-leg standing (s)	2.67 ± 5.57	5.75 ± 7.59	.041

differences in age, gender distribution, height, weight, the score of the rapid dementia screening test, and the visual acuity score (binocular acuity scored on the basis of a Landolt C; Table 1). Furthermore, comparisons of the scores of the TMT-A test between the two groups partly showed did not show any critical group differences in their cognitive impairment (Table 1).

Data Collection and Analyses of the MTST

The MTST was performed on a black elastic mat (10 m long and 1 m wide). There were 45 pieces of a 10 × 10 cm square on the mat (see Figure 1). These squares were arranged into three rows (15 cm between each row) and 15 lines (61 cm between each line). Each square was marked with red, blue, or yellow tape. Each line had one of the three colored squares in a randomized order. One square (blue or yellow) was regarded as a footfall target, whereas the others were distracters. The color of the footfall target was counterbalanced among the participants and announced to each participant prior to initiating walking.

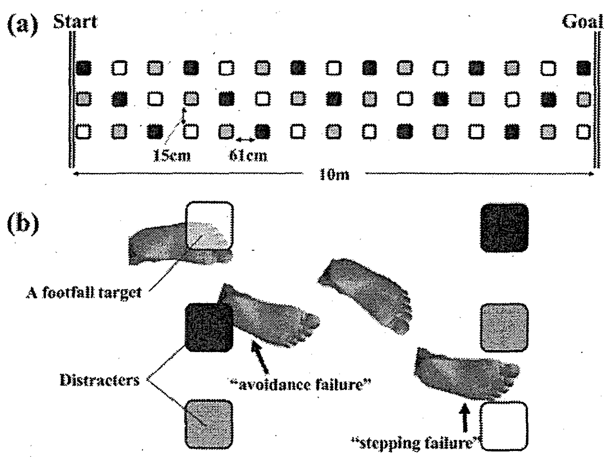

Figure 1. (a) The 10-m walkway used in the multitarget stepping task (MTST). Each square was made of red, blue, or yellow tape. (b) An example of the two types of failure measured in the MTST. A participant intends to step on footfall targets (displayed in white in this figure). The failure to step on the footfall target was regarded as the stepping error. The failure to avoid a distracter was regarded as an avoidance failure. As shown in this figure, avoidance failure was always the result of an accidental step as the participant walked from target to target, but it did not occur as a result of the wrong selection of a target out of the three squares on the line the participants intended to step on.

The participants walked on the mat at a self-selected pace while stepping on the target square placed on each line. The participants were instructed (a) to step on a footfall target with either side of the foot and any part of the sole, (b) to take as many steps as necessary while walking between the lines to comfortably walk toward the next footfall target, and (c) not to step on the distracters. At the beginning of the trial, they stood at the start position with their eyes closed to prevent them from looking at the locations of the targets beforehand. They opened their eyes as soon as they heard an experimenter's command of "Go!" and then started walking toward the first target. The participants performed one main trial. One or two (generally one) practice trials were performed before the main trial until the participants understood the task requirements and were familiar with walking on the mat. To investigate the test–retest reliability of the performance of the MTST, the participants performed the MTST twice (a single main trial each day) with a 2-week interval.

The main dependent measures were two types of failure indicating less accurate stepping performance: a stepping failure (ie, failure to step on the footfall target) and an avoidance failure (ie, failure to avoid distracters). Even a step on the edge of the target was regarded as successful; therefore, the existence of a stepping failure indicated that a participant did not seem to be able to control the placement of the foot on the target. A single experimenter observed the stepping and avoidance failures while walking next to the participant performing the MTST.

The main dependent measures were analyzed statistically from two perspectives. First, the participants who experienced each type of failure at least once were totaled for both the HR and LR groups. For each failure, the numbers, expressed as the frequency of failure occurring in the group (%), were compared statistically between the groups with a chi-square analysis. To investigate the test–retest reliability for the two types of the stepping failure, Kappa coefficients (k values) were calculated. A k value of 0.61–0.80 was regarded as good agreement (27). Second, each number of failure for each participant was statistically compared between the two groups with a t test.

The use of a retrospective fall risk in the present study is less compelling as a risk for falls than the use of prospective falls. To partially address this limitation, we further conducted comparisons of the numbers of each failure for each participant while performing the MTST among three groups, namely, the HR elderly participants who reported more than one fall (the HR multifallers, $n = 11$), those who reported only one fall (the HR single fallers, $n = 20$), and the LR participants ($n = 87$). We expected that the stepping accuracy would be worse for the multifallers than for the single fallers. A one-way analysis of variance was used as a statistical test.

Another dependent measure was the time taken to perform the MTST (a MTST performance time). The time (seccond) required from the verbal command for initiating walking until the participants reached the goal line was measured with a stop watch. A t test was performed to statistically compare the time between the groups. To investigate the test–retest reliability for the MTST performance time, the intertrial correlation coefficient = 1.1 between the two measurements with a 2-week interval was calculated.

Data Collection and Analyses of Other Clinical Tests

The other clinical tests that have been used to identify HR elderly adults in many studies (TUG, FR, OLS, and 10 m walking) were measured prior to performing the MTST on the first measurement day. The order of performing these tests was randomized. The participants performed each task for two trials. The score of each task was calculated as an average of the score obtained from the two trials. A t-test analysis was examined for each clinical test to statistically compare the scores between the HR and LR groups.

In the TUG, the participants were instructed to stand up from a standard chair with a seat height of 40 cm, walk a distance of 3 m at a comfortable pace, turn, walk back to the chair, and sit down. The time required from the verbal command to begin the task until completion was measured with a stopwatch. A TUG score was defined as the time in seconds for the completion in their second trials. In the FR, the participants initially stood next to a wall while raising one arm at 90° in the sagittal dimension with all fingers extended. The participants then intended to reach forward as far as possible without moving or lifting their feet from an initial upright posture. The distance (cm) between the initial and final fingertip positions of the middle finger was obtained from each of two trials. An FR score was defined as the better performance of their two trials.

In OLS, the participants stood initially with both legs in an upright posture with their eyes were open and their arms positioned to their sides. They were then instructed to stand with only their pivot foot without any assistance. The time the participant could stand on one leg was measured with a stopwatch as an OLS score (second). The participants stopped the OLS if the time exceeded 60 seconds. When a participant could not perform the OLS, his/her OLS score was 0 second. In the 10 m walking, the participants walked alone at their usual speed over a distance of 10 m. The time recorded in the two trials was averaged as the 10 m walking score. The number of steps the participants made during the 10 m walking was also averaged in two trials and used as another score of the 10 m walking.

To quantitatively describe the associations between these clinical tests and the stepping performance in the MTST, correlation analyses were conducted between each of the three measurements in the MTST (ie, the number of stepping and avoidance failures and the MTST performance time) and each of the clinical tests.

Logistic Regression Analysis

A multivariate analysis by means of logistic regression using a stepwise-forward method was performed to investigate which of these measurements (ie, the stepping and avoidance failures; MTST performance time; or scores of TUG, FR, OLS, or 10 m walking) was independently associated with falling. For the independent variables that remained in the final step of the regression model, odds ratios (ORs) with 95% confidence intervals (CIs) were presented.

RESULTS

The frequency of failure occurring in the group (%) and the ORs of the two types of failure that occurred in each group are shown in Table 2. The chi-square test indicated that the HR elderly participants showed significantly higher frequency of the stepping failure than the LR elderly participants ($p < .001$). The HR elderly participants also showed significantly higher frequency of the avoidance failure than the LR elderly participants ($p < .001$). Avoidance failure always occurred as the participants were walking from target to target but not when they intended to step on the target. The investigation of test–retest reliability indicated that the kappa coefficient was .758 for the stepping error and .688 for the avoidance error. Both coefficients showed good agreement between the first- and second-time measurements.

The average numbers of each failure occurring in each group are shown in Table 2. The HR elderly participants showed a significantly greater number of stepping and avoidance failures than the LR elderly participants. The average numbers of stepping failures occurring in the HR multifallers, the HR single fallers, and the LR participants were 0.64 ± 1.03, 2.30 ± 2.45, and 0.69 ± 1.53, respectively. The group differences were significant ($p < .01$); the HR single fallers showed significantly greater number of stepping failures than the HR multifallers and LR elderly participants. The average numbers of avoidance failures occurring in the three groups were 1.27 ± 1.73, 1.90 ± 2.55,

Table 2. Group Comparisons of the Stepping and the Avoidance Failure

	High-Risk Elderly Participants, $n = 31$	Low-Risk Elderly Participants, $n = 87$	p
Stepping failure, n (%)	20 (64.5)	22 (25.3)	<.001
Number of stepping failure, times	1.71 ± 2.19	0.69 ± 1.53	<.001
Avoidance failure, number (%)	17 (54.8)	15 (17.2)	<.001
Number of avoidance failure, times	1.68 ± 2.28	0.47 ± 1.28	<.001
Multitarget stepping task performance time (s)	31.58 ± 11.73	21.57 ± 7.64	<.001

and 0.47 ± 1.28, respectively. The significant group differences showed that the HR single fallers had a significantly greater number of stepping failures than the LR elderly participants.

The MTST performance times are also shown in Table 1. The HR elderly participants required significantly more time to perform the MTST than the LR elderly participants ($p < .05$). The investigation of test–retest reliability indicated that the correlation between the first- and second-time measurements was very high (intertrial correlation coefficient = 0.956; 95% CI = 0.92–0.95; $p < .001$).

The average results of the other clinical test are summarized in Table 1. Except for the results of the OLS ($p > .05$), all clinical tests demonstrated that the LR elderly participants had significantly better scores than the HR elderly participants. The correlation between each of the three measurements in the MTST (ie, the number of stepping and avoidance failures and the MTST performance time) and each of the clinical tests is shown in Table 3. The stepping failure was mildly correlated with the time and steps of the 10 m walking and the TUG, OLS, and FR scores, whereas the avoidance failure was mildly correlated with the steps of the 10 m walking and the TUG and OLS scores. The MTST performance time was highly correlated with each of the clinical tests.

The logistic regression analysis indicated that the precise stepping error (OR = 19.365; 95% CI = 3.28–113.95; $p < .001$) and TUG (OR = 1.911; 95% CI = 1.45–2.50; $p = .001$) were the independent variables that remained in the final step of the regression model and, therefore, were considered to be independently associated with falling. The adapted regression model was able to classify 78.0% of cases correctly ($R^2 = .395$, $p < .001$). The specificity was 80.3% and the sensitivity was 75.4%.

Discussion

The aim of the present study was to investigate whether a simplified measurement of stepping accuracy while performing the MTST was able to identify HR elderly individuals. The results demonstrated that 64.5% of the HR elderly participants failed to step precisely on the target at least once. This was a surprisingly high rate of failure when considering our criteria that even a step on the edge of the target was regarded as successful. The HR elderly participants also showed a significantly higher rate of avoidance failure and a slower time for performing the MTST than the LR groups. The test–retest examination showed that these measurements were statistically reliable. Unfortunately, we failed to demonstrate an association between the number of retrospective falls and the number of stepping and avoidance failures; the HR single fallers showed significantly higher frequency of both types of failure. Furthermore, although the logistic regression analysis showed a significantly high OR for the stepping failure (19.365), the very large range of 95% CI indicated that the results need to be interpreted cautiously. Taken collectively, these findings led us to the tentative conclusion that measuring the stepping accuracy while performing the MTST, particularly the stepping error, is potentially an important factor in the identification of HR elderly individuals.

The high rate of stepping failures clearly indicated that HR elderly individuals were unable to step precisely on their intended target, which could result in tripping while walking. The high rate of the avoidance failure also showed that the HR elderly participants were unable to avoid stepping distracters. It is noteworthy that avoidance failure always occurred as a result of an accidental step in the way the participants were walking from target to target but not as a result of the wrong selection of a target from the three

Table 3. The Correlation Variables Between Each of Three Measurements in the Multitarget Stepping Task (MTST) and Each of Clinical Tests

	Number of Stepping Failure	Number of Avoidance Failure	MTST Performance Time
10 m walking time	0.24*	0.15	0.75**
Number of 10 m walking steps	0.21*	0.20*	0.70**
Timed up and go test	0.20*	0.25*	0.70**
One-leg standing	−0.14	−0.19*	−0.35**
Functional reach	−0.21	−0.15	−0.39**
Trail Making Test Part A	0.05	−0.01	0.22
Number of stepping failure		0.345**	0.23*
Number of avoidance failure	0.345**		0.12
MTST performance time	0.23*	0.12	

Note: $^*p < .05$. $^{**}p < .01$.

squares in the line that they intended to step on. Avoidance failure, therefore, resulted mainly from incorrect planning of the walking path from target to target and not from the wrong selection of a target from the three squares in a line due to age-related decline in visual acuity and/or visual search. Correlation analyses between each of the three measurements and standard clinical tests showed that the stepping and avoidance failures were correlated only mildly with several tests (Table 3). This was in contrast with the findings that the MTST performance time was highly correlated with all clinical tests. It seems that a decline in stepping accuracy results in an increased fall risk somewhat independently of the balance and gait features assessed by other standard clinical tests.

One possible explanation for the reason that measuring the stepping accuracy, particularly the stepping failure, could predict falls in spite of the multifocal etiology of falls was that these measurements could be associated directly with increased gait variability (1–3) and a decline in the visuomotor control of foot movement (4–6) in HR elderly individuals. This explanation was plausible, given that some clinical tests that have components of measuring the gait variability and visuomotor control of foot movement, such as the Dynamic Gait Index (28) or the Four Square Step Test (29), contributed to identifying HR elderly individuals.

In addition, some factors characterizing the MTST could make a significant contribution to enhance its predictive power. As in the W-TMT (12), to perform the MTST, the participants visually scanned the target while simultaneously attempting to step on it; participants would thus perform the MTST with the involvement of their executive functions. Due to an apparent decline in executive functions (12–15), HR elderly individuals would have difficulty walking in the MTST. Furthermore, the placement of multiple targets on a walkway could test the ability to step quickly in different directions. Because of the difficulty in maintaining a stabilized upright posture after stepping in different directions (29,30), especially with turning behavior (31), the HR elderly individuals may have less accurate stepping performance. To evaluate the validity of these possible explanations, future studies should investigate age-related changes in gaze behavior while performing the MTST; the frequency of turning behavior; and the functional relationship among the gaze, turning behavior, and accuracy of stepping performance.

We failed to demonstrate an association between the number of retrospective falls and the number of stepping and avoidance failures; the HR single fallers showed significantly higher frequency of both types of failure. This was in contrast to the relatively small individual differences in other standard tests (Table 1). We have no clear explanation for the reasons for such large individual differences; future studies should address this issue to reliably predict future falls on the basis of stepping and avoiding failures. Future studies should also address the possibility that the numbers of stepping and avoidance failures are associated with the circumstances under which falls occurred but not with the frequency of falls.

There are several issues that limit the conclusions to be drawn from this study. First, we measured only a single performance of the MTST from each participant; an examination of the within-participant reliability with a different walking path would be necessary in future research. Second, we did not measure participants' executive functions. Whether the difference in executive functions really underlies group differences between HR and LR elderly individuals should be a topic for future research.

In conclusion, the present findings provide general evidence that measuring the accuracy of foot placement while performing the MTST is potentially an effective clinical tool to identify HR elderly individuals. Possible explanations for the reason that measuring the stepping accuracy, especially the stepping failure, could predict falls would be (a) these measurements could be associated directly with increased gait variability and a decline in visuomotor control of foot movement in HR elderly individuals and (b) performing the MTST required the involvement of executive functions to find a footfall target. However, several findings, such as the lack of an association between the number of retrospective falls and the number of stepping and avoidance failures or the very large range in 95% CI observed in the logistic regression analysis, also suggest that the present results need to be interpreted cautiously.

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Original article

Differential determinants of physical daily activities in frail and nonfrail community-dwelling older adults

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ABSTRACT

Background/Purpose: The purpose of this study was to determine whether or not daily activities determined by average daily steps are associated with age, gender, body mass index, fear of falling, and physical functions (locomotive function, balance function, and muscle power) in community-dwelling nonfrail and frail older adults.
Methods: This is a cross-sectional study conducted in community-dwelling older adults in Japan. Based on the Timed Up and Go (TUG) test, 629 elderly adults were divided into two groups: 515 were grouped to nonfrail elderly (TUG time less than 13.5 seconds, mean age 77.0 ± 7.2 years) and 114 to frail elderly (TUG time of 13.5 seconds or more, mean age 76.1 ± 7.5 years). Daily physical activities were determined by average daily steps measured by pedometer and four other physical function tests (10-m walk test, single-leg standing, functional reach, and five-chair stand test) were performed along with the assessment of fear of falling.
Results: Stepwise regression analysis revealed that age, gender, 10-m walk test, and single-leg standing were significant and independent determinants of the average step counts in the nonfrail elderly ($R^2 = 0.282$, $p < 0.001$), whereas fear of falling was the only significant and independent determinant of the average step counts in the frail elderly ($R^2 = 0.119$, $p < 0.001$).
Conclusion: These results indicate that differential factors may be related to daily activities depending on the level of frailty in community-dwelling older adults.

1. Introduction

Physical activities show positive associations with various components of physical functions, such as walking speed, lower-limb strength, and balance and negative associations with the incidence of coronary artery disease, obesity, osteoporosis, and other causes of morbidity and mortality in elderly.[1–4]

Higher physical activities can also improve quality of life and physical and psychological functions, facilitate independent living, and reduce the risk of dementia in older adults.[5–8] Physical Activity Guidelines for Americans concluded that, for older adults, in addition to the well-known health benefits of a physically active lifestyle, "strong evidence indicates that being physically active is associated with higher levels of functional health and a lower risk of falling."[9]

However, Yoshida et al[10] showed that the association between physical fitness and ambulatory activity is affected by the level of instrumental activity of daily life in elderly women, suggesting the effect of frailty on the association. We demonstrated that the resistance training program is effective at decreasing the fear of falling in frail elderly but not in nonfrail elderly (Yamada et al, present study), indicating the difference of the effect of physical training in elderly with different physical fitness. We hypothesized, therefore, that differential factors could affect the level of physical daily activities in the presence or absence of frailty. The purpose of this study was to determine whether or not physical activities determined by average daily steps are associated with age, gender, body mass index (BMI), fear of falling, and physical function (locomotive function, balance function, and muscle power) in community-dwelling nonfrail and frail older adults.

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2. Methods

2.1. Participants

Participants were recruited by an advertisement in a local press. We used the following criteria to screen participants in the initial interview and invited to participate in this study if he or she was aged 65 years or older , was community-dwelling, had a score of eight or more by Rapid Dementia Screening Test,[11] and was able to walk independently.

We excluded participants based on the following exclusion criteria: the presence of severe cardiac, pulmonary, or musculoskeletal disorders; comorbidities associated with an increased risk of falls (i.e., Parkinson's disease or stroke); and use of psychotropic drugs. We obtained written informed consent from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

2.2. Definition of frailty

The definition of frailty is based on the results of previous study. The Timed Up and Go (TUG) is a simple test developed to screen basic mobility performance and has been shown to be significantly associated with activities of daily living function in frail older adults.[12] It has been reported that elderly with a TUG score greater than 13.5 seconds have an increased risk of falls.[13] Therefore, frailty was defined as a TUG score greater than 13.5 seconds. Based on key components of the screening examination (TUG score greater than 13.5 seconds), 114 elderly were classified as frail, whereas 515 elderly as nonfrail.

2.3. Measurement of physical activities

A valid, accurate, and reliable pedometer, Yamax PowerWalker EX-510 (Yamax Corp., Tokyo, Japan), was used to measure free-living step counts.[14] Measurement of step counts was conducted between October and November 2010. Participants were instructed to wear the pedometer in their pocket of dominant leg for 14 consecutive days except during bathing, sleeping, and performing water-based activities. This pedometer has a 30-day data storage capacity. We calculated the averages of their daily step counts for 2 weeks.

2.4. Measurement of fear of falling

We assessed fear of falling by asking a single yes or no question, "Are you afraid of falling,?" which has a high test-retest reliability.[15] The test-retest reliability using the Kappa coefficient was 0.960.

2.5. Measurement of physical function

The participants received four other physical function tests that are widely used to identify high-risk elderly: 10-m walk test, single-leg standing, functional reach, and five-chair stand. In 10-m walk test, the participants were asked to walk as fast as possible along a 10-m straight line, with a 1 m approach at both ends, making a total length of 12 m. The time required was taken as the measured value. In single-leg standing, the length of time for which participants were able to stand on one leg with their hands placed on their waist was measured. The time was measured twice for each leg and the maximum length of time was taken. Functional reach was measured using the simple clinical apparatus consisting of a leveled yardstick secured to the wall at right acromion height as previously described.[16] In five-chair stand, participants were asked to stand up and sit down five times as quickly as possible and were timed from the initial sitting position to the final standing position at the end of the fifth stand.[17] For each function test, the participants performed twice, and the average score was then calculated. All test measurements were completed before the daily step measurement.

2.6. Statistical analysis

The relationship between the average daily steps and physical function was investigated with the Pearson correlation coefficient. The t test and χ^2 test were used to compare the results of measurements between frail and nonfrail groups.

A multivariate analysis by means of multiple regression using a stepwise method was performed to investigate which of the age, gender, BMI, fear of falling, and five measures of physical function (i.e., 10-m walk test, TUG, single-leg standing, functional reach, and five-chair stand test) were independently associated with the average daily steps in each group.

Data were analyzed using the Statistical Package for Social Science (Windows version 18.0; SPSS Inc., Chicago, IL, USA).

3. Results

There were no significant differences in age (nonfrail = 77.0 ± 7.2, frail = 76.1 ± 7.5, $p = 0.241$), gender (nonfrail = 67.5%, frail = 67.5%, $p = 0.541$), height (nonfrail = 153.5 ± 7.6 cm, frail = 153.7 ± 6.1 cm, $p = 0.743$), weight (nonfrail = 53.0 ± 9.6 kg, frail = 53.6 ± 4.5 kg, $p = 0.576$), and BMI (nonfrail = 22.4 ± 3.2, frail = 22.7 ± 1.9, $p = 0.393$) between the two groups (Table 1). However, all physical function tests and average daily steps were significantly different between the two groups. More fear of falling was observed (nonfrail = 39.1%, frail = 73.6%, $p < 0.001$), longer time was required for 10-m walk test (nonfrail = 9.9 ± 2.2 seconds, frail = 17.1 ± 6.6 seconds, $p < 0.001$), single-leg standing (nonfrail = 13.3 ± 12.1 seconds, frail = 3.1 ± 6.0 seconds, $p < 0.001$), and five-chair stand (nonfrail = 8.9 ± 3.6 seconds, frail = 17.6 ± 8.5 seconds, $p < 0.001$) in frail elderly. Less functional reach (nonfrail = 25.0 ± 8.2 cm, frail = 17.9 ± 8.4 cm, $p < 0.001$), and average daily steps (nonfrail = 4414 ± 2726 steps, frail = 1585 ± 1013 steps, $p < 0.001$) were observed in frail elderly.

To determine the association of average step counts with physical functions and demography, we analyzed Pearson's correlation coefficients in frail and nonfrail elderly. Table 2 shows that average step counts in the nonfrail group were correlated with age ($r = -0.311$, $p < 0.001$), BMI ($r = 0.167$, $p < 0.001$), 10-m walk test ($r = -0.475$, $p < 0.001$), TUG ($r = -0.412$, $p < 0.001$), functional

Table 1
Comparison of demography, fear of falling, and physical function and activities between nonfrail and frail elderly

Items	Nonfrail group ($n = 515$)		Frail group ($n = 114$)		p
	Mean	SD	Mean	SD	
Age (yr)	77.0	7.2	76.1	7.5	0.241
Gender (male = 0, female = 1)	67.5		67.5		0.541[a]
Height	153.5	7.6	153.7	6.1	0.743
Weight	53.0	9.6	53.6	4.5	0.576
BMI (kg/m^2)	22.4	3.2	22.7	1.9	0.393
Fear of falling (yes = 1, no = 0)	39.1		73.6		<0.001[a]
10-m walking time (s)	9.9	2.2	17.1	6.6	<0.001
Timed up & go test (s)	8.8	2.1	20.2	6.8	<0.001
Single leg standing (s)	13.3	12.1	3.1	6.0	<0.001
Functional reach (cm)	25.0	8.2	17.9	8.4	<0.001
Five chair stand (s)	8.9	3.6	17.6	8.5	<0.001
Average daily step (step)	4414.4	2726.3	1585.0	1012.6	<0.001

BMI = body mass index; SD = standard deviation.
[a] χ^2 test.

Table 2
Pearson's correlation coefficients (r) between average daily steps and physical functions, age, and BMI

Items	Nonfrail group ($n = 515$)	Frail group ($n = 114$)	Overall ($n = 629$)
Age (yr)	−0.311**	−0.109	−0.241**
BMI (kg/m^2)	0.167**	−0.013	0.130**
10-m walking time (s)	−0.475**	−0.047	−0.448**
Timed up & go test (s)	−0.412**	−0.131	−0.450**
Functional reach (cm)	0.348**	0.175	0.406**
Five-chair stand (s)	−0.297**	−0.226*	−0.397**
Single-leg standing (s)	0.440**	0.077	0.502**

BMI = body mass index.
*$p < 0.05$; **$p < 0.01$.

reach ($r = 0.348$, $p < 0.001$), five chair stand test ($r = -0.297$, $p < 0.001$), and single-leg standing test ($r = 0.440$, $p < 0.001$). In the frail group, however, a significant association was found only with five-chair stand test ($r = -0.226$, $p < 0.001$). Figure 1 shows linear regressions between physical functions and average step counts in nonfrail and frail elderly. Average step counts had a positive association with functional reach (Fig. 1C) and negative associations with 10-m walk test (Fig. 1A) and TUG (Fig. 1B) only in nonfrail elderly. However, step counts had a negative association with five-chair stand (Fig. 1D) both in nonfrail and frail elderly.

Stepwise regression analysis revealed that age ($\beta = -0.108$, $p = 0.03$), gender ($\beta = 0.255$, $p < 0.001$), 10-m walk test ($\beta = -0.202$, $p < 0.001$) and single-leg standing ($\beta = 0.306$, $p < 0.001$) were

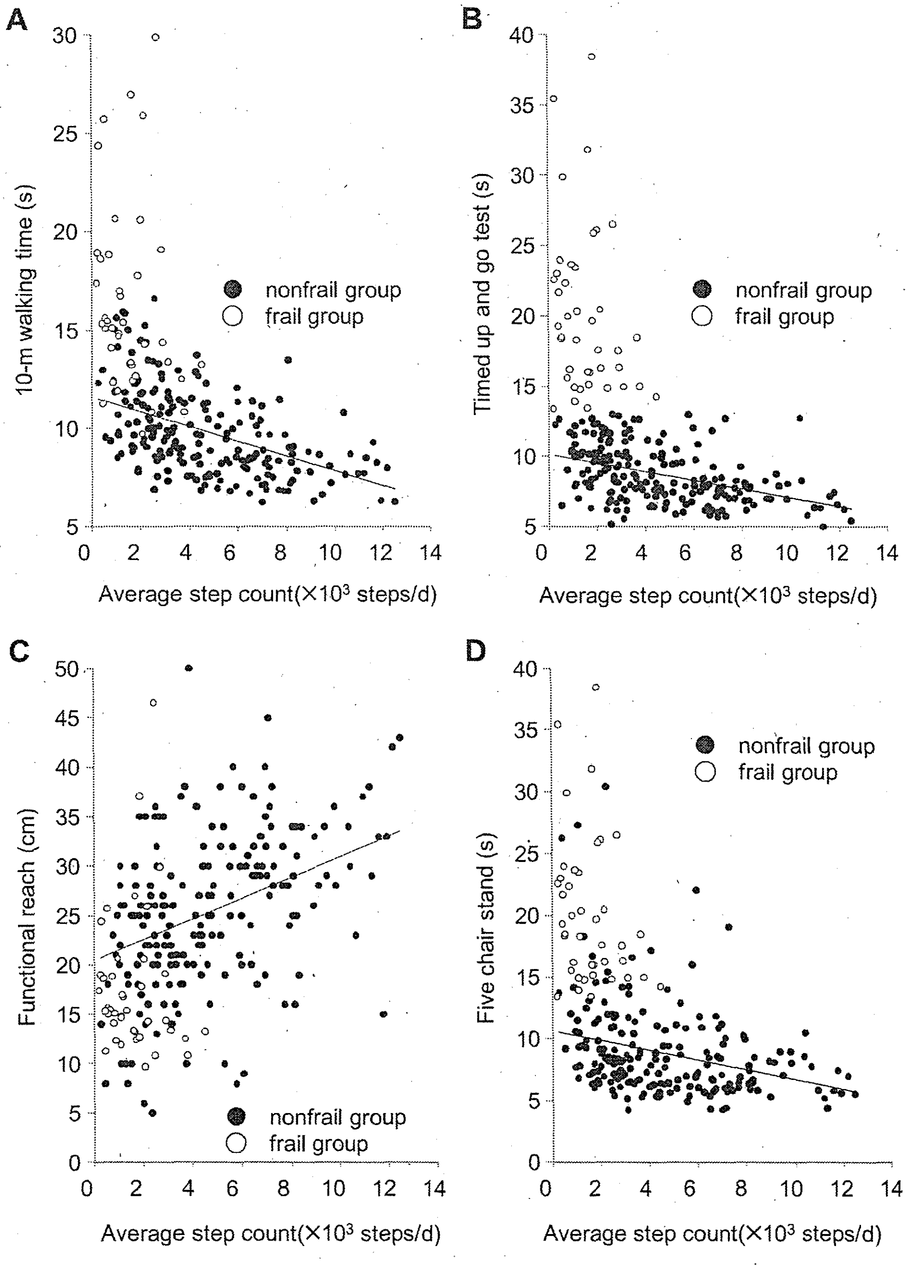

Fig. 1. Relationships between average daily steps and physical function. The physical function was associated with physical activities in nonfrail but not in frail elderly. (A) 10-m walk test; (B) Timed up and go test; (C) Functional reach; (D) Five-chair stand test.

Table 3
Multiple stepwise regression analysis

Independent variables	Nonfrail group Adjusted R^2 value = 0.282 standard regression value	Frail group Adjusted R^2 value = 0.119 standard regression value	Overall Adjusted R^2 value = 0.345 standard regression value
Age (yr)	−0.108*		−0.137**
BMI (kg/m²)			
Gender (male = 0, female = 1)	0.255**		0.238**
Fear of falling (yes = 1, no = 0)		−0.356**	−0.089*
10-m walking time (s)	−0.202**		−0.172**
Timed up & go test (s)			
Functional reach (cm)			
Five chair stand (s)			−0.147**
Single leg standing (s)	0.306**		0.314**

*$p < 0.05$; **$p < 0.01$.

significant and independent determinants of the average step counts in nonfrail elderly ($R^2 = 0.282$, $p < 0.001$) (Table 3). Stepwise regression analysis also revealed that fear of falling ($\beta = -0.356$, $p < 0.001$) was the only significant and independent determinant of the average step counts in frail elderly ($R^2 = 0.119$, $p < 0.001$) (Table 3).

4. Discussion

In the present study, we showed that the differential factors of physical functions may relate to the daily activities in frail and nonfrail community-dwelling elderly Japanese. Our data implicate that physical daily activities can be maintained in the robust elderly with high physical function, whereas fear of falling plays a more important role for the maintenance of physical daily activities if an older adult becomes functionally impaired and frail. Previous studies also indicated that the low self-efficacy for daily activities reduces physical activity, and psychological well-being is an important predictor for staying physically active.[18,19] Thus, differential approaches should be taken to keep the daily activities depending on their physical fitness in elderly.

The physical functions, age, and gender were associated with daily activities in nonfrail elderly but not in frail elderly. Rantanen et al[20] also reported that the relationship between muscle strength and physical disability in older adults is nonlinear. Moreover, in most of previous reports, the participants were nonfrail older adults.[1–4] Therefore, it has been assumed that there is an association between daily activities and physical functions. In addition, daily activities tended to be greater in women than in men. The reason for greater daily activities in women is often ascribed to activities, such as housework and gardening.[20]

On the other hand, we demonstrated that fear of falling was associated with physical daily activities in frail elderly but not in nonfrail elderly. Fear of falling is shown to be associated with frailty.[21,22] Several studies have indicated that people who are afraid of falling appear to enter a debilitating spiral of loss of confidence, restriction of physical activities, physical frailty, lack of social participation, falls, and loss of independence.[23–28] However, Wolf et al[29] reported that increased core and lower extremity strength with exercise decreases the fear of falling. Moreover, cognitive behavioral therapy has been shown to reduce fear of falling.[30–32]

There were several limitations of this study that warrant mention. First, although we used TUG to define frailty, TUG may not be enough to define frailty. Edmonton frail scale adopts eight other domains, such as cognition, general health status, functional independence, social support, medication use, nutrition, mood, and continence other than TUG.[33] Further study is required to test the levels of these domains in this cohort. Second, participants have used pedometer measurements limited to only 2 weeks. If seasonal changes in activity pattern were taken into consideration, long-term use would be more appropriate. Third, the participant's community was not in the rural area. The present study is the result of being restricted to older adults in the urban area.

This is the first study to demonstrate that differential factors affect daily activities depending on the level of frailty. Future work should determine whether individualized intervention can effectively improve physical activity in both nonfrail and frail elderly.

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Research Letter

Effect of resistance training on physical performance and fear of falling in elderly with different levels of physical well-being

SIR—Several factors are involved in the maintenance of activities of daily living (ADL) in older adults. Skeletal muscle mass and strength are important factors for maintaining independence and quality of life in elderly. Several recent cross-sectional studies have shown the associations of muscle strength with physical fitness and disability [1, 2]. Loss of muscle mass (sarcopenia) is prevalent in older adults [3] and represents an impaired state of health with mobility disorders, increased risk of falls and fractures, impaired ability to perform ADL, disabilities and loss of independence [4–6].

Fear of falling is common in older adults. The prevalence varies from 21 to 85%, is higher in women than in men, and increases with age [7]. The risk factors of fear of falling are shown to be physical frailty [8], perception of poor health [9], obesity, cognitive impairment, depression, poor balance [10] and history of at least one fall [7].

Resistance training is an effective intervention to improve the physical function in older adults by increasing strength and physical performance [11]. However, it is still controversial whether resistance training is effective for all levels of elderly people. For example, we reported that decreased muscle power is a reliable predictor of falls only in frail elderly [12].

We hypothesised, therefore, that there is a differential effect of resistance training on physical performance according to the level of physical well-being. The aim of this study was to compare the effects of resistance training on skeletal muscle mass, physical performance and fear of falling in robust and frail elderly.

Methods

Participants

Participants were recruited by an advertisement in a local press. We used the following criteria to screen participants in an initial interview: aged ≥65 years, community dwelling, has visited a primary care physician within the previous 3 years, score of ≥8 by Rapid Dementia Screening Test [13], able to walk independently, willing to participate in group exercise classes for at least 6 months, access to transportation and no regular exercise in the previous 12 months.

We also used the interview to exclude participants based on the following exclusion criteria: severe cardiac, pulmonary, or musculoskeletal disorders, pathologies associated with an increased risk of falls (i.e. Parkinson's disease or stroke) and use of psychotropic drugs. We obtained written informed consent from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

Frailty definition

The frailty classification was based on a composite of previous work. The Timed Up and Go (TUG) is a simple test developed to screen basic mobility performance and has been shown to be significantly associated with ADL in frail older adults [14]. It has been reported that elderly with a TUG score greater than 13.5 s can have an increased risk of falling [15]. Frailty was defined as a TUG score >13.5 s. Based on key components of the screening examination (TUG score greater than 13.5 s), 159 elderly adults were classified as the frail group, whereas 178 elderly adults were classified as the robust group because they had a TUG score of ≤13.5 s.

Resistance training

All participants underwent resistance training sessions twice a week for 50 weeks. All participants performed the seated row, leg press, leg curl and leg extension exercises on resistance-training machines. Training loads were chosen using the 10-repetition maximum (10-RM, the maximal weight that can be lifted 10 times). Participants used the 10-RM for 3 sets of 10 repetitions for each machine exercise. Participants were required to adjust the training weight to ensure failure at the 10-RM. It took approximately 1 h to finish all sessions, with 15-min warm-up at the beginning and 10-min cool-down stretch at the end.

Bioelectrical impedance analysis measurement

A bioelectrical impedance data acquisition system (Physion MD; Physion Co. Ltd, Kyoto, Japan) was used to determine the bioelectrical impedance of the right upper and lower limbs [16]. This system applies a constant current of 800 mA at 50 kHz through the body. Participants lay supine with their arms and legs extended and relaxed during bioelectrical impedance measurement. Leg lean mass (LLM) per whole-body weight was used for the analysis.

Measurement of physical performance

All participants underwent five measurements upon entry into the study (pre-test), which included 10-m walk test, TUG test, single leg standing (SLS), functional reach (FR) and 5-chair stand. The order of performing these tests was random. For each performance task, the participants performed two trials, and an average score was calculated from these two trials. All baseline and pre-test measurements were completed prior to randomisation.

Measurement of fear of falling

Falls Efficacy Scale (FES) [17] is the most frequently used surrogate measure for fear of falling in older adults. The reliability and validity of FES have been previously reported [17]. FES was measured at baseline and at 12 months. FES is based on the operational definition of fear as 'low perceived self-confidence at avoiding falls during essential, relatively nonhazardous activities'. Briefly, participants were asked how concerned they were about the possibility of falling while performing 10 different activities on a 4-category scale from 1 (not at all concerned) to 4 (very concerned). If participants indicated that they did not perform or were unable to perform the activity, they were encouraged to respond hypothetically. FES emphasises mainly indoor, home-based activities.

Required sample size

We designed the effect size of the current study to be 0.4. With a significance level of 0.05, a power of 80%, and a moderate effect size (0.4), a minimum of 100 participants were needed in both the intervention and control groups. Accounting for a potential 20% attrition rate, a total of 240 participants were recruited for this study, which was deemed large enough to detect statistically significant differences.

Statistical analysis

We analysed the effects of resistance training on all outcome measures using a mixed 2 (group: robust and frail groups) × 2 (time: pre-intervention, post-intervention) ANOVA. A 0.05 type 1 error rate was chosen *a priori* to indicate statistical significance. A *post hoc* paired *t*-test for within-group comparisons was performed to compare each dependent variable. The Bonferroni procedure was used to adjust the type 1 error rate of each analysis to 0.025 (0.05/2) as an indication of statistical significance to guarantee an overall type 1 error rate of 0.05. Data were entered and analysed using the Statistical Package for Social Science (Windows version 18.0).

Results

We screened 412 elderly and enrolled 337 (81.8%) who met the inclusion criteria for the trial and agreed to participate (Figure 1A). Most of the elderly who did not meet the inclusion criteria ($n = 66$) were excluded because they had exercised regularly for 6 months prior to the screening. Nine people who might have been eligible for the study declined after telephone screening. Of the 337 individuals who were enrolled in this study, 307 (91.1%) completed the 12-month intervention along with the second interview and the tests at the end of the study. Among them 148 in the robust group (93%) and 159 in the frail group (89%) completed the study.

All 100 scheduled intervention sessions were completed. The median relative adherence was 92% (25–75th

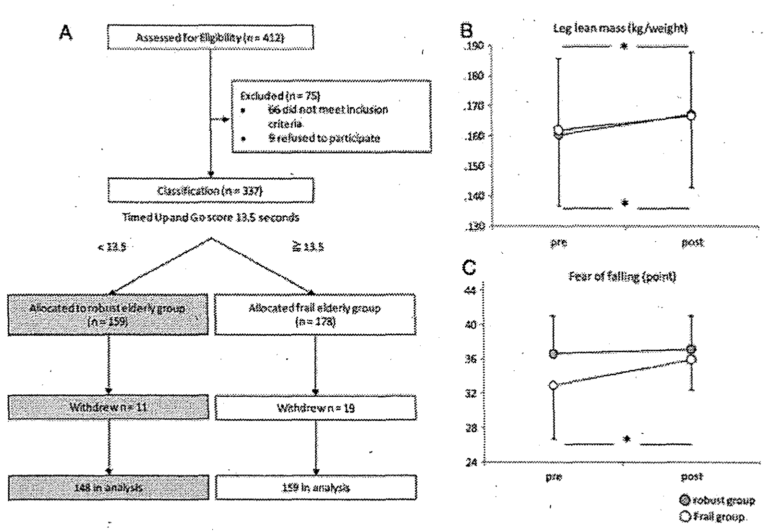

Figure 1. (A) Flow chart showing the disposition of participants throughout the trial. (B) LLM after resistance training in the robust and frail groups was significantly increased from baseline ($P < 0.05$). (C) The frail group had significantly greater improvements in fear of falling ($P < 0.025$).

Table 1. Functional fitness items by group at pre- and post-intervention

	Robust group (n = 148) Mean	SD	E/S	P-value[a]	Frail group (n = 159) mean	SD	E/S	P-value[a]	P-value[b]	F-value 1. Time effect 2. Group × Time
Age, years	75.4	7.7			76.1	8.3			0.440	
Height, cm	157.7	10.1			156.7	9.1			0.266	
Weight, kg	58.2	11.1			56.8	10.9			0.280	
Gender, female n (%)	74 (50.0%)				82 (51.5%)				0.436	
Fall incidence, n (%)	48 (32.4%)				77 (48.4%)				0.003	
Leg lean mass, kg/weight										
Pre	0.160	0.024	0.39	<0.001	0.162	0.024	0.27	0.002	0.448	32.1**
Post	0.167	0.024			0.167	0.021				1.1
Percent change, %	0.05	0.09			0.04	0.11				
Walking time, s										
Pre	10.0	1.9	0.11	0.294	16.1	3.8	0.16	0.130	0.017	1.1
Post	10.2	2.1			15.5	4.1				3.6
Percent change, %	0.3	15.5			−7.7	27.5				
Timed up and go test, sec										
Pre	9.9	1.8	0.09	0.374	17.4	3.0	0.32	0.004	0.002	6.1*
Post	10.1	2.5			16.1	3.9				10.5**
Percent change, %	0.9	18.1			−14.5	37.6				
One leg standing, s										
Pre	9.8	11.8	0.06	0.567	1.7	1.9	0.16	0.160	0.987	0.1
post	9.2	13.9			2.6	5.4				1.4
Percent change, %	−47.3	173.4			46.8	248.3				
Functional reach, cm										
Pre	23.5	5.9	0.01	0.948	18.0	5.6	0.46	<0.001	0.029	7.5**
Post	23.4	5.9			20.9	6.8				8.0**
Percent change, %	−7.2	46.4			23.6	48.1				
Five chair stand, s										
Pre	11.2	3.2	0.07	0.498	16.8	5.2	0.17	0.144	0.004	1.6
Post	11.5	4.7			15.1	8.6				3.1
Percent change, %	5.0	31.3			−29.9	72.8				
Fear of falling, points										
Pre	36.6	4.4	0.18	0.081	32.9	6.2	0.51	<0.001	<0.001	26.2**
Post	37.1	3.9			35.9	3.5				15.4**
Percent change, %	1.5	7.3			12.9	23.3				

E/S, effect size.
[a]As calculated by comparing pre- and post-intervention.
[b]As calculated by group comparison.
*P < 0.05.
**P < 0.01.

percentile, 85–95%) for the robust group and 92% (85–95%) for the frail group. No health problems, such as cardiovascular and musculoskeletal complications, occurred during the training sessions or testing. Minor problems were observed in both groups such as aching muscles after the first training session and fatigue. All the problems were managed easily by adjustment of the intervention and were improved during subsequent interventions.

Effect of the resistance training on outcome measures

LLM after resistance training in the robust and frail groups was significantly increased from the baseline (P < 0.05) (Table 1, Figure 1B). Pre- and post-intervention group statistics and group × time interactions are summarised in Table 1. A statistically significant group × time interaction was observed for TUG, FR and fear of falling (P < 0.05) (Figure 1C). Bonferroni-corrected paired-sample t-tests demonstrated a significant effect of the resistance training on TUG, FR and fear of falling in the frail group (P < 0.025).

Discussion

In this study, we showed that LLM was improved by the resistance training programme in both groups. However, the effect on physical function was limited to frail elderly defined by TUG. The role of muscle strength on physical function is supported by numerous cross-sectional studies that have shown a strong association between low muscle strength and decreased mobility in elderly [18]. On the other hand, muscle strength does not depend solely on muscle mass, and the relationship between strength and mass is not linear [19]. Rantanen *et al.* reported that the relationship between muscle strength and physical disability in older adults is non-linear [20]. The discrepancy between these results may stem from the heterogeneity of subjects. In this study, we stratified subjects into robust and fail elderly groups. In frail elderly, the 50-week resistance training programme was effective for the improvement of LLM and physical performance. In contrast, there was no correlation between the change in LLM and physical performance in robust elderly undergoing the resistance training programme. These results suggested that our resistance training programme is not effective for the improvement of physical performance in robust elderly. Furthermore, resistance training improved muscle strength, but did not improve physical performance in the relatively healthy elderly [21]. On the other hand, in frail elderly, improvements in leg power, independent of strength, appear to make an important contribution to clinically meaningful improvements in physical performance [22].

Resistance training improved balance function, such as FR in frail elderly. Improved balance function with resistance training is hypothesised to occur by reduced motor-unit discharge variability [23]. However, SLS was not improved. These results suggested that balance improvement after power training may be explained, in part, by adaptations in force control. However, resistance training *per se* is not effective for balance function. For the improvement of balance function, it is useful to add not only the resistance training but also balance training, such as Tai Chi Chuan [24].

In addition to improving physical performance, the resistance training programme was effective for decreasing fear of falling, but only in the frail group. It is considered important to reduce fear of falling by targeting downstream factors such as physical functioning [25] or predictors of those factors [26]. Thus, our study has an important implication for the reduction in fear of falling in frail elderly.

There are several limitations to this study that warrant mention. First, although we used only TUG to define frailty, TUG may not be enough to define frailty. For example, the short physical performance battery evaluates balance, gait, strength and endurance by examining an individual's ability [27]. It has been recently recommended by an international working group to use a functional outcome measure in clinical trials in frail older adults [28]. Second, we did not measure muscle force. The relationship between LLM and muscle strength is still unclear and needs to be addressed in future studies. Third, no follow-up was conducted. Evidence regarding the long-term effect of exercise on fall prevention is limited, and, therefore, this issue also needs to be addressed. Finally, a control group was lacking. The participants in both groups may have had higher motivation and interest in health issues than the general elderly population.

This is the first study to demonstrate that the effects of a resistance training programme on physical performance differed according to the level of physical well-being. Future work should determine whether tailor-made interventions can effectively improve physical function in both robust and frail elderly.

Key points

- The current trial compared the effects of resistance training between robust and frail elderly on skeletal muscle mass, physical performance and fear of falling.
- Skeletal muscle mass after resistance training was significantly increased from the baseline in both groups.
- The resistance training programme was more effective for the improvement of physical performance and fear of falling in frail elderly than in robust elderly.

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Conflicts of interest

None declared.

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Seated stepping exercise in a dual-task condition improves ambulatory function with a secondary task: a randomized controlled trial

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ABSTRACT. ***Background and aims:*** *A close relationship exists between dual-task (DT)-related gait changes and the risk of falling in the elderly. However, the impact of DT training on the incidence of falls in the elderly remains unclear. We aimed to evaluate the effects of a seated stepping exercise in DT conditions to improve walking ability in community-dwelling elderly.* ***Methods:*** *This was a randomized controlled trial (RCT) in community-dwelling elderly in Japan. Fifty-three participants were randomly assigned to a DT group (stepping exercise in DT conditions, n=26) and a single-task (ST) group (stepping exercise in ST conditions, n=27). All participants received 50 min group training sessions, once a week for 24 weeks. Outcome measures were based on differences in walking ability in single-task (ST), cognitive-task (CT), and manual-task (MT) conditions between DT and ST groups.* ***Results:*** *Participants in the DT group showed significantly greater improvement in outcome measures, including 10-m gait speed, walking cadence, and cost during cognitive and manual tasks. The number of enumerated figures during CT, as well as the numbers of steps taken and of enumerated figures during stepping with MT demonstrated significant Group × Time interactions (p<0.05).* ***Conclusions:*** *This RCT suggests that the seated stepping exercise is more effective at improving ambulatory function in DT conditions than in ST conditions.*
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INTRODUCTION

In real-life situations, locomotion commonly occurs in complex conditions, cognitive attention being focused on events such as watching traffic or reading signs, rather than on performing specific motor tasks (1). With advancing age, locomotion during activities of daily living becomes more difficult, and often becomes a complex multi-task challenge (2). Hence, it is believed that some falls result from loss of balance during preoccupation with another attention-demanding activity.

Concurrent cognitive or motor tasks, such as talking or carrying objects, are crucial for mobility in daily life. Because of the increasingly recognized role of cognition in postural control and gait, many researchers have used dual-task (DT) paradigms which incorporate a concurrent cognitive task to improve fall risk assessment (3). For example, a concurrent cognitive task during standing postural control tasks can be used to discriminate between elderly with and without a history of falls (4). In addition, complex walking tasks, such as DT walking, may be more sensitive than simple walking tasks in identifying early decline in postural control among non-disabled elderly without apparent limitations in mobility (5). However, DT walking as a reliable predictor of falls is limited to elderly adults with higher functional capacity (6).

The effect of DT training on the incidence of falls in the elderly remains unclear. Melzer et al. (7) reported that regular exercise protects against physical functional loss in the elderly, and that DT performance improves with training and protects against decreases in voluntary step execution times during single-task (ST) but not during DT conditions. Hall et al. (8) showed that Tai Chi improved subjects' ability to allocate attention to balance in DT conditions. Although data on the effects of DT training on balance performance is limited, Kramer et al. (9) investigated DT training using 2 cognitive tasks unrelated to balance. Participants who were trained with variable-priority instructions (shifting attention between tasks) learned tasks faster and performed better than those who received training with fixed-priority instructions (placing equal amounts of attention on both tasks). These results support the importance of an instructional set in DT training.

Key words: Ambulatory function, dual-task, elderly, randomized control trial, stepping exercise.
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