jury (6). All older adults were community-dwelling and lived independently.

Participants were asked to report any neurological or musculoskeletal impairment, and were excluded from the study if any problems were reported. All participants were examined for cognitive functioning by the Mini-Mental State Examination and all attained a score of 24 or above, which was indicative of intact cognitive function. Participants' binocular visual acuity was examined with a Snellen eye chart, and all participants were found to have 20/40 vision or better. No participants wore spectacles during visual screening or the experimental task.

We performed a comfortable 10-m walking test, the timed up and go test, functional reach test, 1 leg standing test, and 5 chair stand test to assess balance and locomotion performance. The Mann-Whitney U-test was used to assess which group showed significant differences. Compared with the faller group, the non-faller group showed no significant differences in any measurement ($p>0.05$) (Table 1).

The experimental protocol was approved by the Kyoto University Graduate School of Medicine and all participants gave written informed consent prior to data collection.

Data collection

Gaze behavior was recorded on a bilateral head-mounted video-based eye tracker at a sampling frequency of 60 Hz (EMR-9, Nac Imagery Technology, Tokyo, Japan). The tracker superimposed gaze location on the video image recorded by a "scene camera" mounted rigidly on the head (7). These video images were used to determine when visual fixation (>50 ms) on the obstacle, walls or floor occurred. For visual fixations on the floor, gaze location was determined relative to a grid marked on the floor. An overhead video camera was used to resolve the step-landing site relative to this same grid and to determine whether obstacle contact occurred. A calibration procedure required each participant to stare at each of 9 points of a matrix placed in the frontal plane. This was followed during data collection by frame calibration, performed before and after each trial, relative to a set of reference points in the travel path.

Protocol

Participants stood with their eyes closed before each trial, while the 3-cm obstacle was placed at a random location between 4 and 6 m away on the walkway. The experimental set-up is illustrated in Figure 1A. On the verbal command of "Go," participants opened their eyes, walked down the walkway, and stepped over the obstacle. Five trials were collected in each condition. A trial began when participants opened their eyes and the gaze cursor first appeared. Participants could then direct their gaze to the locations of interest: on the walkway 4-6 m away, or the obstacle. The height, horizontal width and depth of the obstacle were 3 cm, 100 cm, and 1 cm, respectively.

In the single-task (ST) condition, participants walked down the walkway and stepped over the obstacle at a comfortable speed. In the DT condition, they did exactly the same, but while counting numbers aloud, starting from 100 in reverse order (serial 1s). The importance of walking and counting at the same time was emphasized to all participants, who were asked to walk and count to the best of their capacity without prioritizing either task. Counting mistakes were not corrected (8). Before the test was performed, a trained evaluator gave standardized verbal instructions regarding the test procedure, together with a visual demonstration of the trial. The order of performing these tasks was randomized.

Table 1 - *Baseline characteristics of study participants by group.*

		Faller group (n=9) mean±SD	**Non-faller group (n=9) mean±SD**	***p*-value**
Age		79.9±5.4	83.4±3.6	0.11
Height	cm	149.5±12.6	153.0±8.3	0.58
Body weight	kg	52.2±10.2	49.2±3.3	0.85
Gender, female	n (%)	5 (55.5%)	4 (44%)	0.50
MMSE	point	27.1±2.0	27.6±2.2	0.65
10-m walking time	sec	12.1±4.0	14.1±3.9	0.34
10-m walking steps	steps	22.7±4.1	22.4±2.4	0.86
Timed up and go test	sec	13.8±5.2	15.4±2.8	0.56
Functional reach	cm	24.1±3.8	21.3±3.8	0.16
One leg standing	sec	6.8±6.7	4.4±4.4	0.49
5 chair stand	sec	14.3±4.3	14.4±7.3	0.49

Values are expressed as means±standard deviation.

Data analysis

Frame-by-frame video-based analysis was performed to record which environmental features were fixed following each gaze transfer. Gaze behavior was defined relative to locations and objects within the scene as staring at a location in the walkway or a shift in gaze from one location to another. Two gaze behaviors (stare or saccade) were defined with minimum duration parameters derived from the available literature on eye movements. The minimum duration of a stare varies in the literature, ranging from 80 ms to 150 ms; it was set here at 99.9 ms (3 frames) and defined as stabilization of the gaze on a location in the environment. Therefore, both gaze and scene were moving at the same speed and the scene was not blurred. A saccade was coded when a rapid shift in gaze was observed from one defined location to another, with a movement time of ≥66.6 ms (≥2 frames). During a saccade, the scene was stable and the gaze moved between 2 meaningful locations.

The onset of step 1 was gait initiation. Heel strike defined the onset of subsequent steps. Duration of gaze behavior (obstacle fixation) was quantified for the approach phase, defined from the initiation of gait to the initiation of lead limb swing phase over the obstacle. The timing of gaze transfer from obstacle measures was quantified for 5 steps before the obstacle (n-5), 4 steps before (n-4), 3 steps before (n-3), 2 steps before (n-2), 1 step before (n-1), and finally the step over the obstacle (n).

Statistical analysis

A mixed-design ANOVA was used to evaluate the effects of each participant group (fallers *vs* non-fallers) and task condition (ST condition × DT condition) on the timing of gaze transfer from the obstacle. The *post-hoc* Bonferroni-adjusted Mann-Whitney U-test was used to assess which group showed significant differences (significance level $p<0.025$). The Bonferroni adjusted Wilcoxon test was used to assess which condition showed significant differences in each group (significance level $p<0.025$). Data were recorded and analysed with PASW Statistics 18.

RESULTS

The major findings from statistical analysis are shown in Figure 1. There were no significant main effects of task condition ($F_{(1,16)}=2.716$, $p=0.119$) or group ($F_{(1,16)}=3.277$, $p=0.089$). There was a significant interaction effect between group and task condition ($F_{(1,16)}=7.939$, $p=0.012$).

In the ST condition, compared with the faller group, the non-faller group showed no significant difference in timing of gaze transfer from the obstacle (faller: gaze transfer from obstacle at 1.6±1.1 steps before the obstacle; non-faller: 1.96±0.7 steps before, $p=0.493$) (Fig. 1B). In the DT condition, the faller group chose transfer of gaze strategy from the obstacle significantly earlier than the non-faller group (faller: 2.7±1.4 steps before; non-faller: 1.6±0.5 steps before, $p=0.008$) (Fig. 1B,C,D). There was no significant difference in timing of gaze transfer from the obstacle for the non-faller group between the ST and DT conditions ($p=0.414$) (Fig. 1B). However, there were significant differences in timing of gaze transfer from the obstacle for

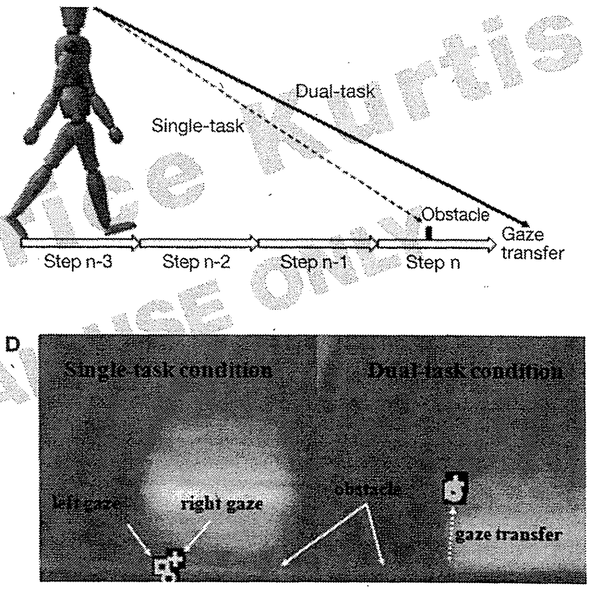

Fig. 1 - *Experimental Protocol and Gaze Behavior.* (A) *Sketch of experimental task. The 3-cm obstacle was placed at a random location 4-6 m away on the walkway. The timing of gaze transfer from the obstacle was quantified for 2 steps before (n-2), 1 step before (n-1) and the step over the obstacle (n).* (B) *In the ST condition, compared with the faller group, the non-faller group showed no significant difference in timing of gaze transfer from obstacle. In the DT condition, the faller group chose a transfer of gaze strategy from the obstacle significantly earlier than the non-faller group. *p<0.025.* (C,D) *Representative gaze behavior in faller group. In the ST condition, fallers looked at obstacle 3 steps before stepping over it. In the DT condition, fallers looked away from the obstacle 3 steps before stepping over it.*

the faller group between the two conditions ($p=0.008$) (Fig. 1B,C,D).

DISCUSSION

The results showed a similar pattern of gaze behavior in both groups in the ST condition. However, in the DT condition, the faller group looked away from the obstacle significantly sooner than the non-faller group.

Chapman and Hollands (8) reported that high-risk older adults looked away from a target significantly sooner and demonstrated less accurate and more variable foot placements than low-risk older adults. These findings suggested that high-risk older adults may prioritize the planning of future actions over the accurate execution of ongoing movements, and that adoption of this strategy may contribute to the increased likelihood of falls. This early transfer of gaze by high-risk older adults was accompanied by a significant increase in foot placement variability. The present study showed that the faller group looked away from the obstacle significantly sooner than the non-faller group. The faller group adopted a strategy whereby, to maximize the amount of time available to the central nervous system to plan future movements, participants transferred their gaze away from the obstacle 3 steps before it. This early transfer of gaze may also represent an attention deficit, anxiety, or additional diligence at a perceived approaching threat. Control of limb movements over an obstacle requires initiation of foot lift without visual input. Participants must use memory to plan and execute footlift, and this plan presumably involves executive cognitive functions. It is well documented that there are a number of psychological risk factors associated with falls in the elderly. Past research has also demonstrated that general anxiety has a detrimental effect on the functional performance of older adults. For example, anxious older individuals have been shown to perform worse during a dynamic postural control task (9, 10), and anxiety has been shown to be a significant predictor of decline in successful obstacle avoidance during locomotion (11).

There are several possible limitations to our study. First, the experimental set-up involving the negotiation of an obstacle course while undertaking a secondary task over a sustained period was more complex than conditions older people commonly encounter during daily activities. Second, obstacle avoidance strategy probably differs in indoor and outdoor environments. Third, an MMSE is not enough to assess cognitive function in a group for a confirmatory DT experiment. Fourth, our limited sample size may introduce some error of inference, reduce the power of the analysis, and limit generalization of results. Thus, the results of the present study should be viewed as preliminary.

Our findings suggest that fallers chose an early transfer of gaze strategy when challenged with an obstacle in DT conditions. Future research should determine whether a prospective cohort study on the relationship between frequency of falls and gaze shift abnormalities is warranted.

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Aging Clinical and Experimental Research

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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In this randomized controlled trial (RCT), we compared the effects of 2 different training approaches for community-dwelling elderly. As the elderly face similar situations in daily life, we attempted to develop a seated stepping exercise in DT conditions that could be easily performed indoors. Our pilot research demonstrated that DT walking ability and seated stepping ability in DT conditions are correlated (unpublished data). In addition, since there is no risk of falling from a seated position, participants may safely exert maximum stepping effort. We hypothesized that divided attention in DT conditions would be improved with a seated stepping exercise in DT conditions (DT stepping exercise) to a greater extent than in ST conditions (ST stepping exercise). We expected that the DT stepping exercise would be more effective in improving locomotive performance in DT conditions.

METHODS

Participants

Participants were recruited through public relations magazine advertisements, and had to be community-dwellers of at least 65 years of age. All participants were classified as strongly right-handed according to the Edinburgh Handedness Inventory (10). An initial interview ensured that participants met the following criteria: age 65+ years, community-dwelling, had seen a primary care physician within the previous 3 years, a total score of 24+ on the Mini-Mental State Examination (11), independently ambulatory (could use a cane), willing to participate in group exercise classes for at least 6 months, access to transportation, minimal hearing and vision impairment, and no regular exercise during the previous 12 months. Exclusion criteria were severe cardiac, pulmonary or musculoskeletal disorders, pathologies associated with increased fall risk (i.e., Parkinson's disease or stroke), osteoporosis, and the use of psychotropic drugs. These criteria were assessed through participant interviews. Seventy-eight subjects volunteered to participate; of these, 25 subjects did not meet the inclusion criteria, resulting in a study population of 53 participants. Written informed consent was obtained from each participant in accordance with guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

Study design and randomization

This RCT included 53 participants who met the inclusion criteria, randomized into 4 blocks. In this sequence, opaque envelopes bearing group names were numbered and the 53 participants were randomly assigned to the DT group (n=26) or ST group (n=27).

Intervention

All participants received 50-min group training sessions once a week for 24 weeks. Participants were randomly assigned to 1 of 2 training groups: 1) seated stepping exercise in DT conditions (DT group) or 2) seated stepping exercise in ST conditions (ST group). In order to judge the effect of pure DT training, a control group was not assigned in this trial. Each group was trained in a standardized format which included 20 min of moderate-intensity aerobic exercise, 20 min of progressive strength training, and 10 min of flexibility and balance exercises while seated, followed by exercises known to improve muscle strength and balance (12, 13). The aerobic exercise, performed from a seated position, involved movement of the legs, trunk and arms to involve all joint and major muscle groups. Strength training involved progressive resistance exercise involving movement of the legs and trunk against an elastic band. Participants did 2 sets (20 repetitions per set) of exercises on each muscle. Balance training consisted of lateral and anterior-posterior weight shifting (upper half of the body), also performed from a seated position. Participants did 2 sets (10 repetitions per set) of exercise in each direction. Although exercises could be performed while seated, there was emphasis on the importance of performing them in a standing position to improve balance. Physiotherapists made 2 evaluations during the study period, to ensure compliance with exercise protocols. The type, volume, and intensity of the exercises were the same in the two groups.

Both groups were instructed on seated stepping exercises using a standard dining room chair (Fig. 1). Par-

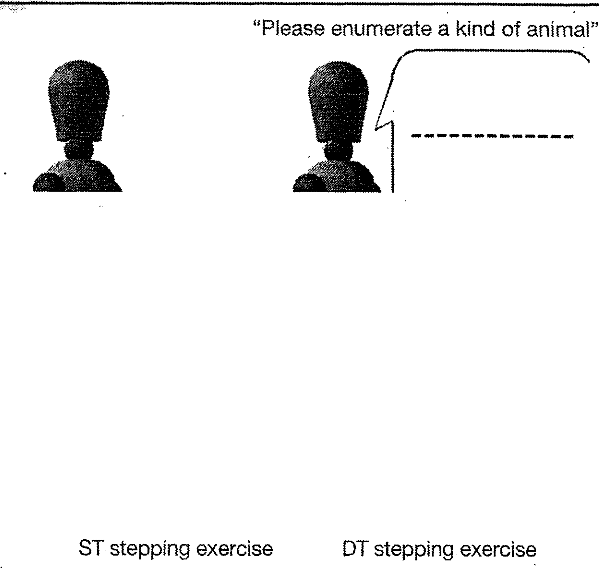

Fig. 1 - *Sketch of seated stepping exercise during dual-task condition. Participants were required to step out with both legs as quickly as possible and return legs to initial starting position. In DT group, participants were asked to perform a verbal fluency task during stepping (DT condition), consisting of enumerating words in a category (e.g., animal name, vegetable name, fruit name, fish name) or letter (e.g., a word that begins with "A") at a self-selected speed. In the ST group, participants were asked to perform stepping only (ST condition).*

ticipants stepped up and down alternating between left and right legs as quickly as possible while returning the legs to the initial starting position. The minimum lifting height for stepping was lifting the plantar surface from the ground. The intensity of the exercise was increased over the 12-week period by increasing the total stepping time. Both groups completed 10 sets of 5 s per set of stepping exercises in weeks 1-12, increasing to 10 sets of 10 s per set in weeks 13-24.

In the DT group, participants were asked to perform a verbal fluency task during stepping (DT condition), consisting of enumerating words within a category (e.g., animal name, vegetable name, fruit name, fish name) or letter (e.g., a word that begins with "A") at a self-selected speed. This task was self-generated; participants did not read from a list, but had to conceptualize and vocalize each word. The verbal fluency task was changed for each exercise session. Participants were not specifically instructed to prioritize either task, but were asked to combine both tasks as best they could. The instructions were as follows: "Please step as quickly as possible, and avoid making mistakes to the best of your ability." In the ST group, participants were asked to step without being given another task (ST condition). During exercises, the amount of stepping and number of terms given during the verbal fluency task were not measured.

Outcome measures

All participants underwent 7 measurements upon entry into the study (pre-test), including: timed up and go (TUG) test (14), functional reach (FR) (15), one-leg stand (OLS), 10-m walk in ST conditions (ST walking) (16), 10 m walk in cognitive-task conditions (CT walking) (17), 10 m walk in manual-task conditions (MT walking), and stepping while seated. After the 24-week period (post-test), they were evaluated by a physiotherapist who was blind to group allocation. All pre-test measures were completed prior to randomization. Before commencing the study, all staff members received training from the author (M.Y.) on the correct protocols for administering all assessment measures included in the study.

TUG is one of the most frequently used tests for balance and gait and is often used to assess fall risk in older adults. During 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. Time measured in seconds began at the word "go" and ended when the participant's back touched the backrest of the chair. Shorter time intervals required to accomplish this task indicate better balance, strength and power. A practice trial was performed, followed by 2 recorded trials. The recorded times for the 2 trials were averaged to give the TUG score.

In FR, each participant was asked to stand near a wall with one arm raised at 90° and fingers extended. A yardstick was mounted on the wall at shoulder height. The distance covered while reaching forward from an initial upright posture to the maximal anterior leaning posture without moving or lifting the feet was visually measured in cm at the third fingertip position against the mounted yardstick. Distances measured for 2 trials were averaged to obtain the FR score, higher value indicating better balancing ability. FR was measured for both arms in all participants.

In OLS, participants were instructed to start from a position with a comfortable base as support, with eyes open and arms hanging by their sides. They were then instructed to stand unassisted on one leg (left or right, participant's choice). 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, longer times indicating better balance. Times measured for the 2 trials were averaged to obtain the OLS score.

In ST walking, participants walked 15 m at a comfortable speed in normal conditions. The time required to complete 10 m within the 15 m walk was recorded by a stopwatch. The times recorded for 2 trials were averaged for the ST walking score. The variables recorded were time, steps, and cadence (in steps/second).

In CT walking, participants walked 15 m at a comfortable speed while counting numbers aloud in reverse order starting at 50. The importance of simultaneous walking and counting was emphasized to all participants, who were asked to walk and count to the best of their ability without prioritizing either task. Before the test was performed, a trained evaluator gave standardized verbal instructions regarding the test procedure, together with a visual demonstration of the walking test (18). The numbers counted and steps taken were video-recorded. We defined the number of enumerated figures while walking as the number achieved at completion of the 10 m distance. Counting mistakes were not corrected (17). Test-retest reliability with the intra-class correlation coefficient (ICC [1.1]) was 0.978. The times recorded for the 2 trials were averaged to obtain the CT walking score. The variables recorded included time, steps, and cadence (in steps/minute). The CT cost was then calculated as follows:

*CT cost [%] = 100 * (ST walking speed – CT walking speed) / ((ST walking speed + CT walking speed) / 2)*

In MT walking, participants walked 15 m at a comfortable speed while carrying a ball (150 g, 7 cm diameter) on a tray (50 g, 17 cm diameter). The instructions were as follows: "Walk at a comfortable speed while carrying this tray and ball in your left hand (or the hand without a cane)". Dropping the ball or tray was considered as a failure. Before the test was performed, a trained evaluator gave standardized verbal instructions regarding the test procedure, together with a visual demonstration of the test. Test-retest reliability with the intra-class correlation coefficient (ICC [1.1]) was 0.976. The times recorded for the 2 trials were averaged to obtain the MT walking score.

Time, steps, and cadence (in steps/minute) were recorded as variables. The MT cost was then calculated as follows:

$$MT\ cost\ [\%] = 100 * (ST\ walking\ speed - MT\ walking\ speed) / ((ST\ walking\ speed + MT\ walking\ speed) / 2)$$

For stepping, participants were asked to count backwards from 70, aloud, while stepping from a seated position at 40 cm. They were asked to step as quickly as possible, and the 5-s step total was measured on a 60 × 55 cm step counter sheet (TKK 5301; Takei Scientific Instruments Co. Ltd., Niigata, Japan). We defined the number of enumerated figures while stepping as the number achieved within 5 s. Test-retest reliability with the intra-class correlation coefficient (ICC [1.1]) was 0.988. The number of steps measured for the 2 trials were averaged to obtain the Stepping score.

Required sample size

A preliminary survey for this study showed that the DT stepping exercise produced a large improvement in CT walking time among 15 community-dwelling Japanese elderly (pre-intervention= 12.6±3.4 s, post-intervention= 9.6±2.5 s). With a significance level of 0.05, a power of 80%, and a large effect size (0.9), 21 participants were needed in both intervention and control groups. Accounting for a potential 20% attrition rate, 50 participants were targeted for this study. The number of recruited participants was large enough to detect statistically significant differences.

Statistical analysis

Differences in baseline characteristics were compared between the DT and ST groups by Student's *t*-test or the chi-square test. The Kolmogorov-Smirnov test and Mann-Whitney U-test were used to evaluate the normality of distributions and differences in baseline characteristics between groups, respectively.

Analysis of covariance (ANCOVA) was used to determine the effect of the exercise program on each outcome measure, with baseline values as covariates. Tukey's *post-hoc* test was used to assess which group or time showed a significant difference. Data were analysed with the Statistical Package for Social Science (Windows version 11.0). A *p*-value <0.05 was considered statistically significant.

RESULTS

We enrolled 53 of 78 screened individuals (68%) who were eligible for this study. Of those who did not meet the inclusion criteria (n=25), most were excluded because they had exercised regularly for 6 months prior to screening. Three people who may have been eligible declined after a round of telephone screening. Of the 53 subjects, 50 (94%) completed the protocols and returned for their exit interviews and final testing (mean age, 80.8±6.7 yrs; range, 67-97 yrs) (Fig. 2).

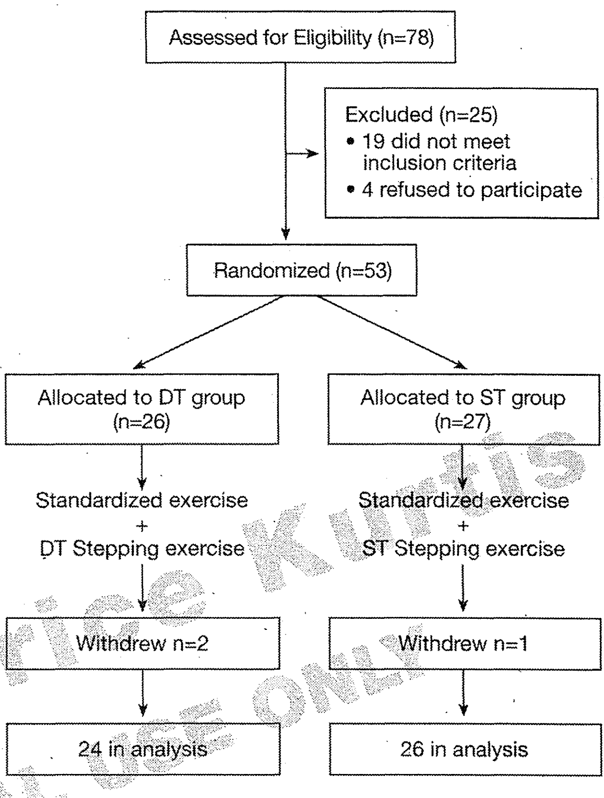

Fig. 2 - *Flow chart depicting participant positions throughout trial.*

All 24 of the scheduled intervention sessions were completed. The median relative compliance was 100% (25th-75th percentile, 95.8-100%) for the DT group and 100% (95.8-100%) for the ST group. No health problems, including cardiovascular or musculoskeletal complications, occurred during training or testing. Minor problems observed in both groups included aching muscles after initial training sessions and fatigue. All problems were easily managed through adjustment of the intervention and improved during intervention.

Baseline characteristics

The Kolmogorov-Smirnov test showed that the weight and MMSE score were not normally distributed. The DT and ST groups were comparable and well matched with regard to their baseline characteristics. No significant differences were noted between group means for age (DT= 80.3±5.4, range 67-97 yrs; ST= 81.2±7.6, range 71-89 yrs; *p*=0.631), gender distribution (DT= 75.0% female and ST= 76.9% female, *p*=0.567), body weight (DT= 52.8±6.9 kg, ST= 49.9±8.1 kg; *p*=0.151), height (DT= 148.1±5.6 cm, ST= 146.6±7.2 cm; *p*=0.394), walking aids (DT= 12.5%, ST= 34.5%; *p*= 0.704), fall occurrence within the previous year (DT=29.1%, ST=23.0%; $p=0.751$) or MMSE score (DT= 28.0±2.1 points, ST= 27.8±1.8 points; $p=0.820$).

Effect of exercise program on outcome measures

Pre-intervention and post-intervention group statistics and Group × Time interactions are shown in Tables 1 and 2. Significant differences were observed between the 2 groups for CT 10-m gait speed, CT 10-m walking cadence, CT cost, number of enumerated figures during CT, MT-10 m gait speed, MT-10 m walking cadence, MT cost, quantity of stepping, and number of figures enumerated during stepping with significant Group × Time interactions. Participants in the DT group demonstrated marked improvements in the above test items ($p<0.05$; Tables 1 and 2). Tukey's *post-hoc* test showed significant differences in favor of the DT group in MT 10-m gait speed, 10-m walking cadence, and cost ($p<0.05$).

DISCUSSION

Community ambulation requires the ability to integrate walking with other tasks in a complex environment. DT gait assessment may prove helpful for identifying those individuals with general gait performance difficulty when tested in a complex environment. In the present study, gait performance in DT conditions im-

Table 1 - *Functional fitness (locomotion) before and after intervention.*

	Pre-intervention	Post-intervention		Group × Time F-value p-value
SINGLE-TASK CONDITION				
ST 10-m gait speed, m/sec				
DT group	1.24±0.27 (0.55-1.53)	1.12±0.32 (0.60-1.94)		0.545
ST group	0.95±0.30 (0.57-1.83)	1.00±0.30 (0.62-1.80)		0.464
ST 10-m walking step, steps				
DT group	21.3±4.9 (14-30)	20.8±5.0 (14-30)		2.284
ST group	22.2±5.0 (14-32)	23.0±5.6 (16-38)		0.113
ST 10-m walking cadence, steps/min				
DT group	126.6±15.7 (98.3±158.7)	132.1±17.3 (95.5-162.7)		2.803
ST group	120.1±17.6 (78.8-153.8)	130.4±18.1 (103.7-172.6)		0.101
DUAL-TASK CONDITION				
CT 10-m gait speed, m/sec				
DT group	0.88±0.30 (0.39-1.53)	0.97±0.31 (0.46-1.63)	†	6.509
ST group	0.85±0.30 (0.36-1.69)	0.83±0.28 (0.41-1.68)		0.014*
CT 10-m walking step, steps				
DT group	21.2±4.6 (14-34)	20.3±4.6 (14-32)		0.862
ST group	22.2±4.5 (14-32)	22.1±4.8 (12-32)		0.429
CT 10-m walking cadence, steps/min				
DT group	105.9±22.4 (54.5-142.8)	112.4±21.8 (72.6-157.4)		5.128
ST group	108.3±25.9 (56.5-154.2)	103.5±17.8 (63.4-131.9)		0.027*
CT cost				
DT group	18.5±21.9 (-14.1-72.0)	14.7±17.5 (-11.7-67.3)		7.614
ST group	12.4±21.0 (-16.0-72.0)	22.0±17.5 (-8.8-56.2)		0.008**
CT number of enumerated figures, number/sec				
DT group	1.16±0.24 (0.6-1.6)	1.28±0.34 (0.6-2.0)	†	6.360
ST group	1.19±0.25 (0.6-1.6)	1.17±0.25 (0.8-1.7)		0.015*
MT 10-m gait speed, m/sec				
DT group	1.02±0.28 (0.43-1.54)	1.14±0.30 (0.51-1.69)	†	15.681
ST group	0.99±0.33 (0.40-1.84)	0.95±0.33 (0.54-1.86)	$	<0.001**
MT 10-m walking step, steps				
DT group	21.5±5.7 (14-38)	20.8±5.2 (16-36)		1.732
ST group	22.5±6.9 (14-46)	23.1±6.8 (14-42)		0.195
MT 10-m walking cadence, steps/min				
DT group	124.2±15.8 (95.2-153.1)	134.5±17.9 (101.1-162.1)	†	5.128
ST group	128.7±19.4 (79.4-163.6)	122.1±19.3 (91.3-156.1)	$	0.027*
MT cost				
DT group	2.17±16.45 (-35.8-40.2)	-1.63±9.60 (-25.3-17.6)		10.989
ST group	-2.62±15.66 (-24.3-35.5)	8.13±14.71 (-20.5-28.5)	$	0.002**

Columns indicating pre- and post-intervention values provide mean±standard deviation (minimum - maximum). †As calculated by comparison with pre-intervention values: p<0.05. $As calculated by group comparison; p<0.05. *p<0.05, **p<0.01.

Table 2 - *Functional fitness (other function) before and after intervention.*

	Pre-intervention	**Post-intervention**		**Group × Time F-value p-value**
TUG, s				
DT group	11.3±2.6 (8.0-17.2)	10.8±3.6 (6.8-21.8)		1.575
ST group	12.0±3.3 (6.6-18.4)	12.2±4.5 (5.6-24.3)		0.215
Functional reach, cm				
DT group	25.4±7.4 (8-35)	26.2±7.4 (8-36)		0.023
ST group	24.7±6.2 (11-41)	25.3±6.0 (15-38)		0.881
One leg standing, s				
DT group	7.3±6.8 (1.1-21.3)	8.7±6.0 (1.1-21.3)		0.379
ST group	6.9±8.2 (0.50-28.5)	10.5±17.5 (1.37-59.0)		0.541
Stepping step, steps/5sec				
DT group	25.1±7.7 (10-39)	28.6±7.3 (16-45)	†	10.458
ST group	26.4±10.3 (7-55)	25.0±11.8 (8-55)		0.002**
Stepping number of enumerated figures, number/5sec				
DT group	6.83±2.77 (3-12)	8.12±2.34 (3-11)	†	6.435
ST group	7.39±2.39 (4-12)	7.21±2.18 (3-12)		0.014*

Columns indicating pre- and post-intervention values provide mean±standard deviation (minimum - maximum). †As calculated by comparison with pre-intervention values; $p<0.05$. $As calculated by group comparison; $p<0.05$. *$p<0.05$, **$p<0.01$.

proved after intervention. Therefore, our novel DT stepping exercise program may help improve ambulatory function in the community.

Balance did not improve after intervention, as evaluated by TUG, FR and OLS. In other words, neither standard exercises nor stepping exercises improved balance. TUG is constructed by a number of elements: standing up, walking, turning, and sitting down. A stepping exercise only affects the walking component, not the standing up, turning, or sitting down components, which may account for the lack of TUG improvement. These results suggest that standard and stepping exercises are limited in preventing fall risk.

This study demonstrated significant improvements in walking speed in CT and MT conditions following DT stepping exercise. The reasons for these positive findings remain unclear. However, we used a task-oriented program in this study. Previous research on cognitive-sensory-motor DT situations has shown that older participants decline more in DT-related performance than young adults, and tend to focus their attention more strongly on the sensory-motor task when given two demanding tasks (19). Another explanation may be that traditional exercise regimens emphasize balance training in ST conditions, which may only improve ST functioning. This hypothesis is supported by Silsupadol et al. (20), who found that the elderly can improve their balance in DT conditions only following DT balance training. These outcomes also support the hypothesis of Kramer et al. (9) that improvements in novel DT processing skills can be generalized to other simultaneous tasks which are not directly trained. This suggests that explicit instructions should be provided to focus attention during balance training in DT conditions.

It is important to note that walking speed improved in both CT and MT conditions, despite the use of a cognitive task such as verbal fluency during exercise. This finding suggests that the elderly are able to improve their walking speed in DT conditions only after specific types of training. This in turn suggests that improvement in DT walking may be the result of both automatization of an individual task and the development of task coordination skills. Participants in the DT group may have learned to coordinate performances efficiently between the 2 tasks as they improved in each task (9). These results indicate the importance of instructions given while training in DT conditions. Participants may learn to allocate their limited attention between primary and secondary tasks during the DT stepping exercise. Improvements in division of attention may then influence DT walking ability. This motivates training across different DT modalities (cognitive and manual) to improve divided attention. This study demonstrated that our seated stepping exercise program can improve divided attention in DT conditions. Locomotive speed in a real-life environment is not necessarily fast because the walking speed at examination is fast. The improvement in DT walking speed becomes manifest as increased capacity in a real-life environment.

There are several limitations to this study. First, for the DT group, stepping numbers may have been reduced in comparison with those in the ST group because of the added burden of the secondary task. If the stepping numbers were normalized in the DT and ST groups in training, the DT group may experience further improvement. Second, no follow-up was conducted. Evidence regarding the long-term effects of exercise on fall prevention is poorly understood. Third, statistical analyses were performed for each of the 6 outcome measures, including the physical performance test, which increases the possibility of false-positive findings. Fourth, no control group was enrolled. The participants in both groups may have had greater motivation and interest in health issues and fall risk than the general elderly population.

CONCLUSIONS

This is the first study to examine DT stepping exercise in the elderly. The results suggest that the DT stepping exercise is more effective at improving ambulatory function in cognitive and manual task conditions than when performed in isolation.

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Rhythmic stepping exercise under cognitive conditions improves fall risk factors in community-dwelling older adults: Preliminary results of a cluster-randomized controlled trial

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Objective: The purpose of this pilot trial was to evaluate whether a 24-week program of rhythmic stepping exercise (RSE) would be effective in improving physical function and reducing fear of falling in older adults.
Participants: Four units ($n = 52$) randomized into an RSE group (two units, $n = 25$) and a non-rhythmic stepping exercise (NRSE) group (two units, $n = 27$) participated in a pilot cluster randomized controlled trial.
Methods: Each exercise group received 60 min group training sessions once a week for 24 weeks. Measurement was based on the difference in physical functions between the RSE and NRSE groups.
Results: Significant differences were observed between the two groups for locomotive function with significant group × time interaction. Relative risk was calculated as 2.778 (95% CI: 1.030–7.492) for fear of falling for participants in the NRSE group compared with patients in the RSE group ($p = 0.037$).
Conclusions: The results of this pilot trial suggest that the RSE program is more effective in improving locomotive function and fear of falling.

Keywords: rhythmic stepping exercise; fall risk; older adults

Introduction

Approximately half of the community-living older population experiences fear of falling (Fletcher & Hirdes, 2004; Howland et al., 1998; Tinetti, Richman, & Powell, 1990; Yardley & Smith, 2002). The wide range of prevalence estimates for fear of falling (29–77%) may be due to differences between sample groups with respect to age, sex, activity level, history of falls, measures of fear, and other comorbidities (Arfken, Lach, Birge, & Miller, 1994; Friedman, Munoz, West, Rubin, & Fried, 2002; Lachman et al., 1998; Lawrence et al., 1998; Tinetti, Mendes de Leon, Doucette, & Baker, 1994; Vellas, Wayne, Romero, Baumgartner, & Garry, 1997). 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 and social participation, physical frailty, falls, and loss of independence (Arfken et al., 1994; Cumming, Salkeld, Thomas, & Szonyi, 2000; Delbaere, Crombez, Vanderstraeten, Willems, & Cambier, 2004; Friedman et al., 2002; Howland et al., 1993; Lachman et al., 1998; Yardley & Smith, 2002). In addition to the adverse effects often displayed by individuals who suffer from fear of falling, there are also consequences for public expenditure as healthcare utilization increases (Cumming et al., 2000). It is therefore considered important to reduce fear of falling by targeting the downstream factors, such as increasing physical functioning (Delbaere et al., 2004), or predictors of those factors, such as the use of improved medication (Friedman et al., 2002). As older people with fear of falling often adapt their gait, commonly described as 'cautious' or 'fearful' gait (Giladi, Herman, Reider-Groswasser, Gurevich, & Hausdorff, 2005), this fear can lead to imbalance during walking. In contrast to static balance, however, little is known about dynamic balance in older people, which may be more important and directly related to falls and fear of falling (Maki, 1997), since most falls occur during movement.

In real-life situations, the requirements for stepping commonly occur under more complicated circumstances with cognitive attention focused on a particular task, such as watching traffic or reading street signs or advertisements, rather than performing a specific motor task (Chen et al., 1996). With advancing age, the performance of daily life activities in addition to walking becomes increasingly difficult, and can often lead to complex multi-task situations, which increases the risk of falling (Bloem, Valkenburg, Slabbekoorn, & Willemsen, 2001). Hence, it is considered that certain falls result from the inability to recover from a misstep during an additional attention-demanding task during daily life activities. Mobility involving concurrent cognitive or motor tasks, such as talking or carrying objects, is crucial in daily life. Due to the increasingly recognized role of cognition in postural control and gait, a number of researchers have used dual-task (DT) paradigms that incorporate a concurrent cognitive task (CT) to improve fall risk assessment (Woollacott & Shumway-Cook, 2002).

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Dual tasking requires individuals to divide their attention, which may interfere with gait and balance control (Shumway-Cook & Woollacott, 2000). Based on Gaze's study on the influence of anxiety on attentional demands during walking, it is thought that the fear of falling reduces the amount of cognitive resources available for gait and balance control (Gage, Sleik, Polych, McKenzie, & Brown, 2003). The effect of fear of falling on gait and balance may therefore be more apparent when people perform a second task during walking, as often occurs in daily life. However, the effect of training on the incidence of falls and ability under DT conditions in older adults remains unclear.

The ability to modulate attention may also play an important role in the acquisition of multiple-task coordination skills. We proposed that rhythmic stepping exercise (RSE) under cognitive conditions may help improve DT ability, as RSE simultaneously requires both cognitive (reaction, short-term memory, etc.) and motor function (step to multi-direction).

In this trial, we evaluated whether a newly developed 24-week RSE program would be effective in improving physical function and reducing fear of falling in community-dwelling older adults. We hypothesized that physical function would be improved to a greater extent in elderly individuals who performed RSE than those who did non-rhythmic stepping exercise (NRSE).

Methods

Participants

Participating institutions were recruited by means of an advertisement in the local press. Four living areas in Kyoto, Japan, including 62 community-dwelling older adults participated in a 24-week randomized controlled trial. From each living area, defined as a cluster, individuals were selected according to the following inclusion criteria: age 65 years or older, community dwelling, had visited a primary care physician within the previous three years, a Rapid Dementia Screening Test (Kalbe, Calabrese, Schwalen, & Kessler, 2003) score of 8 or greater, ability to walk independently, 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. We also used an interview to exclude participants based on the following exclusion criteria: severe cardiac, pulmonary, or musculoskeletal disorders; pathologies associated with increased risk of falls, such as Parkinson's disease or stroke; osteoporosis; and the use of psychotropic drugs.

After the collection of baseline data, a researcher not involved in the study allocated clusters using computer-generated randomization lists. We obtained written informed consent from each participant who was included in the trial in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine (Approval number: E-547) and the Declaration of Human Rights, Helsinki, 2000.

Intervention

All participants received 60-min group training sessions once a week for 24 weeks. Participants were randomly assigned to one of the two training groups: (1) a standardized training with RSE group and (2) a standardized training with NRSE group.

The exercise classes were individualized for each group and were supervised by a physiotherapist. Each exercise class used a standardized format that included 15 min of moderate-intensity aerobic exercises, 15 min of progressive strength training, 10 min of flexibility and balance exercises, and 10 min of cool-down activities, followed by exercises known to improve muscle strength and balance (Buchner et al., 1997; Gardner, Robertson, & Campbell, 2000).

The stepping exercises were performed on a thin elastic mat (150 × 150 cm) that was partitioned into five squares (50 cm each) to form a cross (Figure 1A). The stepping exercises included forward, backward, and sideways step patterns. In the RSE group, the participants were required to step at a tempo of 60–120 beats per min according to the accompanying rhythm sound, and step into the square indicated verbally by the supervisor (e.g., 'right,' 'forward,' 'back,' etc.) (Figure 1C). For the RSE group, a cognitive function (reaction, short-term memory, etc.) and motor function (step to multi-direction) were simultaneously required of the participants. In order to vary the levels of difficulty, the instruction method transposed not only direction, but also an index of a color (e.g., 'red,' 'blue') or a number (e.g., '3,' '7') (Figure 1B). Participants completed five sets of one min per set of stepping exercises between weeks one and eight, which were then increased to three sets of three min per set between weeks 9 and 16, and three sets of five min per set between weeks 17 and 24. The instructions given at the beginning of each class were as follows: 'Please step as correctly as possible, and avoid making mistakes to the best of your ability'. During the exercises, the number of mistakes made during the stepping tasks was not recorded.

NRSE was a simple reaction stepping task. The participants were required to maintain a standing position, and step into the indicated square as quickly as possible after a verbal command from the supervisor (e.g., 'right,' 'forward,' 'back,' etc.) (Figure 1D). These sessions were designed as controls for the additional element of physical activity and reaction training in the RSE session. Participants completed five sets of 10 steps per set of stepping exercises between weeks 1 and 8, which were then increased to three sets of 30 steps per set between weeks 9 and 16, and three sets of 50 steps per set between weeks 17 and 24. The instructions given at the beginning of each class were

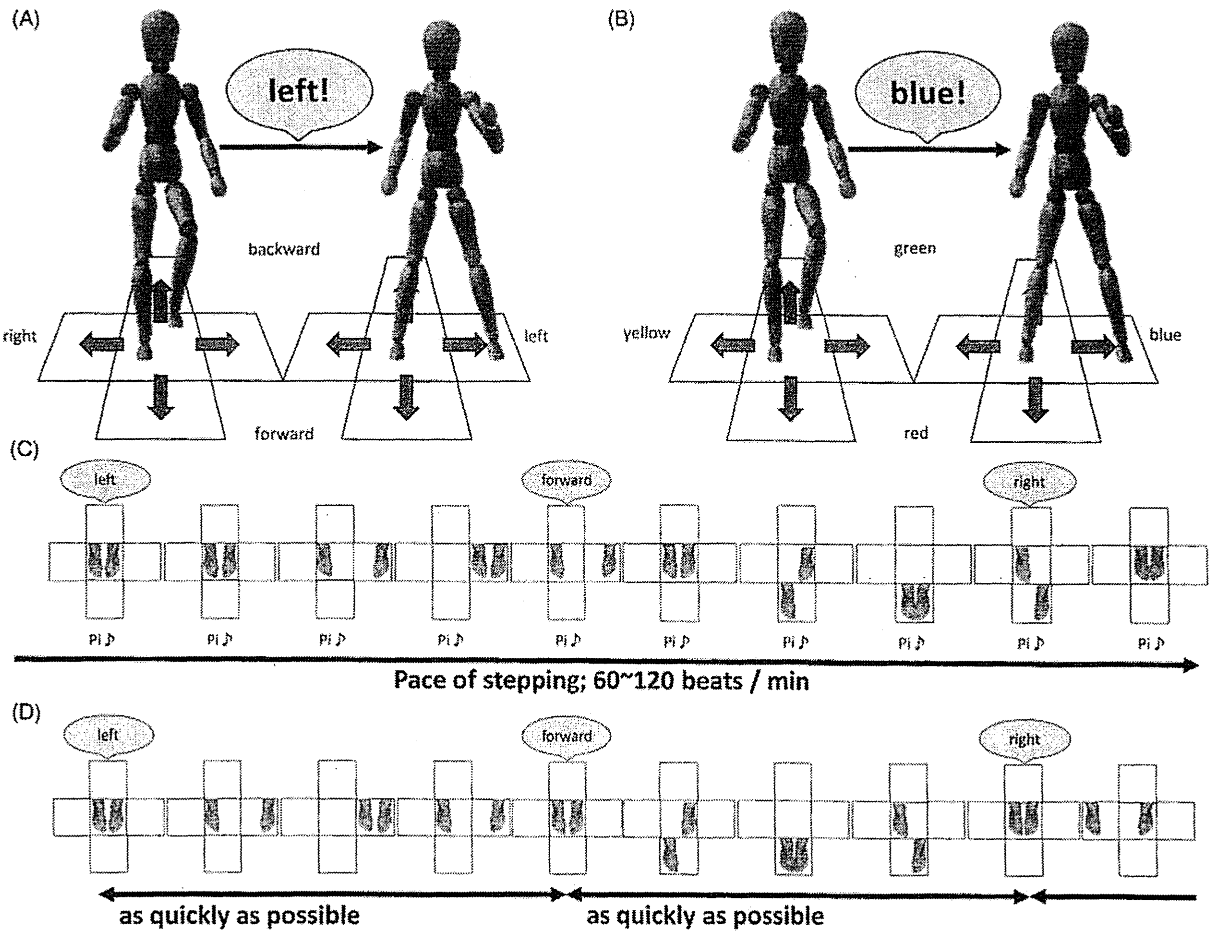

Figure 1. (A) Schematic representation of the stepping exercises. The stepping exercises were performed on a thin elastic mat that was partitioned into five squares (50 cm^2 each) to form a cross shape. The stepping exercises included forward, backward, and sideways step patterns. (B) Schematic representation of the version which made directions the 'color.' The participants were required to step into the square indicated verbally by the supervisor (e.g., 'red,' 'yellow,' 'blue,' etc.). (C) Schematic representation of the RSE. In the RSE group, participants were required to step at a tempo of 60–120 beats per min according to the accompanying rhythm sound, and step into the square verbally indicated by the supervisor (e.g., 'right,' 'forward'). The instructions were as follows: 'Please step as correctly as possible, and avoid making mistakes to the best of your ability'. The RSE required simultaneous cognitive (reaction, short-term memory, etc.) and motor function (step to multi-direction). (D) Schematic representation of the NRSE. In the NRSE group, participants were required to maintain a standing position and step into the indicated square as quickly as possible after a verbal command from the supervisor (e.g., 'right,' 'forward'). The instructions were as follows: 'Please step as quickly as possible, and avoid making mistakes to the best of your ability'. The NRSE required separate cognitive (reaction, short-term memory, etc.) and motor function (step to multi-direction).

as follows: 'Please step as quickly as possible, and avoid making mistakes to the best of your ability'. The NRSE required cognitive function (reaction, short-term memory, etc.) and motor function (step to multi-direction) separately.

Fear of falling

We assessed fear of falling by asking the single yes or no question 'Are you afraid of falling?', which has a high test–retest reliability (Reelick, van Iersel, Kessels, & Rikkert, 2009). This question was asked at the pre- and post-intervention. The test–retest reliability using the Kappa coefficient was 0.960.

Secondary outcome measures

All participants underwent nine measurements upon entry into the study (pre-test), which included: body weight, height, 10-m walk under a single-task (ST) condition (ST walking; Lopopolo, Greco, Sullivan, Craik, & Mangione, 2006), 10-m walk under a cognitive-task condition (CT walking; Beauchet et al., 2007), 10-m walk under a manual-task condition (MT walking), timed up and go (TUG) test (Podsiadlo & Richardson, 1991), and functional reach (FR; Duncan, Studenski, Chandler, & Prescott, 1992). In CT walking, participants walked 15 m at an individually comfortable speed while counting numbers aloud in reverse order starting at 50. In MT walking, participants walked 15 m at an individually comfortable speed while carrying a ball (7 cm in diameter, 150 g in weight) on a tray (17 cm in diameter, 50 g in weight). The ST gait speed was subtracted from the CT (MT) gait speed to represent CT (MT) cost as a percentage, which was then further divided by the ST gait speed to produce a percentage change in performance with the addition of a second task. A physiotherapist blinded to the group

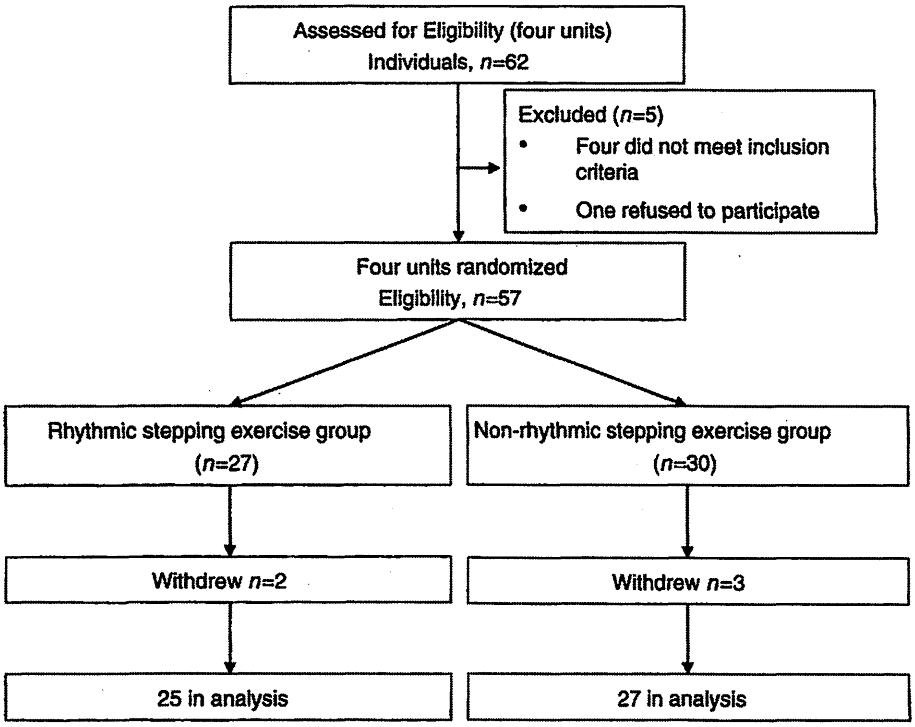

Figure 2. Flow chart showing the dispositions of participants throughout the trial.

allocations administered these measures at baseline and upon completion of the 24-week intervention.

Statistical analysis

We designed the effect size of this study to detect 0.8. With a significance level of 0.05, a power of 80%, and a large effect size (0.8), 26 participants were needed in both the intervention and control groups. Accounting for a potential 10% attrition rate, a total of 58 participants were targeted for this study, which was large enough to detect statistically significant differences.

We first compared baseline characteristics between the RSE and NRSE groups to examine comparability between the two groups. Differences in the data of physical function variables between the RSE and NRSE groups were analyzed by the Student's t-test or chi-squared test. The Kolmogorov–Smirnov and Mann–Whitney U-tests were used to test the normality of distributions and differences in physical function variables between the groups, respectively. We analyzed the effect of exercise on outcome measurements using a mixed 2 (group: RSE and NRSE groups) x 2 (time: pre-intervention, post-intervention) ANOVA. Tukey's *post hoc* tests were used to assess which group or time periods showed significant differences. Relative risk was then calculated, and the chi-squared test was used to evaluate the effect of intervention on fear of falling.

Data were entered and analyzed using the Statistical Package for Social Science (Windows Version 18). $p < 0.05$ was considered statistically significant for all analyses.

Results

We enrolled 57 of the 62 screened individuals (91.9%) who were eligible for this study (Figure 2). Of those who did not meet the inclusion criteria ($n = 4$), most were excluded because they had exercised regularly during the six months prior to screening. Three people who were eligible for the study declined after the initial telephone screening. Of the 57 selected subjects, 52 (91.2%) completed the study protocols and returned for their exit interviews and final testing (mean age, 71.8 ± 4.5 years; range, 65–79 years).

All 24 of the scheduled intervention sessions were completed. The median relative compliance was 100% (25th–75th percentile, 95.8–100%) for the RSE group and 95.8% (91.6–100%) for the NRSE group. No health problems, including cardiovascular or musculoskeletal complications, occurred during the training sessions or testing. Minor problems observed in both groups included aching muscles after initial training sessions and fatigue; however, all problems were easily managed through adjustments of the intervention, and subsequently improved during intervention.

Baseline characteristics

The RSE and NRSE groups were comparable and well-matched with regard to their baseline characteristics (Table 1).

Effect of the exercise program on secondary outcome measures

Pre- and post-intervention group statistics and group-time interactions are summarized in Table 2.

Table 1. Baseline characteristics of study participants by randomized RSE and NRSE groups.

Characteristic	RSE ($n=25$)	NRSE ($n=27$)	p
Age (y)	70.8±4.6	72.8±4.3	0.120
Body weight (kg)	50.1±4.8	54.4±8.1	0.068
Height (cm)	152.1±4.2	154.8±9.6	0.157
Gender, female, *n* (%)	20 (80.0%)	20 (74.1%)	0.431
Walking aids, *n* (%)[a]	0 (0%)	0 (0%)	
Falls in the last year, *n* (%)[b]	7 (28.0%)	8 (29.6%)	0.571
RDST (point)	9.8±1.7	9.6±2.0	0.270

Notes: RSE, rhythmic stepping exercise; NRSE, non-rhythmic stepping exercise; RDST, rapid dementia screening test; and values represent the mean ± standard deviation.
[a]Number (percentage) of participants who used walking aids
[b]number (percentage) of participants who experienced one or more falls in the last year.

Participants in the RSE group had significantly greater improvements in outcome measures including ST 10-m walking time, CT 10-m walking time, CT cost, MT 10-m walking time, and TUG ($p < 0.05$).

Effect of the exercise program on fear of falling

In the pre-intervention period, fear of falling was 44.0% and 37.0% for the RSE and NRSE groups, respectively. The relative risk was calculated as 0.842 (95% CI: 0.434–1.631) for fear of falling for participants in the NRSE group compared with patients in the RSE group ($p=0.778$). In the post-intervention phase, fear of falling had reduced to 16.0% for the RSE group and had slightly increased to 44.4% for the NRSE group. Relative risk was calculated as 2.778 (95% CI: 1.030–7.492) for fear of falling for participants in the NRSE group compared with patients in the RSE group ($p=0.037$).

Discussion

The RSE under cognitive condition program requires the use of multiple domains, such as reaction, short-term memory, and stepping to multi-directions, that when impaired, have been shown to increase fall risk among elderly individuals (Dite & Temple, 2002; Melzer, Kurz, Shahar, Levi, & Oddsson, 2007; Sturnieks, George, Fitzpatrick, & Lord, 2008; Yamada & Ichihashi, 2010). Our cluster-randomized controlled trial demonstrated that RSE, which represents a novel exercise program, was more effective than simple reaction stepping exercise for improving ambulatory function under ST and DT conditions in older adults. Furthermore, perceived fear of falling was significantly improved in the RSE group upon completion of the 24-week exercise program. The RSE program is postulated to have effects on ambulatory function under ST and DT conditions that might directly affect fear of falling.

In this study, significant improvements in walking ability under CT and MT conditions following the RSE program were identified. These results indicate the importance of instructions when step training under complex-task conditions, and also suggest that effectively improving these functions leads to decreased fear of falling. The RSE program requires simultaneous cognitive and motor functions, and therefore represents training under DT conditions. Previous research on cognitive–sensory–motor DT situations has shown that older participants have reduced DT-related performance compared to young adults, and tend to focus their attention more strongly on the sensory–motor task when presented with two demanding tasks (Rapp, Krampe, & Baltes, 2006). Another explanation for the observed improvements in the RSE group might be that traditional exercise regimens emphasize balance training under ST conditions, and therefore only improve functions for ST conditions. This speculation is supported by a study of Silsupadol, Siu, Shumway-Cook and Woollacott (2006), who found that the elderly can improve their balance under DT conditions, but only following DT balance training. Taken together, these findings suggest that explicit instructions which serve to focus attention should be provided during balance training under complex-task conditions.

It is important to note that walking ability improved under both CT and MT conditions despite using a CT during exercise, such as verbal fluency. This result suggests that the elderly are able to improve their walking performance under DT conditions only after specific types of training. Improvement in DT walking may therefore be the result of automatization of an individual task and the development of task coordination skills. As the participants in the RSE group improved in the multiple tasks through the course of the study period, they may have learned to efficiently coordinate performances between the multiple tasks, leading to improved walking ability. These results indicate the importance of instructions when training under multiple-task conditions, as participants may learn to allocate their limited attention between motor and CTs during RSE. Improvements in division of attention may then positively impact DT walking ability. This study demonstrated that our devised RSE program promotes training across different DT modalities (cognitive and manual), leading to improvements in divided attention.

In addition to the beneficial results identified in this study, RSE could potentially be used as a means of public health promotion as it has a number of advantages over conventional exercise programs. First, it is possible for fewer staff members to simultaneously supervise several older adults because the RSE training can be performed within a small indoor space. Second, outdoor walkers can substitute walking with RSE during periods of inclement weather.

Table 2. Functional fitness items by group at pre- and post-intervention.

Item	Pre-intervention	Post-intervention	F-value Time effect Group × Time
ST 10-m walking time (sec)			
RSE	7.65 ± 0.71	6.90 ± 0.34[a]	3.75
NRSE	7.61 ± 1.27	7.73 ± 0.95[a]	7.26*
CT 10-m walking time (sec)			
RSE	10.01 ± 3.76	7.47 ± 0.51[a]	4.54*
NRSE	10.41 ± 3.82	10.52 ± 1.28[a]	5.32*
CT cost (%)			
RSE	21.14 ± 25.76	7.86 ± 3.37[a]	1.29
NRSE	25.63 ± 31.41	30.34 ± 15.87[a]	5.71*
MT 10-m walking time (sec)			
RSE	8.69 ± 1.64	6.79 ± 0.45[a]	9.56**
NRSE	9.17 ± 1.82	8.90 ± 2.08[a]	5.45*
MT cost (%)			
RSE	11.21 ± 19.17	−2.08 ± 7.15[a]	7.54**
NRSE	17.74 ± 18.64	12.50 ± 17.80[a]	1.43
TUG (sec)			
RSE	7.57 ± 1.38	6.43 ± 0.61[a]	4.28*
NRSE	7.85 ± 1.78	7.85 ± 1.36[a]	4.31*
FR (cm)			
RSE	26.18 ± 3.74	33.29 ± 10.04	21.11**
NRSE	28.69 ± 4.37	33.37 ± 6.49	0.89

Notes: Columns indicating pre– and post–intervention values are expressed as mean ± standard deviation.
[a] As calculated by group comparison.
**$p < 0.01$; *$p < 0.05$.

Third, the RSE program requires limited materials and can be implemented with minimal cost. Increasing the number of feasible exercise options for elderly individuals is considered important for health promotion. In this context, the RSE program presented in this study represents a promising new form of exercise for older adults.

There are several limitations of this study that warrant mention. First, no follow-up was conducted. Second, these findings should be considered as preliminary because of the relatively small sample size ($n = 57$). Third, statistical analyses were performed for each of the nine outcome measures separately, including the physical performance tests, which increased the possibility of false-positive findings (type 1 error). Finally, as indicated by their willingness to participate in this study, participants in both groups may have had higher motivation and interest in health issues and fall risk than the general elderly population.

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DUAL-TASK WALK IS A RELIABLE PREDICTOR OF FALLS IN ROBUST ELDERLY ADULTS

To the Editor: Falls are relatively common in elderly people, with approximately 30% of individuals aged 65 and older falling at least once a year and approximately half experiencing repeated falls.[1] In daily-life situations, locomotion occurs under complicated circumstances with cognitive attention focused on a particular task, such as watching traffic or reading street signs, rather than performing the specific motor task of walking. A seminal study demonstrating that the characteristic "stops walking when talking" could serve as a predictor of falls introduced a novel method for fall prediction based on dual-task (DT) performance.[2] Recently, a number of studies have evaluated DT walking in elderly people, but one found that reliable conclusions based on DT results for fall prediction cannot be made because of the lack of standardization in DT paradigms.[3] The aim of the current study was therefore to examine prospectively whether two kinds of DT walking (cognitive task (CT) and manual task (MT)) could predict the risk of falls in a community-dwelling elderly population according to physical function.

The study population consisted of 1,038 community-dwelling elderly Japanese people aged 65 and older (401 men, 637 women, mean age 77 ± 8) in 2009. Six items of physical function were assessed: single-task (ST) 10-m walking time, DT (CT and MT) 10-m walking time, Timed Up and Go (TUG) Test,[4] functional reach, and five-chair stand test (Table 1). In CT walking, participants walked 15 m at the most comfortable speed while counting numbers aloud in reverse order starting at 100. In MT walking, participants walked 15 m at the most comfortable speed while carrying a ball (7 cm in diameter, 150 g in weight) on a tray (17 cm in diameter, 50 g in weight). The DT cost (CT and MT) was then calculated as follows:

$$\text{DT cost}[\%] = 100 \times (\text{DT walking time} - \text{ST walking time}) / ((\text{ST walking time} + \text{DT walking time})/2)$$

Information on the incidence of falls during the following year was collected from participants in a monthly

Table 1. Characteristics of 1,038 Individuals Aged 65 to 97 According to Quartiles of Timed Up and Go Test Results (Seconds)

	Mean ± Standard Deviation							
	Fastest (≤ 8.3) (n = 230)		Faster (8.4–11.0) (n = 258)		Slower (11.1–14.9) (n = 264)		Slowest (≥ 15) (n = 286)	
Characteristic	Faller, 46 (20.0%)	Nonfaller,	Faller, 47 (18.2%)	Nonfaller	Faller, 90 (34.1%)	Nonfaller	Faller, 126 (44.1%)	Nonfaller
Age	77.9 ± 7.9	78.4 ± 6.6	77.4 ± 7.3	78.2 ± 8.0	77.5 ± 8.1	78.2 ± 8.8	77.6 ± 9.3	77.3 ± 8.3
Height, cm	154.4 ± 8.4	153.3 ± 6.8	156.5 ± 9.5	154.7 ± 9.4	157.6 ± 8.3	156.3 ± 11.1	153.6 ± 10.2	154.2 ± 9.6
Body, kg	55.6 ± 11.0	53.6 ± 8.3	50.1 ± 22.9	48.9 ± 16.8	51.7 ± 14.7	53.3 ± 9.3	50.4 ± 17.1	49.7 ± 26.1
Locomotive function, seconds[*]	9.6 ± 2.0	9.2 ± 2.0	10.5 ± 1.9	10.5 ± 2.5	11.4 ± 2.7	11.2 ± 3.6	17.5 ± 7.1	16.8 ± 7.3
Balance function, cm[†]	27.1 ± 5.5	25.0 ± 5.4	24.3 ± 7.2	22.6 ± 6.4	21.4 ± 7.9	21.6 ± 7.6	16.6 ± 7.0	18.6 ± 7.0
Muscle power, seconds[‡]	7.7 ± 1.7	7.5 ± 1.9	9.7 ± 2.8	9.9 ± 2.4	12.8 ± 4.7	11.4 ± 3.5[§]	17.4 ± 9.8	14.9 ± 5.9[§]
Cognitive task costs, %	18.7 ± 29.7	16.4 ± 25.5	21.8 ± 23.6	10.6 ± 19.1[§]	20.2 ± 17.2	20.1 ± 22.2	20.8 ± 20.9	23.1 ± 23.6
Manual task costs, %	8.5 ± 15.8	0.2 ± 11.0[§]	2.2 ± 14.0	5.8 ± 14.7	12.8 ± 14.0	14.5 ± 16.5	14.5 ± 19.7	16.3 ± 20.7

[*] Time to complete single-task 10-m walk.

[†] Distance of functional reach.

[‡] Time to complete five-chair stand.

[§] Independent variable that remained in the final step of the regression model.

telephone interview. A fall was defined as any event that led to unplanned, unexpected contact with a supporting surface during walking.

For analysis, the TUG test results were divided into quartiles (fastest, faster, slower, and slowest). A multivariate analysis using logistic regression with a stepwise-forward method was performed to investigate which of the five measures of physical function (ST walking time, CT cost, MT cost, functional reach, and five-chair stand test) was independently associated with falls.

In the fastest group (n = 230), the regression analysis indicated that the MT cost (odds ratio (OR) = 1.068, 95% confidence interval (CI) = 1.04–1.10, $P<.001$) was an independent predictor of falling that remained in the final step of the regression model. In the faster group (n = 258), the regression analysis indicated that the CT cost (OR = 1.03, 95% CI = 1.01–1.04, $P<.001$) was an independent predictor of falling. In the slower (n = 264) and slowest groups (n = 286), the five-chair stand test (slower group OR = 1.11, 95% CI = 1.03–1.19, $P<.001$; slowest group OR = 1.05, CI = 1.01–1.09, $P=.045$) was found to be an independent predictor of falling.

In conclusion, this study demonstrated that DT cost is an independent and prospective predictor of falls in elderly adults with higher functional capacity (faster and fastest groups), although DT cost did not predict falls in elderly adults with lower functional capacity (slower and slowest groups). Thus, the finding that DT walking is a reliable predictor of falls is limited to the robust elderly population.

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TAURINE DIURETIC AND RENAL-REVITALIZING EFFECTS IN NONAGENARIANS

To the Editor: Congestive heart failure (CHF) is the most ominous cause of edema in older adults living in extended-care nursing homes. Despite no obvious CHF, edema resistant even to diuretic doses that cause hypotension, especially in fragile nonagenarians, often develops, and an alternative was sought.

Long-term oral taurine (OT 3 g/d) ameliorates CHF,[1] so it was desired to determine whether OT (1.0 g three times per day) relieves edema without causing hypotension in nonagenarians. Forty-nine residents of an extended-care nursing home (20 taking antihypertensive therapy) who developed edema (score ≥ 2, Appendix A) despite hospital-prescribed diuretics or excessive hypotension precluding effective diuretic usage were enrolled from March 1, 2007, to March 31, 2010.

The remarkable effects of OT on edema were apparent within the first month of treatment (Figure 1A); decreases in body weight occurred with some delay. Required doses of diuretics decreased after institution of OT in the majority of residents. Serum albumin levels increased in 32 hypoalbuminemic residents (Figure 1B).

Significant increases were observed in estimated glomerular filtration rate (eGFR) expressed as a percentage of baseline values from 6 months to 2.25 years of treatment in residents with chronic kidney disease (CKD) Stage 3 or greater (Figure 1C, lower panel); the effects of OT were distinctly greater in residents with CKD Stage 3 or greater than in those with CKD Stage 2 or less (two-way analysis of variance $P<.001$), with differences reaching significance in the third year (Figure 1C upper panel; Bonferroni***). The hyperuricemia ($\geq$ 8.6 mg/dL) observed in eight residents became normal in 6 to 9 months (Figure 1D).

Factors other than CHF play a significant pathogenic role in edema in older extended-care nursing home residents

→

Figure 1. (A) Effects of taurine are strongest on edema, significantly decreasing body weight. (B) Taurine increases albumin levels in patients with <3.8 g/dL at baseline. (C) Effects of taurine on renal function: Lower panel: taurine significantly increases estimated glomerular filtration rate (eGFR) in patients with chronic kidney disease (CKD) Stage 3 or greater when normalized to baseline values by the sixth month of treatment, and continues to improve significantly for up to 2.25 years. Upper panel: greater improvement of eGFR in residents with CKD Stage 3 or greater compared that in those with CKD Stage 2 of less (two-way analysis of variance $P<.001$) reaches significance after 3 years of treatment (Bonferroni***). (D) Taurine decreases hyperuricemia greater than 8.6 mg/dL to normal levels in 3 to 6 months. ANOVA = analysis of variance; SEM = standard error of the mean.

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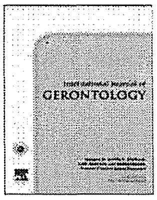

Original Article

Development of a New Fall Risk Assessment Index for Older Adults[☆]

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SUMMARY

Background: Falls are the third-leading cause of a bedridden state and are a major cause of morbidity in elderly people. Therefore, it is important to determine an older person's risk of falling using a simple and reliable method. The aim of the present study was to examine whether our newly developed index for the assessment of complex-task locomotion can predict falls in robust elderly people.

Methods: The new index consisted of four items (stand-up, turn, walk and trip tests). It was used to assess 780 community-dwelling elderly Japanese people (mean age 76.0 ± 7.4 years, 300 men and 480 women) who could complete a Timed Up and Go test in less than 13.5 seconds. We used receiver operating characteristic curves (ROC) to validate the index and to determine its cut-off point to predict falls.

Results: The area under the curve was 0.15 ($p < 0.001$, 95% CI: 0.675-0.755). The ROC curve analysis enabled the best cut-off (1 point) to discriminate fallers from non-fallers (sensitivity 80.8%, specificity 60.6%).

Conclusion: We have demonstrated that the new index is a reliable indicator for falls in elderly people who have higher levels of functional capacity. Our data suggest that a score of more than 1 point by the new index can predict falls in robust elderly people.

1. Introduction

In Japan, falls are the third-leading cause of a bedridden state and are a major cause of morbidity in older people[1]. Falls are relatively common among the elderly, with approximately 30% of individuals aged 65 years or older falling at least once a year[2]. Because falls tend to occur as a result of the activities of daily living, previous research has focused on identifying age-related changes in locomotive function[3]. Several performance measures, such as walking speed[4], Timed Up and Go (TUG) test[5], one-leg stand (OLS)[6], functional reach[7], five times chair stand[8], and Tinetti balance[9], have been used to evaluate the physical performance of community-dwelling older people.

Several studies have suggested that a cut-off point of 13.5 seconds in a TUG test is a useful indicator that an individual has an increased risk of falling[10]. However, some older adults who have higher levels of functional capacity can complete a TUG test in less than 13.5 seconds but remain susceptible to falls, so it is important to develop accurate prediction systems for these individuals. In daily-life situations, the requirements for locomotion typically occur under complicated circumstances with cognitive attention focused on a particular task. In recent years, numerous studies have evaluated complex-task locomotion for fall prediction in older adults[11–13]. However, more simple and reliable methods are necessary for elderly people living in the community.

The aim of the present study was to examine whether our newly developed index to assess complex-task locomotion was related to falls in the robust elderly population.

2. Methods

2.1. Participants

We recruited 780 community-dwelling elderly Japanese people (mean age 76.0 ± 7.4 years, 300 men and 480 women) for this study. We excluded participants based on the following exclusion criteria: the presence of severe cardiac, pulmonary or musculoskeletal disorders, co-morbidities associated with an increased risk of falls (i.e., Parkinson's disease or stroke), and a TUG score greater than 13.5 seconds. The simple TUG test was developed to screen

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[☆] All contributing authors declare no conflict of interest.

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