basic mobility performance and has been shown to be significantly associated with activities of daily living function in frail older adults[5]. It has been reported that elderly people with a TUG score greater than 13.5 seconds are at increased risk of falling[10].

2.2. Questionnaire

The new index was developed in our university by a working group of medical doctors, physical therapists, occupational therapists, public health nurses and an epidemiologist. It consisted of four questions, rated as 0 or 1 by self-report as follows:(1) "Can you stand up without a support?" No = 1; (2) "Can you turn in the opposite way, while holding an empty glass?" No = 1; (3) "Can you walk without dropping a glass of water?" No = 1; and (4) "Have you ever tripped over an obstacle while going to the bathroom or picking up the telephone?" Yes = 1. The test–retest reliability for each item and the total points using the Kappa coefficient (k-value) and the inter-trial correlation coefficient (ICC [1.1]) between the two measurements with a 2-week interval in a sample of 312 participants were calculated as follows: Question 1 (k-value = 0.881); Question 2 (k-value = 0.816); Question 3 (k-value = 0.881); Question 4 (k-value = 0.882); and total point (ICC [1,1] = 0.941).

2.3. Data collection for other physical performance tests

The participants were subjected to five other physical performance tests that are widely used to identify high-risk elderly adults: 10 m walk under a single-task condition (ST walking)[4]; 10 m walk under a dual-task (DT) condition (comfortable walking while counting numbers aloud in reverse order starting from 50) (DT walking)[14]; a TUG test[5]; functional reach (FR)[7]; one-leg stand (OLS)[6]; and five times chair stand tests[8]. The tests were performed in a random order. For each performance task, the participants performed two trials and the average score was calculated.

2.4. Falls

Information on fall incidents within the past year was collected from participants by interview. A fall was defined as an event that resulted in a person unintentionally coming to rest on the ground, floor, or other lower level with or without loss of consciousness or injury[15]. We excluded falls resulting from extraordinary environmental factors (e.g., traffic accidents or falls while riding a bicycle).

2.5. Statistical analysis

Differences in the data between the falls and non-falls were analyzed by Student t test or Chi-square test. To compare physical performance in the two groups, effect sizes were calculated as follows: (faller mean − non-faller mean)/standard deviation. The relationship between the total point and the six previously validated tests was assessed using Spearman's correlation coefficient. The utility of the total points used to distinguish fallers from non-fallers was tested using receiver operating characteristic (ROC) curves for cut-off points on the index. Data were registered and analyzed using the Statistical Package for Social Science (Windows version 18.0).

3. Results

Of the 780 study participants, 203 (26%) reported at least one or more falls within 1 year of administering the new index. Based on these self-reported incidences of falling, the participants were divided into two groups: fallers and non-fallers. The demographic characteristics of the two groups are summarized in Table 1. No significant differences were observed between the groups for age, body weight, height and gender. Fallers scored significantly more points in "Question 1" (odds ratio = 2.79, 95% CI; 1.94–4.03), "Question 2" (odds ratio = 3.20, 95% CI; 1.64–6.24), "Question 3" (odds ratio = 2.14, 95% CI; 1.46–3.15), "Question 4" (odds ratio = 3.46, 95% CI; 2.50–4.87), and total points than non-fallers ($p < 0.001$).

Table 1
Comparison of demographic characteristics and measurements in fallers and non-fallers.

	Faller (n = 203)	Non-faller (n = 577)	Odds (95% CI)	*E/S*	*P-value*
Age	76.8 ± 8.1	75.0 ± 8.3			0.180 [a]
Weight, kg	57.9 ± 9.9	54.3 ± 11.6			0.406 [a]
Height, cm	155.7 ± 10.3	157.4 ± 11.6			0.071 [a]
Gender, female	122 (60.1%)	358 (62.0%)			0.560 [a]
Q1 (0,1) [c]	70 (34.5%)	91 (15.8%)	2.79 (1.94–4.03)		<0.001[b]
Q2 (0, 1) [c]	19 (9.4%)	18 (3.1%)	3.20 (1.64–6.24)		<0.001[b]
Q3 (0, 1) [c]	55 (27.1%)	85(14.7%)	2.14 (1 .46–3.15)		<0.001[b]
Q4 (0, 1) [c]	115 (56.7%)	157 (27.2%)	3.46 (2.50–4.87)		<0.001[b]
Total points (0–4)	1.27 ± 0.86	0.61 ± 0.88		0.77	<0.001[a]
ST walking time, sec	10.45 ± 2.46	9.48 ± 2.59		0.39	<0.001[a]
DT walking time, sec	14.17 ± 4.73	12.75 ± 4.76		0.30	<0.001[a]
TUG, sec	9.90 ± 2.26	9.05 ± 2.22		0.37	<0.001[a]
OLS, sec	6.43 ± 8.67	9.82 ± 12.60		0.39	<0.001[a]
Functional reach, cm	23.83 ± 6.98	26.06 ± 7.90		0.32	<0.001[a]
Five chair stand, sec	11.45 ± 5.94	9.92 ± 3.63		0.26	<0.001[a]

[a] Student t test.
[b] Chi-square test.
[c] Q1: "Can you stand up without a support?" Yes = 0, No = 1; Q2: "Can you turn in the opposite way, while holding an empty glass?" Yes = 0, No = 1; Q3: "Can you walk without dropping a glass of water?" Yes = 0, No = 1; Q4: "Have you ever tripped over an obstacle while going to the bathroom or picking up the telephone?" Yes = 1, No = 0.
DT = manual-task; OLS = one-leg standing; ST = single-task; TUG test = Timed Up and Go test.

All physical performance tests demonstrated that the elderly participants in the non-faller group had significantly lower scores than those in the faller group. The largest effect size was the total point in all measurements. The results for total points was weakly, but significantly, correlated with those for ST walking time ($r = 0.179$, $p < 0.001$), DT walking time ($r = 0.421$, $p < 0.001$), OLS ($r = -0.154$, $p < 0.001$), and functional reach ($r = -0.083$, $p = 0.021$).

The ROC curve for the total points for the classification of fall incidents is shown in Fig. 1. The area under the curve was 0.715 ($p < 0.001$, 95% CI; 0.675–0.755). The ROC curve analysis enabled us to indicate the positive value of 1 point (sensitivity 80.8%, specificity 60.6%) and negative value of 2 points (sensitivity 0.394%, specificity 83.4%).

4. Discussion

In this study we have demonstrated that our new index is a reliable indicator for falls in elderly people who have higher levels of functional capacity. The results of the total score on the new index were moderately correlated with those of DT walking time. Moreover, the total new index score demonstrated statistically significant difference between faller and non-faller groups. Therefore, the new index may be considered a measurement that is related to walking ability under DT conditions. These results implicate the role of the total score in the fall risk assessment. A

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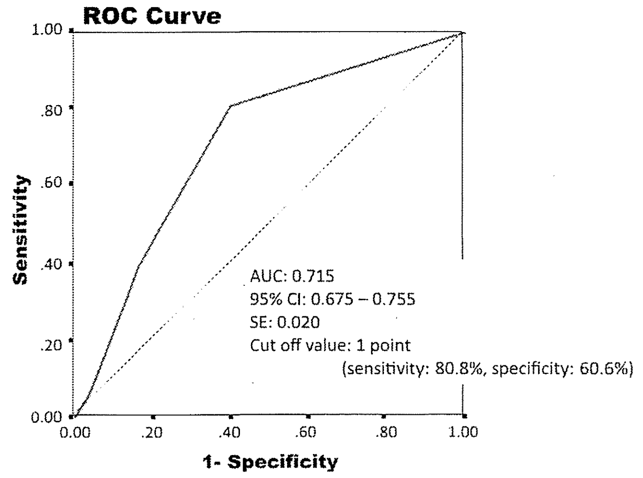

Fig. 1. The receiver operating characteristic (ROC) curve for the total points used for the classification of fall risk. The area under the curve (AUC) was 0.715. Concerning the total points, the cut-off value was determined at 1 point (sensitivity, 80.8%; specificity 60.6%).

score of 1 point by the new index was considered to represent the fall-related cut-off value. In addition, the total score on the new index had the largest effect size in the other screening tool for falls. Therefore, the index may be useful as a screening tool for fall prediction in robust community-dwelling elderly people.

The total points on the new index were weakly correlated with previous validated performance tests. The concept of the new index was assessed to complex-task locomotion related to falls. Therefore, it is not surprising that the new index was weakly correlated with simple performance tests.

In addition to the benefits of the new index as a clinical assessment tool[4–8], we assessed whether this index could be used as a tool for fall risk screening. The new index has a number of advantages over conventional fall risk screening tests. First, it takes a shorter time for the measurement. Second, it is easy to do the assessment in non-clinical settings. However, there is a limitation in this study. The new index could not predict falling in older adults as this study was based on the participants having experienced falls in the previous year. A prospective cohort study to further evaluate the relationship between fall incidents and the new index, in addition to a comparison with existing indices, is being planned.

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Research Letter

Using a Smartphone while walking: a measure of dual-tasking ability as a falls risk assessment tool

Sir—Falls are relatively common among older people; ~30% of 65-year-old community-dwelling adults experience at least one fall per year. Of these falls, 6% result in fractures [1, 2]. Falls typically occur during locomotion; therefore, previous studies have focused on identifying the changes in locomotor performance which occur with increasing age [3, 4].

In every-day life, locomotion typically occurs under complicated circumstances with cognitive attention focused on other tasks. Lundin-Olsson *et al.* [5] reported a novel method for predicting falls based on the dual-task (DT) performance of subjects. In recent years, numerous studies have evaluated DT walking in elderly people. However, Beauchet *et al.* [6] reported that reliable conclusions cannot be drawn from the prediction of falls based on DT results due to the lack of standardisation in DT paradigms. We considered that the two main limitations of the previous research using DT protocols [7–12] were: (i) insufficient evaluation of the performance of the secondary task and (ii) the lack of standardisation of the DT protocols.

The aim of the present study was to evaluate the use of a Smartphone-based application for assessing dual-tasking ability as a tool for predicting the risk of falls in a community-dwelling elderly population.

Methods

Participants

Participants for this study were recruited through advertisements placed in local newspapers. A total of 318 community-dwelling older individuals (mean age, 78.9 [7.3] years) participated in this study. The exclusion criteria ensured that none of the participants had any indications of the following clinical conditions: (i) serious visual impairment, (ii) inability to ambulate independently (those individuals requiring the assistance of a walking frame were excluded), (iii) a score of <7 on the Rapid Dementia Screening Test [13], (iv) symptomatic cardiovascular disease, (v) Parkinson's disease or stroke, (vi) peripheral neuropathy of the lower extremities or (vii) severe arthritis. 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. Each participant was categorised as either a high-risk (HR) or low-risk (LR) elderly individual on the basis of whether they had experienced at least one fall within the past year (self-reported). A fall was defined as any event that led to unplanned, unexpected contact with a supporting surface during walking. On the basis of this classification, the participants were divided into HR ($n = 90$) and LR ($n = 228$) groups (Table 1).

Smartphone data collection

The Android-based Smartphone Android Dev Phone 2 (HTC Corp., Taiwan) was used as a measurement device. Android is a popular operating system for Smartphones. The phone is lightweight (123 g with battery) and has triaxial accelerometers. The use of Android-based applications is advantageous because they are free to develop, offer flexible design options, and can be easily and rapidly distributed over the Internet. The author (K.O.) developed an Android application (RollingBall) for the assessment of fall risk (available for download at http://www.kuhp.kyoto-u.ac.jp/~kazuya/RollingBall.apk) in which a small blue ball (1.5 cm in diameter) is moved on a large white circle (4 cm in diameter) by tilting the phone. The inclination of the phone is determined by the triaxial accelerometers (Figure 1). The Android application also calculates a score based on coordinate data of the ball on the circle; higher scores indicate that the blue ball is nearer to the centre of the circle. The application was based on the 'walking while carrying a ball on a tray' task, previously demonstrated to be a good predictor of falling (Yamada M., unpublished data).

Participants used the application in single- (ST) and dual-task conditions. In the ST condition, participants used the application for 15 s while stationary (ST Android test). The instructions were as follows: 'Using your left hand (or the hand without a cane), please control the Smartphone to keep the blue ball in the centre of the white circle'. The score calculated by the application was recorded as a variable. In the DT condition, the participants walked 15 m at a comfortable speed while using the Android application. The participants were instructed as follows: (i) They should walk at a comfortable speed while positioning and maintaining the blue ball at the centre of the white circle with the left hand (or the hand without a cane). (ii) It was not necessary to constantly look at the Smartphone screen. (iii) The exercise should be performed safely to ensure that no accidents, such as falls, occurred. The score calculated

Table 1. Characteristics of the participants in the GR and LR groups

Characteristic	HR ($n = 90$) Mean (SD)	LR ($n = 228$) Mean (SD)	P-value	Effect size	95%CI
Age	79.1 (7.4)	78.8 (7.2)	0.733	0.04	−1.41 to 2.00
Height, cm	153.3 (6.7)	153.6 (6.4)	0.703	0.05	−1.81 to 1.22
Weight, (kg)	53.7 (10.2)	54.2 (9.8)	0.695	0.05	−2.78 to 1.86
Gender, female, *n* (%)	62 (56.3%)	146 (64.0%)	0.435		
ST walking time, s	13.3 (5.3)	11.6 (4.3)	0.001*	0.34	0.70 to 2.87
DT walking time, s	27.8 (28.2)	20.9 (22.9)	0.019*	0.24	1.14 to 12.67
ST android, score	39.7 (14.5)	36.9 (12.5)	0.081	−0.23	−0.35 to 6.09
DT android, score	29.5 (12.4)	34.8 (9.5)	<0.001*	0.56	−7.78 to −2.84
DT time lag, %	52.2 (35.1)	39.4 (32.4)	0.001*	0.36	5.00 to 20.49
DT point lag, %	34.8 (46.4)	3.8 (34.1)	<0.001*	0.67	21.89 to 39.97
DT total lag, %	86.9 (52.6)	42.9 (47.7)	<0.001*	0.84	32.51 to 55.54
TUG, s	15.8 (12.6)	11.8 (5.3)	0.000*	0.32	2.01 to 6.03
One leg standing, s	7.5 (12.8)	10.4 (11.4)	0.046*	0.25	−5.74 to −0.05
FR, cm	21.5 (8.2)	24.5 (9.5)	0.006*	0.32	−5.12 to −0.89
Five-chair stand test, s	12.9 (6.9)	10.7 (4.5)	0.001*	0.34	1.03 to 3.59

*Indicates statistical significance, Student's *t*-test, $P < 0.05$.

CI, confidence interval; DT, dual-task; ST, single task; DT time lag (%) = 100 * (DT walking time − ST walking time)/ST walking time. DT point lag (%) = 100 * (DT Android score − ST Android score)/ST Android score. DT total lag (%) = DT point lag + DT time lag. TUG, time up and go.

Figure 1. The developed Android application allowed users to control the position of a small blue circle (1.5 cm in diameter) on a large white circle (4 cm in diameter). The score was automatically calculated on the basis of the coordinate tracking data of the blue circle.

by the application and the time taken to walk 15 m were recorded as variables. Before the tests were carried out, a trained evaluator gave standardised verbal instructions regarding the test procedure and a visual demonstration of the tests. The test–retest reliability, determined using the inter-class correlation coefficient (ICC [1.1]). was 0.976. The tests were performed in a random order. The score under each condition was calculated as an average of the scores obtained from the two trials. The reduction in performance due to walking, the DT lag, was calculated as follows for both the application score (DT point lag) and walking time (DT time lag) variables [14]:

$$\text{DT lag}(\%) = 100 * \frac{(\text{DT condition} - \text{ST condition})}{\text{ST condition}}$$

The DT total lag was then calculated using the following equation:

$$\text{DT total lag }(\%) = \text{DT point lag} + \text{DT time lag}$$

Data collection for other physical performance tests

In addition to DT walking, the participants were subjected to five other physical performance tests that are widely used to identify HR elderly adults: 10 m walk under an ST condition (ST walking) [15], timed up and go (TUG) test [16], functional reach (FR) [17], one-leg stand [18] and five-chair stand tests [19]. The tests were performed in random order. For each performance task, the participants performed two trials and an average score was calculated.

Statistical analysis

Differences in the physical performance variables between the HR and LR groups were analysed using a Student's *t*-test. To compare physical performance in the two groups, effect sizes were determined. The effect size was calculated as: (HR mean − LR mean)/standard deviation. The relationship between the scores from the Smartphone test and the five previously validated tests was assessed using Pearson's correlation coefficient. All data analysis was carried out in the Statistical Package for Social Science (Windows version 11.0). A P-value of <0.05 was considered statistically significant for all analyses.

Results

Descriptive statistics for patient characteristics in the two fall risk groups are summarised in Table 1. Participants in the HR and LR groups were comparable and well-matched in terms of their age, height, weight and gender. With the exception of the ST Android, DT walking time, one-leg standing and FR test results ($P > 0.05$), all physical performance tests demonstrated that the elderly participants in the LR group had significantly better scores than those in the HR group. The largest effect size was the DT total lag in all physical performance tests. The results for DT total lag were weakly, but significantly, correlated with those for ST walking time ($r = 0.267$, $P < 0.001$) and those for the TUG ($r = 0.194$, $P = 0.001$), one-leg standing ($r = -0.195$, $P = 0.001$), FR ($r = -0.202$, $P < 0.001$) and five-chair stand ($r = 0.161$, $P = 0.005$) tests.

Discussion

This is the first study to examine the use of a Smartphone device for DT-based fall risk assessment. The present findings support the conclusion of previous experimental studies that measurement of changes in gait while dual tasking is an effective tool in the clinical assessment of fall risk [7–12]. Several characteristics of the Smartphone application developed here are considered to contribute to increasing the demands on the attention of HR elderly participants during DT walking. First, the application represents a simple manual task (i.e. maintaining a small circle in a central position on a large circle) that participants can easily understand and perform. Second, the application provides the ability to measure performance in both the principal and secondary tasks. This constitutes an improvement over previous DT-related reports, which did not sufficiently evaluate the participants' performance in secondary tasks [7–12]. Changes in physical performance during dual tasking are considered to be due to the competing demands for the participant's attention required to successfully complete both tasks [20, 21]. Therefore, performance in both the principal and secondary tasks needs to be evaluated. The results for DT total lag weakly correlated with those from previously validated physical performance tests. Our results reveal that the Smartphone test evaluates the risk of falls by using a different parameter from that used in previously validated physical performance tests.

In addition to the benefits of the developed Smartphone application as a clinical assessment tool, we assessed whether this application could be used as tool for public health promotion. The Smartphone application has a number of advantages over conventional DT-based fall risk assessment tests. First, it is able to measure performance in both principal and secondary tasks. Second, because the application is downloadable from the Internet, it can be readily accessed and distributed throughout the world. Third, the simplicity and portability of the application permits self-assessment of fall risk by concerned individuals in non-clinical settings. However, there is a serious limitation in this study. The developed Smartphone application could not predict falling in older adults as this study was based on the participants having experienced falls in the previous year.

Key points

- A Smartphone-based application was used to assess dual-tasking ability as a measure of the risk of falls.
- The results for DT total lag weakly correlated with those for previously validated physical performance tests.
- This is the first study to examine the use of a Smartphone device for the assessment of the risk of falling.

Conflicts of interest

None declared.

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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

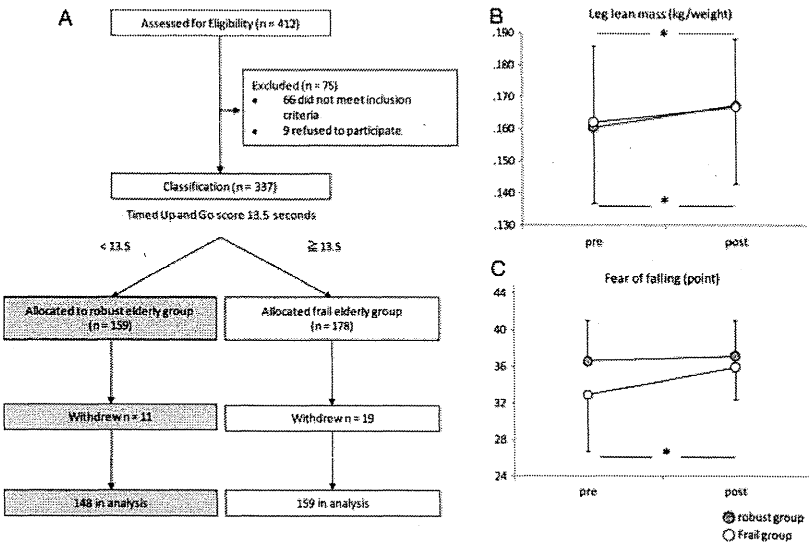

Figure 1. (A) Flow chart showing the disposition of participants throughout the trial. (B) LLM after resistance training in the robust and frail groups was significantly increased from baseline ($P < 0.05$). (C) The frail group had significantly greater improvements in fear of falling ($P < 0.025$).

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

	Robust group ($n = 148$)		E/S	P-value[a]	Frail group ($n = 159$)		E/S	P-value[a]	P-value[b]	F-value 1. Time effect 2. Group × Time
	Mean	SD			mean	SD				
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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The Reliability and Preliminary Validity of Game-Based Fall Risk Assessment in Community-Dwelling Older Adults

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The purpose of this study was to examine whether the Nintendo Wii Fit program could be used for fall risk assessment in healthy, community-dwelling older adults. Forty-five community-dwelling older women participated in this study. The "Basic Step" and "Ski Slalom" modules were selected from the Wii Fit game program. The following 5 physical performance tests were performed: the 10-m walk test under single- and dual-task conditions, the Timed Up and Go test under single- and dual-task conditions, and the Functional Reach test. Compared with the faller group, the nonfaller group showed a significant difference in the Basic Step ($P < .001$) and a nonsignificant difference in the Ski Slalom ($P = .453$). The discriminating criterion between the 2 groups was a score of 111 points on the Basic Step ($P < .001$). The Basic Step showed statistically significant, moderate correlations between the dual-task lag of walking ($r = -.547$) and the dual-task lag of the Timed Up and Go test ($r = -.688$). These results suggest that game-based fall risk assessment using the Basic Step has a high generality and is useful in community-dwelling older adults. (*Geriatr Nurs* 2011;32:188-194)

Falls are a major health problem among the elderly. Approximately 30% of 65-year-old community-dwelling older adults fall at least once a year, and 6% of these falls result in fractures.[1,2] Most falls occur during locomotion, and thus previous studies focused on identifying age-related differences in locomotor performance.[3,4] Several performance balance measures, such as the Timed Up and Go (TUG),[5] one-leg stand,[6] Functional Reach[7] (FR), and Tinetti Balance[8] tests are available for risk assessment in community-dwelling older people.

Dual tasking (DT), or engaging in 2 activities at the same time, is common in daily living. From a widely accepted view, the degree of DT interference is a measure of the attentional requirements of component tasks.[9] Although neural mechanisms that underlie age-related cognitive decline remain equivocal, age-related reduction in brain volume[10] and cortical thickness[11] are the most pronounced in the prefrontal cortex. Executive processes supported by the prefrontal cortex, including attention, inhibition, and working memory, are highly susceptible to age-related brain degeneration.[12-14]

With advancing age, the addition of walking to activities of daily living can create difficulties that lead to complex multitask situations, thus increasing the risk of falling.[15] Thus, it is believed that some falls occur because of an inability to recover from a near fall during an additional attention-demanding task when performing the activities of daily living. DT-related gait changes result from interference caused by competition between the attention demands of gait and walking-associated attention-demanding tasks.[16] Therefore, DT interference suggests a limitation of attentional resources.[17] Exploring DT-related gait changes is of particular interest for clinicians because a strong relationship has been found to exist between DT-related gait changes and the risk of falling in older adults.[18-20] Thus, it is believed that some falls occur because of an inability to recover from a fall during an additional attention-demanding task when performing the activities of daily living.

Professionals from various fields are increasingly exploring the use of the Nintendo Wii Fit program as a next-generation game machine. In addition to the mouse, the Nintendo Wii Fit Balance Board has a sensor like many other commercial game products. A peripheral Wii Balance Board is available with the Nintendo Wii video game console. It has a shape similar to that of a body scale and a flat rectangular design. It is a wireless device that can be powered for up to 60 hours with 4 AA batteries and communicates via Bluetooth with the Wii console. For persons with disabilities, the Wii Balance Board can be used as a high-performance, standing-posture detector. It has 4 pressure sensors situated at each corner from which enough information is available to obtain calibrated readings. The sensors show different pressure values when a user's standing posture changes, and these changes in posture can be calculated by analyzing the changes in the pressure values of the 4 sensors.

The Wii Fit program requires the distribution of attention to the motor task and the monitor (cognitive task). Thus, it is assumed that the Wii Fit program includes a constituent of DT. There are few reports about game-based trials, but there are no reports about game-based assessment. Hence, the purpose of this study is to examine whether the Wii Fit program can be used for fall risk assessment in healthy, community-dwelling older adults.

Methods

Participants

The participants were recruited by advertisements in the local press. An initial interview was conducted, and the participants were screened on the basis of the following criteria: age 65 years or older, community-dwelling, had visited a primary care physician in the last 3 years, had received a sum score of 5 or more on the Rapid Dementia Screening Test (RDST) (dementia may be assumed if the RDST score is less than 5 points),[21] were independently ambulatory with or without a cane (those individuals requiring the assistance of a walker were excluded), and had minimal hearing and vision impairment.

Fifty-three subjects volunteered to participate in this study. Of these, 8 participants did not meet the inclusion criteria. The exclusion criteria, as noted in the interview, were severe cardiac, pulmonary, or musculoskeletal disorders; pathologies associated with increased risk of falls (i.e., Parkinson's disease or stroke); and the use of psychotropic drugs. Written informed consent was obtained from the remaining 45 older women who were included in the trial in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and Declaration of Human Rights, Helsinki, 1975.

Game-Based Performance Measures

Participants learned to swing their bodies using the Wii Fit Balance Board (Nintendo Wii; Nintendo, Minami-ku, Kyoto, Japan) with the guidance of a research assistant. As mentioned earlier, the target response was due to a change in the participants' foot position (or change in sitting posture). In this study, a Wii Fit Balance Board, which was placed under the participants' feet (or buttocks) to detect a target response, was used to transmit target response signals to a control system. Changes in foot position (or sitting posture) signals (including a change in the pressure of the 4 sensors) were transmitted via Bluetooth to the control system. This was connected to a 40-inch monitor with cables.

The "Basic Step" and "Ski Slalom" measures were selected from the Wii Fit game program. The games were modified so that they could be played in a sitting position on a standard dining room chair with a seat height of 40 cm (Figure 1). For safety and generality, modification of the position was required. Only the Basic Step and Ski Slalom could be performed in a modified seated position in the pilot experiment. The distance between the chair and monitor was 2 m. The monitor was located on a TV board that was 40 cm high. The Basic Step involves stepping on and off the Wii Fit Balance Board in time to a specified rhythm. The Ski

Slalom involves skiing down the mountain slope and trying to navigate through the flags by controlling the body (shifting weight to the right, left, or forward) on the Wii Fit Balance Board. Test–retest reliability was assessed by repeating the Wii Fit game program within 1 hour of the first trial.

Physical Performance Measures

All participants underwent 5 measurements—the 10-m walk test under single-task (ST) and DT conditions, the TUG test under ST and DT conditions, and the FR test—in the presence of a physiotherapist. Before starting the study, all staff members received training from the authors (MY and BT) concerning the correct protocols for administering all assessment measures included in the study. The locomotive functions were assessed by the 10-m walk test under ST conditions (ST walking),[22] 10-m walk test under DT conditions (DT walking),[23] TUG test under ST conditions,[5] TUG test under DT conditions,[24] DT lag of walking and TUG,[25] and FR test.[26]

In ST walking, the participants walked 15 m at a comfortable speed, and the time taken to complete the 10-m mark was recorded using a stopwatch. The time recorded in the 2 trials was averaged as the ST walking score. The parameters recorded were the time and number of steps.

In DT walking, the participants walked 15 m at a comfortable speed while counting numbers loudly, starting from 50, in reverse order. The importance of walking and counting at the same time was emphasized to all of the participants, who were asked to walk and count to the best of their capacity without prioritizing either task. Possible counting mistakes were not corrected.[23] The parameters recorded were the time and number of steps.

TUG is one of the most frequently used tests for balance and gait and is often used to assess the risk of falls in older adults. In TUG, the 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 was counted from the moment the word "go" was said and stopped when the participant's back touched the chair backrest. Lesser time taken to accomplish this task indicated better balancing ability. The time recorded in the 2 trials was averaged to obtain the TUG score.

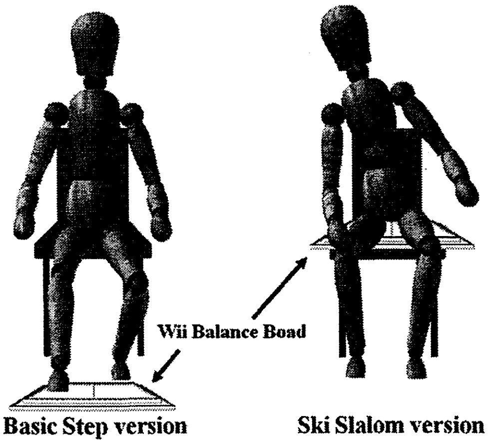

Figure 1. Schematic diagram of the game in a sitting position. The configuration of this study included a Wii Fit Balance Board, which was placed under the participants' feet (Basic Step) or buttocks (Ski Slalom). It was connected with cables to a TV for broadcasting the participants' videos.

Relative DT lag of walking and TUG were calculated using the ST performance as the comparison condition. The DT lag was then calculated as follows:[14]

$$DT\ lag\ (\%) = 100^{*}(DT\ condition - ST\ condition)/ST\ condition.$$

In FR, each participant was positioned next to a wall with 1 arm raised to a 90° level and the fingers extended. A yardstick was mounted on the wall at shoulder height. The distance that a participant could reach while extending forward from an initial upright posture to the maximal anterior leaning posture without moving or lifting the feet was visually measured in centimeters as the position of the third fingertip against the mounted yardstick. Distances measured in the 2 trials were averaged to obtain the FR score, with greater distances indicating better balancing ability. In this trial, the participants used both arms for FR.

Fall Experience

The occurrence of falls within the previous year was also measured. A fall was defined as "an event that results in a person coming to rest inadvertently on the ground or other lower level regardless of whether an injury was sustained, and not as a result of a major intrinsic event or overwhelming hazard."[27] The date, number, characteristics (e.g., while rising from a lying or sitting position, while turning in the opposite direction, while tripping over an obstacle), and consequences (e.g., bruise, fracture) of the falls were recorded using a standardized questionnaire.

Statistical Analysis

Differences in physical function variables between the groups were assessed by Student's *t* test. The Kolmogorov–Smirnov test and Mann–Whitney *U* test were used to evaluate the normality of distributions and differences in physical function variables between the groups. Test–retest reliability was examined with intraclass correlation coefficients [$ICC_{(1,1)}$] for the scores of the Basic Step and Ski Slalom, using analysis of variance. Differences in the data on physical performance variables between faller and nonfaller groups were analyzed by Student's *t* test. The utility of the Basic Step and Ski Slalom for distinguishing fall and nonfall was tested using discriminant analysis for a cutoff point on the index. Criterion-related validity was determined by evaluating the correlation between the game-based scores and physical performance using Spearman's correlation coefficient. Data were registered and analyzed using the Statistical Package for Social Science (Windows version 11.0). A P value $< .05$ was considered statistically significant for the analyses.

Results

Within the previous year, 16 older adults (35.5%) had experienced falls. The Kolmogorov–Smirnov test showed that the RDST was not normally distributed. There were no significant differences between groups for age (faller = 84.8 ± 10.1, nonfaller = 80.2 ± 6.4, $P = .549$), height (faller = 154.5 ± 6.4 cm, nonfaller = 148.2 ± 9.2 cm, $P = .327$), weight (faller = 47.5 ± 4.8 kg, nonfaller = 47.3 ± 9.6 kg, $P = .327$), body mass index (faller = 19.6 ± 3.3, nonfaller = 23.4 ± 4.8, $P = .098$), and RDST (faller = 7.2 ± 2.6, nonfaller = 7.3 ± 2.3, $P = .934$; Table 1). Individuals in the faller group had significantly higher mean values in ST ($P = .023$, effect size = 1.36) and DT number of steps ($P = .008$, effect size = 1.48) and lower mean values in the Basic Step score ($P < .001$, effect size = 1.65) compared with those in the nonfaller group. Compared with the faller group, the nonfaller group showed no significant difference in the Ski Slalom ($P = .453$, effect size = .30).

Test–Retest Reliability

Considerable consistency was observed in the test–retest reliability of the Basic Step ($ICC_{1,1} = 0.785$; 95% confidence interval [CI], 0.35–0.93; $P = .035$) and Ski Slalom ($ICC_{1,1} = 0.611$; 95% CI, −0.08 to 0.86; $P = .004$).

Discriminant Validity

Discriminant analysis was performed using the Basic Step scores that showed a significant difference between the 2 groups (Table 1). The discriminating criterion between the 2 groups was a score of 111 points on the Basic Step, by which 88.6% of the cases were correctly classified ($P < .001$; Figure 2).

Criterion-Related Validity

The Basic Step showed statistically significant moderate correlations with DT lag of walking ($r = -.547$, $P = .023$) and DT lag of TUG ($r = -.688$, $P = .003$). The relationship between the Basic Step and physical function was not significant ($P > .05$). The Ski Slalom showed no significant association with physical performance ($P > .05$), nor were there any significant associations between the Basic Step and Ski Slalom. See Table 2.

Discussion

The results of this study indicate that as the ICCs of both the Basic Step and Ski Slalom were substantial, and they appear to be reliable measurements. The results of the Basic Step were moderately correlated with those of DT lag of walking and DT lag of TUG. Moreover, the Basic Step showed discriminant validity in both the faller and nonfaller groups. There were no significant differences in any of the participants' characteristics between the 2 groups. Therefore, the Basic Step may be considered a measurement that is related to walking ability under DT conditions. These results suggest that the Basic Step shows high generality in the risk assessment of falls.

In real-life situations, the requirement to step commonly occurs under more complicated circumstances, with cognitive attention focused

Table 1.
Subject Characteristics and Physical Performances of Faller and Nonfaller Groups

Characteristic	All (*n* = 45)	Faller (*n* = 16)	Nonfaller (*n* = 28)	*P*	Effect Size
Age, years	81.3 ± 7.4	84.8 ± 10.1	80.2 ± 6.4	.549	0.61
Body Weight, kg	47.3 ± 8.6	47.5 ± 4.8	47.3 ± 9.6	.956	0.03
Height, cm	149.3 ± 8.8	154.5 ± 6.4	148.2 ± 9.1	.327	0.72
Body Mass Index	22.2 ± 4.7	19.6 ± 3.3	23.4 ± 4.8	.098	0.25
RDST, points	7.2 ± 2.3	7.2 ± 2.6	7.3 ± 2.3	.934	0.03
Wii Score					
Basic Step, points	123.0 ± 39.9	81.1 ± 19.7	147.0 ± 26.2	<.001	1.65
Ski Slalom, seconds	106.3 ± 22.2	110.7 ± 37.3	104.1 ± 8.9	.453	0.30
Walking Ability					
ST Walking Time, points	16.5 ± 7.3	22.4 ± 6.1	14.7 ± 6.9	.079	1.05
ST No. of Steps	29.2 ± 9.7	39.3 ± 10.5	26.1 ± 7.3	.023	1.36
DT Walking Time, seconds	21.7 ± 11.1	30.0 ± 5.3	19.1 ± 11.3	.079	0.97
DT No. of Steps	31.6 ± 10.7	43.5 ± 9.0	27.7 ± 8.1	.008	1.48
DT Lag, Walking Time, seconds	31.2 ± 28.9	46.8 ± 35.7	26.4 ± 26.2	.269	0.70
DT Lag, No. of Steps	6.9 ± 6.6	12.3 ± 7.6	5.1 ± 5.5	.103	1.09
Balance Ability					
ST TUG, seconds	16.4 ± 8.4	23.2 ± 8.4	14.9 ± 7.9	.111	1.00
DT TUG, seconds	22.1 ± 14.7	33.0 ± 10.9	19.6 ± 14.6	.082	0.92
DT Lag, TUG, seconds	28.2 ± 28.4	45.9 ± 26.7	24.1 ± 28.1	.111	0.77
Functional Reach, cm	20.3 ± 7.3	14.8 ± 4.0	22.0 ± 7.3	.079	1.00

DT = dual task; RDST = Rapid Dementia Screening Test; ST = single task; TUG = Timed Up and Go test.
Columns indicating fallers' and nonfallers' values are expressed as mean ± SD.

on such things as watching traffic or reading street signs or advertisements rather than performing a specific motor task.[4] With advancing age, the addition of walking to the activities of daily living can create difficulties that lead to complex multitask situations, thus increasing the risk of falling.[15] Exploring DT-related gait changes is of particular interest for clinicians because a strong relationship exists between DT-related gait changes and the risk of falling in older adults.[19] Thus, it is believed that some falls occur because of an inability to recover from a fall during an additional attention-demanding task during the activities of daily living. The Basic Step score was correlated with ability during an attention-demanding task. Thus, the Basic Step may include the constituent of a real-life situation.

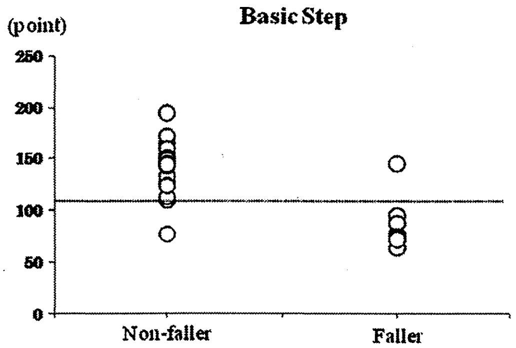

Figure 2. Scatter chart of Basic Step. A score of 111 points on the Basic Step was used to classify correctly 88.6% of the cases ($P <$ .001). The borderline demonstrates the cutoff point.

DT performance is sensitive to cognitive changes associated with aging. One theory as to why DT lag increases with aging relates to the slowed perceptual speed[28] and increased complexity of the DT situation, which then requires more processing.[29] Others theorize that the reduced capacity of the working memory, attention, or perceptual-motor ability leads to greater difficulty for older adults in performing 2 tasks simultaneously.[30] Yet another theory of age-related decline in DT performance suggests

Table 2.
Correlation between Basic Step, Ski Slalom, and the Other Measures

	Basic Step	Ski Slalom
Basic Step		−0.491
Ski Slalom	−0.251	
ST Walking Time	−0.311	0.100
ST No. of Steps	−0.311	0.164
DT Walking Time	−0.429	0.147
DT No. of Steps	−0.334	0.102
DT Lag, Walking Time	−0.547*	0.138
DT Lag, No. of Steps	−0.204	0.025
ST TUG	−0.221	0.159
DT TUG	−0.372	0.187
DT Lag, TUG	−0.688*	0.262
Functional Reach	0.085	−0.100

DT = dual task; ST = single task; TUG = Timed Up and Go test.
$^*P < .05$.

that there is difficulty in the coordination and allocation of attention to multiple tasks by older adults. Kramer et al.[31] reported that there are several mechanisms responsible for the DT lag observed with aging. The Basic Step scores were moderately correlated with those of DT lag of walking and TUG. Thus, the Basic Step score might include the constituent of DT lag.

The Basic Step score showed discriminant validity in both the faller and nonfaller groups. Some researchers reported that many tests were useful for measurements related to judging the risk of fall.[5,22-26] However, there was nothing that placed the home-based fall risk assessment within professional bounds. Physical performance under DT conditions is particularly difficult. This study suggests that the Basic Step shows high generality in risk assessment for home-based falls. The home of each participant was equipped with a television set in the living room so that only the purchase of Wii would be required to continue with the activities. Game-based fall risk assessment using the Basic Step has a high generality and is useful in community-dwelling older adults. A score of 111 points on the Basic Step was considered the fall-related cutoff point. In addition, the Basic Step had the largest effect size in all of the physical performance tests. This result suggests that the Basic Step is a reliable indicator for fall risk in older adults.

There are several limitations in this study. First, the Basic Step could not predict falling in older adults because this study was based on fall experiences within the previous year. It is possible that the fall experience report may have been incorrect, because the participants were required to accurately remember their fall experiences. Second, the test—retest reliability of the Ski Slalom is not highly reliable. Third, the experimental setup involved the negotiation of the "learning curve" of using the Wii Fit program. Thus, it remains unclear how long older adults practiced before being able to complete the demanded task. Fourth, the participants were probably more motivated and showed greater interest in health issues and risk of falls than the general elderly population.

Our recent studies have shown that specific exercises are effective at improving ambulatory function under DT conditions.[32,33] Future research should focus on the specific exercises that are effective at improving this function using the Basic Step. This is the first study to examine game-based fall risk assessment in older adults. The results suggest that game-based fall risk assessment using the Basic Step has a high generality and is useful in community-dwelling older adults. A score of 111 points on the Basic Step was considered the fall-related cutoff point. The simplicity and generality of the Basic Step permits the self-administration of fall risk assessment by nurses in nonclinical settings (e.g., while visiting homes).

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PEDOMETER-BASED BEHAVIORAL CHANGE PROGRAM CAN IMPROVE DEPENDENCY IN SEDENTARY OLDER ADULTS: A RANDOMIZED CONTROLLED TRIAL

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Abstract: *Background:* Recent studies suggested that pedometer-based walking programs are applicable to older adults. *Objectives:* The purpose of this study was to evaluate the use of pedometer in sedentary older adults to improve physical activity, fear of falling, physical performance, and leg muscle mass. *Design:* This was a pilot randomized controlled trial (RCT). *Setting and participants:* Eighty-seven community dwelling sedentary older adults living in Japan. *Intervention:* The intervention group (n=43) received a pedometer-based behavioural change program for 6 months, while the control group (n=44) did not. The participants in the intervention group were instructed to increase their mean daily steps by 10% each month. Thus, at the end of 6 months, participants in the intervention group were expected to have 77 % more daily steps than their baseline step counts. Written activity logs were monthly averaged to determine whether the participants were achieving their goal. *Measurements:* Outcome measures were physical activity, fear of falling, physical performances, and leg muscle mass. *Results:* In this 6-month trial 40 older adults (93%) completed the pedometer protocol with good adherence. In the intervention group, average daily steps were increased by 83.4% (from 20311323 to 3726 1607) during the study period, but not in the control group (from 20471698 to 22671837). The pedometer-based behavioral change program was more effective to improve their physical activity, fear of falling, locomotive function, and leg muscle mass than control ($P<0.05$). *Conclusion:* These results suggested that the pedometer-based behavioral change program can effectively improve the physical activity, fear of falling, physical performance, and leg muscle mass in sedentary older adults.

Key words: Pedometer-based behavioral change program, physical activity, sedentary older adults, RCT.

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 the elderly (1-5). On the other hand, increased physical activity is associated with improvement in numerous health conditions, such as quality of life and physical and psychological functions, and can facilitate independent living and reduce the risk of dementia in older adults (6-9).

Behavioral change intervention should be based on scientific theory, and interventions should use evidence-based behavioral change techniques such as goal setting, planning, and self-monitoring (10-12). Pedometers are attracting interests as potential means to enhance the effectiveness of interventions and to promote physical activities, yet surprisingly few trials have been conducted using pedometers (13, 14). Most pedometer-based studies have been focused on middle-aged adults and have measured health outcomes such as body mass index and blood pressure (13).

Only a few reports have evaluated the use of pedometers in older adults. A 12-week trial of a pedometer-based walking program in older adults (mean age, 73 years) showed a 21% to 34% increase in physical activity over baseline (15). In a 4-week trial of pedometer-based walking program in older adults (mean age, 82 years), a significant improvement was observer in average number of daily steps (2992 to 3670) and physical function (16). These data suggested that pedometer-based walking programs are applicable to older adults.

The purpose of this randomized controlled trial (RCT) was to evaluate the use of pedometer in sedentary older adults to improve their physical activity, fear of falling, physical performance, and leg muscle mass. We hypothesized that our pedometer-based behavioral change program could lead to a 10% monthly increase in average daily steps in each month during the 6-month intervention, and was effective in fear of falling, physical performance, and leg muscle mass.

Methods

Participants

Participants were recruited using an advertisement in the local press. The following criteria were used to screen

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participants: age 65 years or over, participants who walked less than 5,000 steps/day by pedometer, community-dwelling, had visited a primary care physician within the past 3 years, had no severe cognitive impairment (Rapid Dementia Screening Test (RDST) score of 4 or less) (17), could walk independently (or with a cane), willingness to participate in group exercise classes for at least 6 months, had access to transportation, had no significant hearing and vision impairments, and had no regular exercise in the last 12 months. We used the cutoff of 5,000 steps/day because the average daily steps were 5,0812,633 step/day in sarcopenic older Japanese (18).

The interview was also used to exclude participants based on the following exclusion criteria: severe cardiac, pulmonary, or musculoskeletal disorders; co-morbidities associated with greater risk of falls, such as Parkinson disease and stroke; and use of psychotropic drugs. Written informed consent was obtained from each participant for the trial in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

Study design and randomization

Participants were randomized into 2 groups. Opaque envelopes bearing group names were numbered and the 87 participants were then randomly assigned to either a pedometer-based behaviour change program (intervention) group (n=43) or a control group (n=44).

Intervention

Participants randomized to the intervention group received pedometer-based behavioural change programs for 6 months. A valid, accurate, and reliable pedometer, Yamax Powerwalker EX-510 was used to measure free-living step counts (19). The physical activity of older adults is susceptible to weather change (temperature and precipitation). Therefore, this intervention was conducted between November 2010 and April 2011, because in Japan, we have almost the same temperature and precipitation in October and May and tried to avoid the rainy season (June and July). We expected that the outcome measures were not affected by a remarkable difference in temperature before and after the intervention.

We instructed the participants to increase the number of daily steps by 10% each month. Thus, at the end of 6 months, participants were expected to walk 77 % above their baseline step counts. Written activity logs were averaged monthly to determine whether the participants were achieving their step goal.

The intervention consisted of motivation for walking followed by goal setting, self-monitoring, and feedback. Participants were asked to record the date on the calendar, steps taken at the end of each day. A sheet for brief feedback and setting the number of daily steps was mailed to all participants to evaluate the recorded calendar monthly. We checked the adherence by the recorded calendar.

Measurement of physical performance

For all participants, the following 4 measures were obtained: 10-m walking time (20), the timed up and go (TUG) test (21), the functional reach (FR) test (22), and the five chair stand (5CS) test (23). A physiotherapist blinded to group allocation was responsible for these measures at baseline, and after the intervention. All baseline measures were completed before randomization. Before the study started, all staff members received training on correct protocols for administering all assessment measures included in the study from one of the authors (MY). If a walking aid was normally used at home, this aid was used during the 10-m walking test and TUG test.

In 10-m walking, each participant was requested to walk comfortably without assistance for 15-m and the time was measured for the intermediate 10-m to allow for acceleration and deceleration. The average time calculated from two trials was used for the present analyses.

In the TUG test, 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 maximum pace, turn, walk back to the chair, and sit down. The time recorded from 2 trials was averaged to obtain the TUG score.

In the FR test, each participant was positioned next to a wall with one arm raised at 90° and fingers extended. A meter stick was mounted on the wall at shoulder height. The distance that a participant could reach while extending forward from an initial upright posture to the maximal anterior leaning posture without moving or lifting the feet was visually measured in centimetres according to the position of the tip of the third finger against the mounted meter stick. The distances measured in 2 trials were averaged to obtain the FR score.

In 5CS, 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.The5CS score was defined as the better performance of their two trials.

Bioelectrical impedance analysis (BIA) 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 [24]. This system applies a constant current of 800 mA at 50 kHz