

adults. The results of this study suggested that the rhythmic stepping exercise program was indeed effective at improving DT walking ability and fear of falling (Yamada et al., 2011e).

5.2 Seated stepping exercise

The participants were instructed on how to perform the seated stepping exercises by using a standard dining room chair (Fig. 8). The participants 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 the lifting of the plantar surface above the ground. The intensity of the exercise was increased over the 12-week period by increasing the total stepping time. The participants completed 10 sets of 5 s per set in weeks 1–12, increasing to 10 sets of 10 s per set in weeks 13–24. The participants were asked to perform a verbal fluency task during stepping (DT condition). This task consisted of listing words within a category (e.g., animals, vegetables, fruits, fish) or by letter (e.g., a word that begins with “A”) at a self-selected speed. This task was self-generated; the 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. The participants were not specifically instructed to prioritize either task but were asked to combine both tasks as much as they could. The instructions were as follows: “Please step as quickly as possible, and avoid making mistakes as much as you can.”

“Please enumerate kind of a vegetables.”

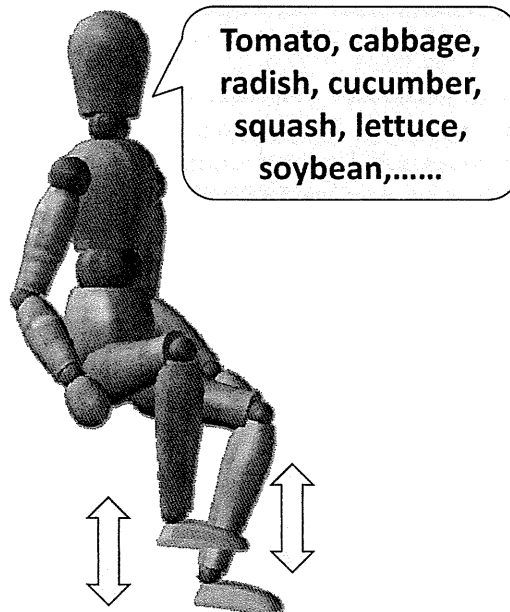


Fig. 8. Schematic representation of the seated stepping exercise

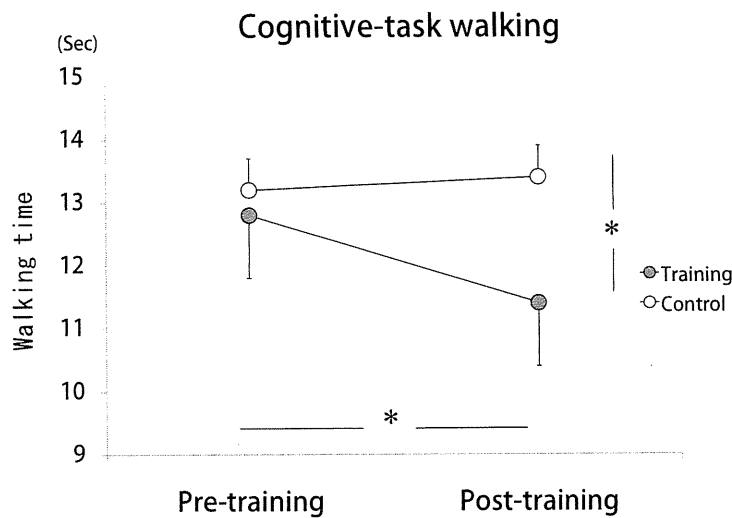


Fig. 9. Cognitive task walk time in training (seated stepping exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

We evaluated whether a 24-week seated stepping exercise program would effectively improve physical functioning in community-dwelling elderly adults. The results of this trial suggested that the seated stepping exercise program was indeed effective at improving DT walking ability (Yamada et al., 2010a).

However, unsupervised exercise is difficult to control and monitor in many elderly adults. In recent years, several studies have demonstrated the effectiveness of various video- or internet-based exercises in elderly adults or orthopedic patients.

We also investigated the feasibility and effectiveness of a DVD-based seated stepping exercise for the improvement of DT walking capability in community-dwelling elderly adults. The participants received 20 min of group training twice a week for 24 weeks (Fig. 10). The exercise class used an exercise DVD that included a 15-min basic exercise section and a 5-min seated DT stepping exercise section. An exercise DVD with 4 volumes was used. The basic training involved stretching, strength, and agility training while seated. An example from the exercise program is shown below:

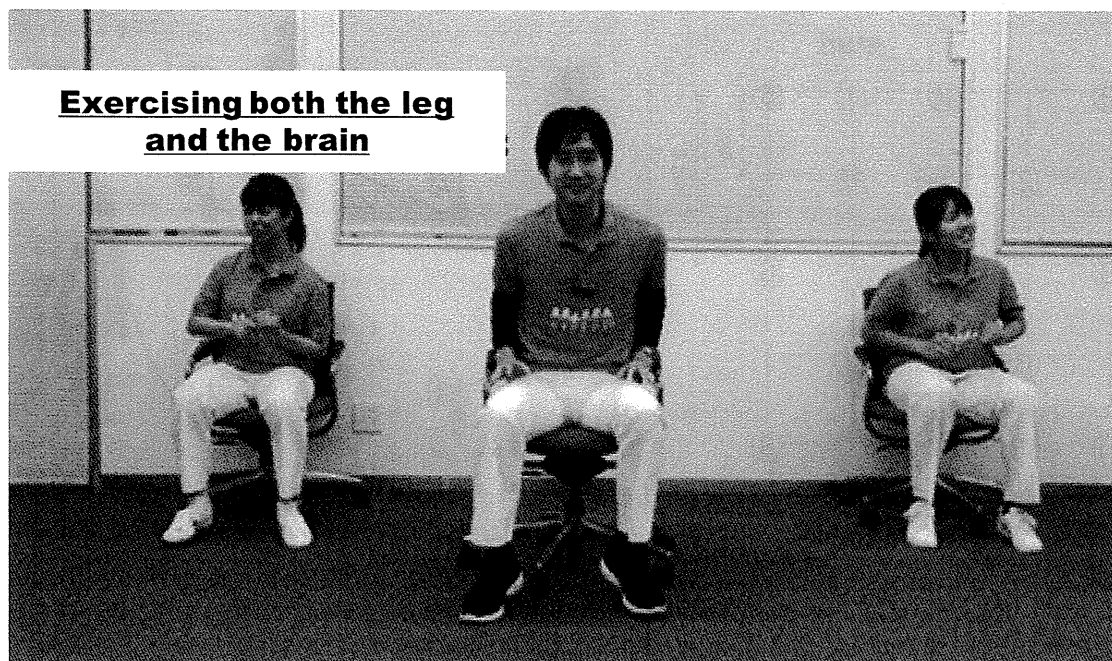
<http://www.youtube.com/watch?v=1391kzEYMJM>

and

<http://www.youtube.com/watch?v=mcaWhPLN7Es>. This study reports the feasibility and effectiveness of DVD-based exercise for the improvement of DT walking capability (Yamada et al., in press b).

5.3 Trail walking exercise

In the trail walking exercise, flags were set randomly at each of 15 positions in a 25-m² area (5 m × 5 m; Fig. 12). Participants were asked to pass sequentially from No. 1 to No. 15. A circle 30 cm in diameter was drawn on the ground around each flag, and participants were required to step in the circle to pass the flag. The height of the flag was 30 cm. The tester gave the following instructions to the participants: "Please move to No. 15 as quickly and correctly as possible." The 24-week program included a progressive aspect in which the



“Subjects were asked to imitate vegetables”

Fig. 10. Schematic representation of the DVD-based seated stepping exercise.

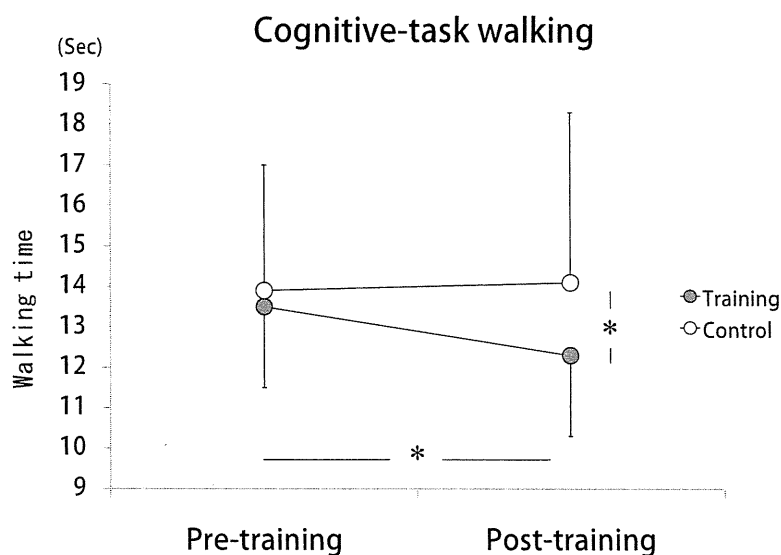


Fig. 11. Cognitive task walk time in training (DVD-based seated stepping exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

participants were asked to pass sequentially from No. 1 to No. 15 during weeks 1 to 12 but were asked to pass sequentially from No. 15 to No. 1 during weeks 13 to 24. The flag positions were changed for each day of training.

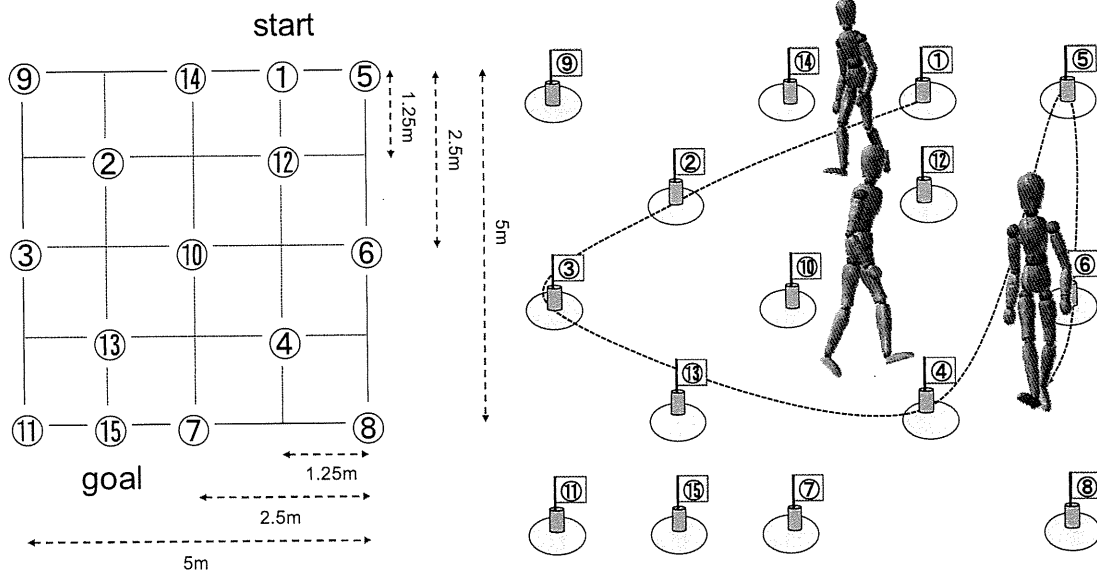


Fig. 12. Schematic representation of the trail walking exercise

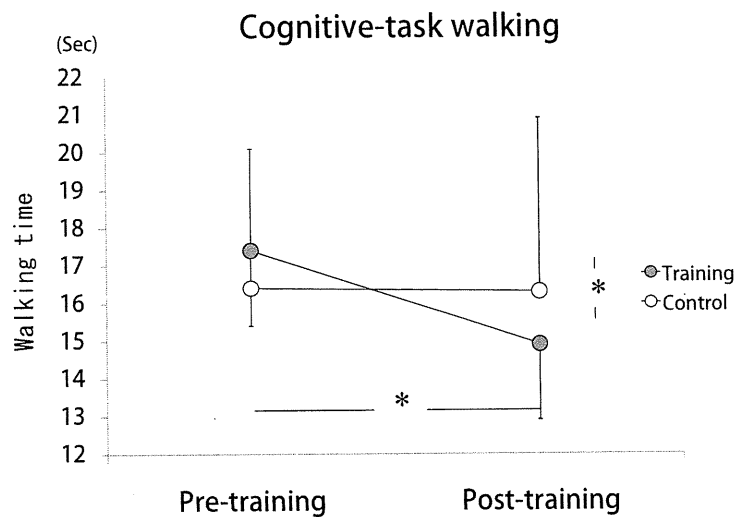


Fig. 13. Cognitive task walk time in training (trail-walking exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

We evaluated whether a 16-week trail walking exercise program would effectively improve physical functioning and reduce fall incidents in community-dwelling elderly adults. The results of this trial suggested that the trail walking exercise program was indeed effective at improving DT walking ability and decreasing the incident rate of falls 6 months after trial completion (Yamada et al., 2010b).

5.4 Resistance exercise for frail elderly adults

The participants underwent resistance training sessions twice a week for 24 weeks. All participants performed 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 maximum weight that can be lifted 10 times). The participants used the 10-RM for 3 sets of 10 repetitions for each machine exercise. The 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 a 15-min warm-up at the beginning and a 10-min cool-down stretch at the end.

We compared the effects of resistance training on skeletal muscle mass, physical performance, and fear of falling in pre-frail and frail elderly adults. The results of this trial suggested that the skeletal muscle mass was increased by the resistance training program in both groups. However, improvements in the fear of falling and physical functioning were limited to the frail elderly adults (Yamada et al., 2011f).

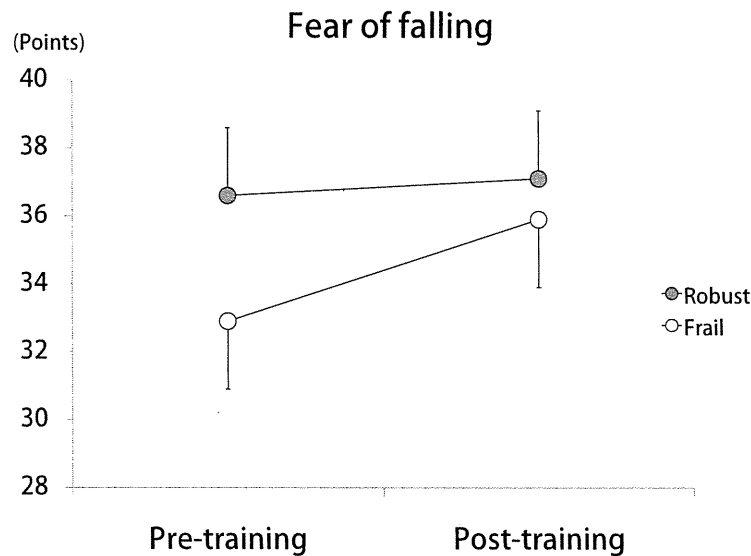


Fig. 14. Fear of falling in robust and frail groups during pre- and post-resistance training. Significant differences were observed between the 2 groups ($p < 0.05$).

6. Conclusions

The findings of this review suggest that fall prevention programs should be tailored to an individual’s level of physical well-being; robust elderly adults should be given the rhythmic stepping exercise; intermediate elderly adults, the trail walking exercise; pre-frail elderly adults, the seated stepping exercise; and frail elderly adults, resistance exercises. A summary of interventions tailored to the individuals’ levels of physical well-being is shown in Fig. 15.

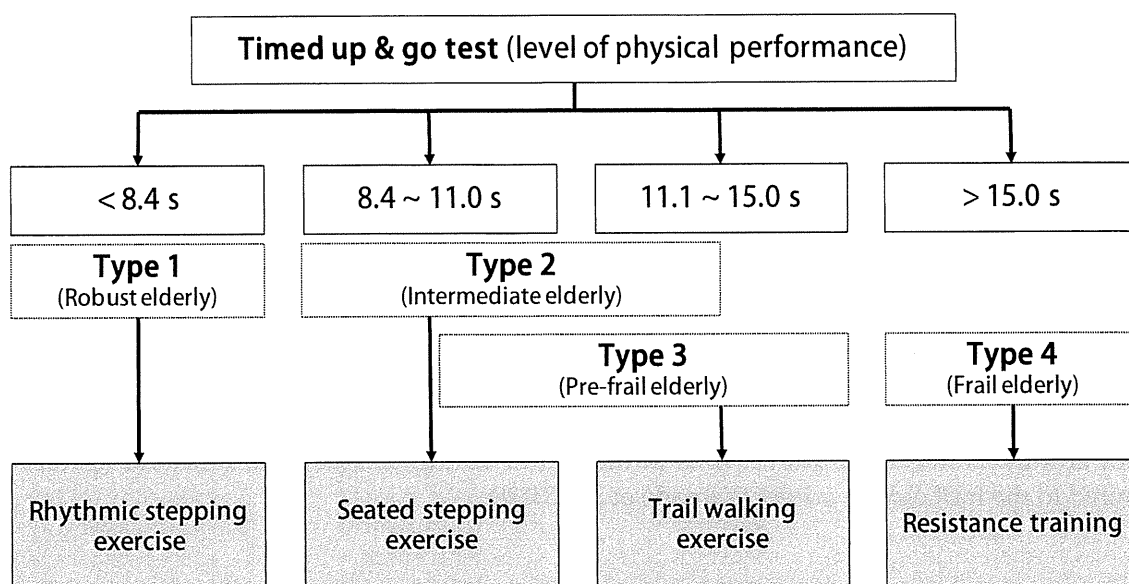


Fig. 15. Flow chart showing interventions tailored to levels of physical well-being.

7. Acknowledgments

We would like to thank all of the volunteers for participating in our studies and the staff of the day-service center, community center, and geriatrics institute.

8. References

- Beauchet O, Dubost V, Allali G, Gonthier R, Herrmann FR, Kressig RW. 'Faster counting while walking' as a predictor of falls in older adults. *Age Ageing* 2007 Jul;36(4):418-23. Epub 2007 Mar 9.
- Beauchet O, Allali G, Annweiler C, Berrut G, Maarouf N, Herrmann FR, Dubost V. Does change in gait while counting backward predict the occurrence of a first fall in older adults? *Gerontology* 2008;54(4):217-23. Epub 2008 Apr 14.
- Beauchet O, Annweiler C, Allali G, Berrut G, Herrmann FR, Dubost V. Recurrent falls and dual task-related decrease in walking speed: is there a relationship? *J Am Geriatr Soc*. 2008 Jul;56(7):1265-9. Epub 2008 May 26.
- Bootsma-van der Wiel A, Gussekloo J, de Craen AJ, van Exel E, Bloem BR, Westendorp RG.: Walking and talking as predictors of falls in the general population: the Leiden 85-Plus Study. *J Am Geriatr Soc* 51: 1466-71, 2003
- Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. *J Gerontol* 1990;45:M192-M197.
- Faulkner KA, Redfern MS, Cauley JA, Landsittel DP, Studenski SA, Rosano C, Simonsick EM, Harris TB, Shorr RI, Ayonayon HN, Newman AB; Health, Aging, and Body Composition Study.: Multitasking: association between poorer performance and a history of recurrent falls. *J Am Geriatr Soc* 55: 570-6, 2007
- Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with

- self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994; 49: M85-M94.
- Kressing RW, Herrmann FR, Grandjean R, Michel JP, Beauchet O.: Gait variability while dual-tasking: fall predictor in older inpatients?. *Aging Clin Exp Res* 20: 123-130, 2008
- Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet* 1997; 349: 617.
- Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; 39: 142-8.
- Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc* 2008 Dec;56(12):2234-43.
- Springer S, Giladi N, Peretz C, Yogev G, Simon ES, Hausdorff JM.: Dual-tasking effects on gait variability: the role of aging, falls, and executive function. *Mov Disord* 21:950-7, 2006
- Stalenhoef PA, Diederiks JP, Knottnerus JA, Kester AD, Crebolder HF. A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol.* 2002 Nov;55(11):1088-94.
- Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988; 319:1701-7.
- Toulotte C, Thevenon A, Watelain E, Fabre C.: Identification of healthy elderly fallers and non-fallers by gait analysis under dual-task conditions. *Clin Rehabil* 20: 269-76, 2006
- Verghese J, Buschke H, Viola L, Katz M, Hall C, Kuslansky G, Lipton R. Validity of divided attention tasks in predicting falls in older individuals: a preliminary study. *J Am Geriatr Soc* 2002 Sep;50(9):1572-6.
- Yamada M, Arai H, Nagai K, Tanaka B, Uehara T, Aoyama T. Development of a new index for fall risk assessment in older adults. *Int J Gerontol* (in press a)
- Yamada M, Aoyama T, Hikida Y, Takamura M, Tanaka Y, Kajiwara Y, Nagai K, Uemura K, Mori S, Tanaka B. Effects of a DVD-based seated dual-task stepping exercise on the fall risk factors among community-dwelling elderly adults: A pilot feasibility study. *Telemed J E-Health* (in press b)
- Yamada M, Aoyama T, Arai H, Nagai K, Tanaka B, Uemura K, Mori S, Ichihashi N. Dual-task walk is a reliable predictor of falls in robust elderly adults. *J Am Geriatr Soc* 2011a; 59: 163-4.
- Yamada M, Aoyama T, Nakamura M, Tanaka B, Nagai K, Tatematsu N, Uemura K, Nakamura T, Tsuboyama T, Ichihashi N. The reliability and preliminary validity of game-based fall risk assessment in community-dwelling older adults. *Geriatr Nurs* 2011b; 32(3):188-94.
- Yamada M, Aoyama T, Okamoto K, Nagai K, Tanaka B, Takemura T. Using a Smartphone while walking: a measure of dual-tasking ability as a falls risk assessment tool. *Age Ageing* 2011c;40(4):516-9.
- Yamada M, Higuchi T, Tanaka B, Nagai K, Uemura K, Aoyama T, Ichihashi N. Measurements of stepping accuracy in a multitarget stepping task as a potential indicator of fall risk in elderly individuals. *J Gerontol A Biol Sci Med Sci* 2011d Jul 11. [Epub ahead of print]

- Yamada M, Tanaka B, Nagai K, Aoyama T, Ichihashi N. Rhythmic stepping exercise under cognitive condition improves fall risk factors in community-dwelling older adults: preliminary results of cluster-randomized controlled trial. *Aging Ment Health* 2011e: 15; 647-53.
- Yamada M, Arai H, Uemura K, Mori S, Nagai K, Tanaka B, Terasaki Y, Iguchi M, Aoyama T. Effect of resistance training on physical performance and fear of falling in elderly with different levels of physical well-being. *Age Ageing* 2011f. [Epub ahead of print]
- Yamada M, Aoyama T, Tanaka B, Nagai K, Ichihashi N. Seated stepping exercise under a dual-task condition improves ambulatory function with a secondary task: a randomized controlled trial. *Aging Clin Exp Res* 2010a [Epub ahead of print]
- Yamada M, Tanaka B, Nagai K, Aoyama T, Ichihashi N. Trail-walking exercise and fall risk factors in community-dwelling older adults: preliminary results of a randomized controlled trial. *J Am Geriatr Soc* 2010b: 58(10):1946-51.

The Reliability and Preliminary Validity of Game-Based Fall Risk Assessment in Community-Dwelling Older Adults

Minoru Yamada, RPT, PhD
 Tomoki Aoyama, MD, PhD
 Masatoshi Nakamura, RPT
 Buichi Tanaka, RPT
 Koutatsu Nagai, RPT
 Noriatsu Tatematsu, RPT
 Kazuki Uemura, RPT
 Takashi Nakamura, MD, PhD
 Tadao Tsuboyama, MD, PhD
 Noriaki Ichihashi, MD, PhD

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 Reach⁷ (FR), and Tinetti Balance⁸ 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 volume¹⁰ and cortical thickness¹¹ 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 pri-

mary 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.

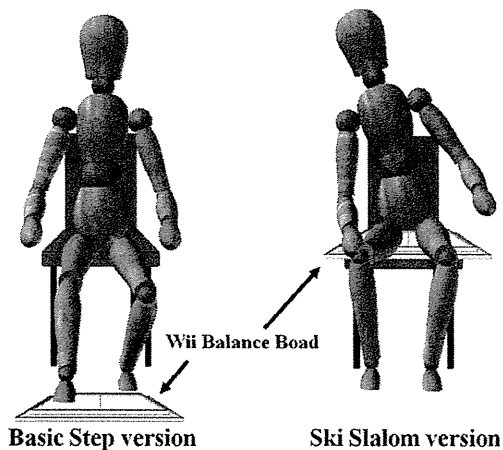


Figure 1. Schematic diagram of the game in a sitting position. The configuration of this study included a Wii Fit Balance Board, which was placed under the participants’ feet (Basic Step) or buttocks (Ski Slalom). It was connected with cables to a TV for broadcasting the participants’ videos.

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 com-

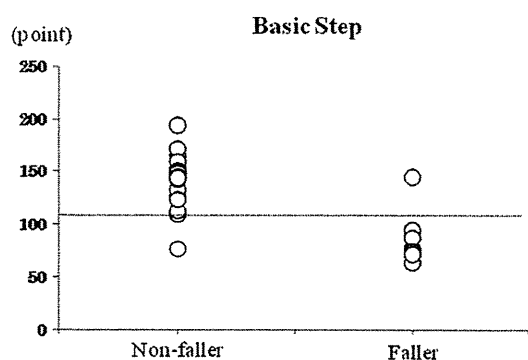


Figure 2. Scatter chart of Basic Step. A score of 111 points on the Basic Step was used to classify correctly 88.6% of the cases ($P < .001$). The borderline demonstrates the cutoff point.

plex 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.

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 speed²⁸ 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).

References

1. Blake AJ, Morgan K, Bendall MJ, et al. Falls by elderly people at home: prevalence and associated factors. *Age Ageing* 1988;17:365-72.
2. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988;319:1701-7.
3. Chen HC, Ashton-Miller JA, Alexander NB, et al. Stepping over obstacles: gait patterns of healthy young and old adults. *J Gerontol* 1991;46:M196-203.
4. Chen HC, Schultz AB, Ashton-Miller JA, et al. Stepping over obstacles: dividing attention impairs performance of old more than young adults. *J Gerontol A Biol Sci Med Sci* 1996;51:M116-22.
5. Podsiadlo D, Richardson S. The Timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;39:142-8.
6. Vellas BJ, Wayne SJ, Romero L, et al. One-leg balance is an important predictor of injurious falls in older persons. *J Am Geriatr Soc* 1997;45:735-8.

7. Duncan PW, Weiner DK, Chandler J, et al. Functional reach: a new clinical measure of balance. *J Gerontol* 1990;45:M192-7.
8. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc* 1986;34:119-26.
9. Brown LA, Shumway-Cook A, Woollacott MH. Attention demands and posture recovery: the effects of aging. *J Gerontol A Biol Sci Med Sci* 1999;54A:M165-71.
10. Raz N, Gunning-Dixon F, Head D, et al. Aging, sexual dimorphism, and hemispheric asymmetry of the cerebral cortex: replicability of regional differences in volume. *Neurobiol Aging* 2004;25:377-96.
11. Salat DH, Buckner RL, Snyder AZ, et al. Thinning of the cerebral cortex in aging. *Cereb Cortex* 2004;14:721-30.
12. West R. Visual distraction, working memory, and aging. *Mem Cognit* 1999;27:1064-72.
13. Grady CL, Craik FI. Changes in memory processing with age. *Curr Opin Neurobiol* 2000;10:224-31.
14. Andres P, Guerrini C, Phillips LH, et al. Differential effects of aging on executive and automatic inhibition. *Dev Neuropsychol* 2008;33:101-23.
15. Bloem BR, Valkenburg VV, Slabbeboom M, et al. The multiple task test: development and normal strategies. *Gait Posture* 2001;14:191-202.
16. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture* 2002;16:1-14.
17. Verghese J, Buschke H, Viola L, et al. Validity of divided attention tasks in predicting falls in older individuals: a preliminary study. *J Am Geriatr Soc* 2002;50:1572-6.
18. Verhaeghen P, Cerella J. Aging, executive control, and attention: a review of meta-analyses. *Neurosci Biobehav Rev* 2002;31:369-76.
19. Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet* 1997;349:617.
20. Perry RJ, Hodges JR. Attention and executive deficits in Alzheimer's disease. A critical review. *Brain* 1999;122:383-404.
21. Kalbe E, Calabrese P, Scgwalen S, et al. The Rapid Dementia Screening Test (RDST): a new economical tool for detecting possible patients with dementia. *Dementia Geriatr Cogn Disord* 2003;16:193-9.
22. Lopopolo RB, Greco M, Sullivan D, et al. Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. *Phys Ther* 2006;86:520-40.
23. Beauchet O, Dubost V, Allali G, et al. "Faster counting while walking" as a predictor of falls in older adults. *Age Ageing* 2007;36:418-23.
24. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Phys Ther* 2000;80:896-903.
25. McCulloch KL, Mercer V, Giuliani C, et al. Development of a clinical measure of dual-task performance in walking: reliability and preliminary validity of the Walking and Remembering Test. *J Geriatr Phys Ther* 2009;32:2-9.
26. Duncan PW, Studenski S, Chandler J, et al. Functional reach: predictive validity in a sample of elderly male veterans. *J Gerontol* 1992;47:M93-8.
27. Tinetti ME, Speechley M, Ginter SF. Risk factor falls among elderly persons living in the community. *N Eng J Med* 1988;319:1701-7.
28. Salthouse TA, Rogan JD, Prill KA. Division of attention: age differences on a visually presented memory task. *Mem Cognit* 1984;12:613-20.
29. McDowd JM, Craik FIM. Effects of aging and task difficulty on divided attention performance. *J Exp Psychology Hum Percept Perform* 1988;14:267-80.
30. Crossley M, Hiscock M. Age-related differences in concurrent-task performance of normal adults: evidence for a decline in processing resources. *Psych Aging* 1992;7:499-506.
31. Kramer AF, Larish JF, Strayer DL. Training for attentional control in dual task settings: a comparison of young and old adults. *J Exp Psychol* 1995;1:50-76.
32. Yamada M, Aoyama T, Tanaka B, et al. Seated stepping exercise under a dual-task condition improves ambulatory function with a secondary task: a randomized controlled trial [Epub ahead of print Oct 27]. *Aging Clin Exp Res* 2010.
33. Yamada M, Tanaka B, Nagai K, et al. Trail-walking exercise and fall risk factors in community-dwelling older adults: preliminary results of a randomized controlled trial. *J Am Geriatr Soc* 2010;58:1946-51.

MINORU YAMADA, RPT, PhD, Assistant Professor, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. TOMOKIAOYAMA, MD, PhD, Associate Professor, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. MASATOSHI NAKAMURA, RPT, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. BUICHI TANAKA, RPT, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. KOUTATSU NAGAI, RPT, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. NORIATSU TATEMATSU, RPT, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. KAZUKI UEMURA, RPT, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. TAKASHI NAKAMURA, MD, PhD, Professor, Department of Orthopaedic Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan. TADAO TSUBOYAMA, MD, PhD, Professor, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan. NORIAKI ICHIHASHI, MD, PhD, Professor, Department of Human Health Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan.

ACKNOWLEDGMENTS

We thank all of the volunteers for participating in this study, as well as the staff of the day-service center at Sawarabi and Shimogamo-Minamishima. We also acknowledge Nintendo Co. Ltd. for their contribution to the data collection, Professor Shuji Higuchi for his helpful advice, and Dr. Satoshi Teramukai for his statistical advice and valuable discussions.

0197-4572/\$ - see front matter
 © 2011 Mosby, Inc. All rights reserved.
 doi:10.1016/j.gerinurse.2011.02.002

Minority Aging Research Award P30AG031054 from the National Institute on Aging (NIA). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIA or the National Institutes of Health. Dr. Markland received support through a Veterans Health Administration Career Development Award.

Author Contributions: Alayne D. Markland: study concept and design, data analysis, interpretation of data, and manuscript preparation. Patricia S. Goode, Kathryn L. Burgio, and Holly E. Richter: study concept and design, interpretation of data, and critical review of the manuscript. David T. Redden: study concept and design, data analysis, interpretation of data, and critical review of the manuscript. Patricia S. Baker and Richard M. Allman: study concept and design, acquisition of subjects and data, interpretation of data, and critical review of the manuscript.

Sponsor's Role: The sponsors had no active role in the design, methods, subject recruitment, data collection, analysis, or manuscript preparation.

REFERENCES

- Lisi DM. Fecal incontinence: Possible role for drug-induced etiology. *J Am Geriatr Soc* 2010;59:161-162.
- Markland AD, Goode PS, Burgio KL et al. Incidence and risk factors for fecal incontinence in black and white older adults: A population-based study. *J Am Geriatr Soc* 2010;58:1341-1346.
- Quander CR, Morris MC, Melson J et al. Prevalence of and factors associated with fecal incontinence in a large community study of older individuals. *Am J Gastroenterol* 2005;100:905-909.

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:

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

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)

Characteristic	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)	
	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.

Minoru Yamada, PT, PhD
Tomoki Aoyama, MD, PhD
Hidenori Arai, MD, PhD
Kotatsu Nagai, PT
Buichi Tanaka, PT
Kazuki Uemura, PT
Shuhei Mori, PT
Noriaki Ichihashi, PT, PhD

Department of Human Health Sciences
Kyoto University Graduate School of Medicine
Shogoin, Sakyo-ku
Kyoto, Japan

ACKNOWLEDGMENTS

We thank all the elderly participants in each community in Japan.

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

Author Contributions: MY, TA, HA, NI: study concept and design, analysis and interpretation of data, and preparation of the manuscript. KN, BT, KU, SM: acquisition of subjects and data and discussion of data.

Sponsor's Role: None.

REFERENCES

1. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988;319:1701–1707.

2. Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet* 1997;349:617.
3. Beauchet O, Annweiler C, Dubost V et al. Stops walking when talking: A predictor of falls in older adults? *Eur J Neurol* 2009;16:786–795.
4. Podsiadlo D, Richardson S. The timed "Up & Go": A test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;39:142–148.

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 (≥ 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

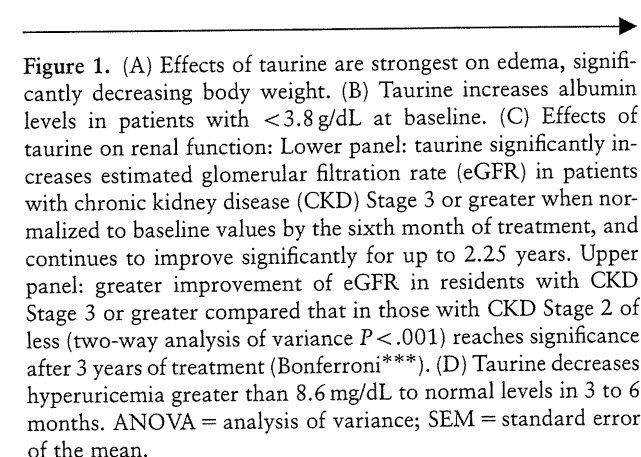
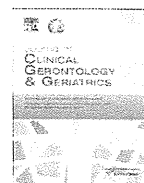


Figure 1. (A) Effects of taurine are strongest on edema, significantly decreasing body weight. (B) Taurine increases albumin levels in patients with < 3.8 g/dL at baseline. (C) Effects of taurine on renal function: Lower panel: taurine significantly increases estimated glomerular filtration rate (eGFR) 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 or 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.



Original article

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

Minoru Yamada, RPT, PhD*, Hidenori Arai, MD, PhD, Koutatsu Nagai, RPT, Kazuki Uemura, RPT, Shuhei Mori, RPT, Tomoki Aoyama, MD, PhD

Department of Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan

ARTICLE INFO

Article history:

Received 14 January 2011
Received in revised form
26 January 2011
Accepted 8 February 2011

Keywords:

Fear of falling
Frail adults
Physical function
physical activity

ABSTRACT

Background/Purpose: The purpose of this study was to determine whether or not daily activities determined by average daily steps are associated with age, gender, body mass index, fear of falling, and physical functions (locomotive function, balance function, and muscle power) in community-dwelling nonfrail and frail older adults.

Methods: This is a cross-sectional study conducted in community-dwelling older adults in Japan. Based on the Timed Up and Go (TUG) test, 629 elderly adults were divided into two groups: 515 were grouped to nonfrail elderly (TUG time less than 13.5 seconds, mean age 77.0 ± 7.2 years) and 114 to frail elderly (TUG time of 13.5 seconds or more, mean age 76.1 ± 7.5 years). Daily physical activities were determined by average daily steps measured by pedometer and four other physical function tests (10-m walk test, single-leg standing, functional reach, and five-chair stand test) were performed along with the assessment of fear of falling.

Results: Stepwise regression analysis revealed that age, gender, 10-m walk test, and single-leg standing were significant and independent determinants of the average step counts in the nonfrail elderly ($R^2 = 0.282$, $p < 0.001$), whereas fear of falling was the only significant and independent determinant of the average step counts in the frail elderly ($R^2 = 0.119$, $p < 0.001$).

Conclusion: These results indicate that differential factors may be related to daily activities depending on the level of frailty in community-dwelling older adults.

Copyright © 2011, Asia Pacific League of Clinical Gerontology & Geriatrics. Published by Elsevier Taiwan LLC. All rights reserved.

1. Introduction

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

Higher physical activities can also improve quality of life and physical and psychological functions, facilitate independent living, and reduce the risk of dementia in older adults.^{5–8} Physical Activity Guidelines for Americans concluded that, for older adults, in addition to the well-known health benefits of a physically active

lifestyle, “strong evidence indicates that being physically active is associated with higher levels of functional health and a lower risk of falling.”⁹

However, Yoshida et al¹⁰ showed that the association between physical fitness and ambulatory activity is affected by the level of instrumental activity of daily life in elderly women, suggesting the effect of frailty on the association. We demonstrated that the resistance training program is effective at decreasing the fear of falling in frail elderly but not in nonfrail elderly (Yamada et al, present study), indicating the difference of the effect of physical training in elderly with different physical fitness. We hypothesized, therefore, that differential factors could affect the level of physical daily activities in the presence or absence of frailty. The purpose of this study was to determine whether or not physical activities determined by average daily steps are associated with age, gender, body mass index (BMI), fear of falling, and physical function (locomotive function, balance function, and muscle power) in community-dwelling nonfrail and frail older adults.

* Corresponding author. Department of Human Health Sciences, Graduate School of Medicine, Kyoto University, 53 Kawaharcho, Shogoin, Sakyo-ku, Kyoto 606-8507, Japan.

E-mail address: yamada@hs.med.kyoto-u.ac.jp (M. Yamada).

2. Methods

2.1. Participants

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

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

2.2. Definition of frailty

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

2.3. Measurement of physical activities

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

2.4. Measurement of fear of falling

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

2.5. Measurement of physical function

The participants received four other physical function tests that are widely used to identify high-risk elderly: 10-m walk test, single-leg standing, functional reach, and five-chair stand. In 10-m walk test, the participants were asked to walk as fast as possible along a 10-m straight line, with a 1 m approach at both ends, making a total length of 12 m. The time required was taken as the measured value. In single-leg standing, the length of time for which participants were able to stand on one leg with their hands placed on their waist was measured. The time was measured twice for each leg and the maximum length of time was taken. Functional reach was measured using the simple clinical apparatus consisting of a leveled yardstick secured to the wall at right acromion height as previously described.¹⁶ In five-chair stand, participants were asked to stand up and sit down five times as

quickly as possible and were timed from the initial sitting position to the final standing position at the end of the fifth stand.¹⁷ For each function test, the participants performed twice, and the average score was then calculated. All test measurements were completed before the daily step measurement.

2.6. Statistical analysis

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

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

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

3. Results

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

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

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

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

BMI = body mass index; SD = standard deviation.

^a χ^2 test.

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

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

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

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

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

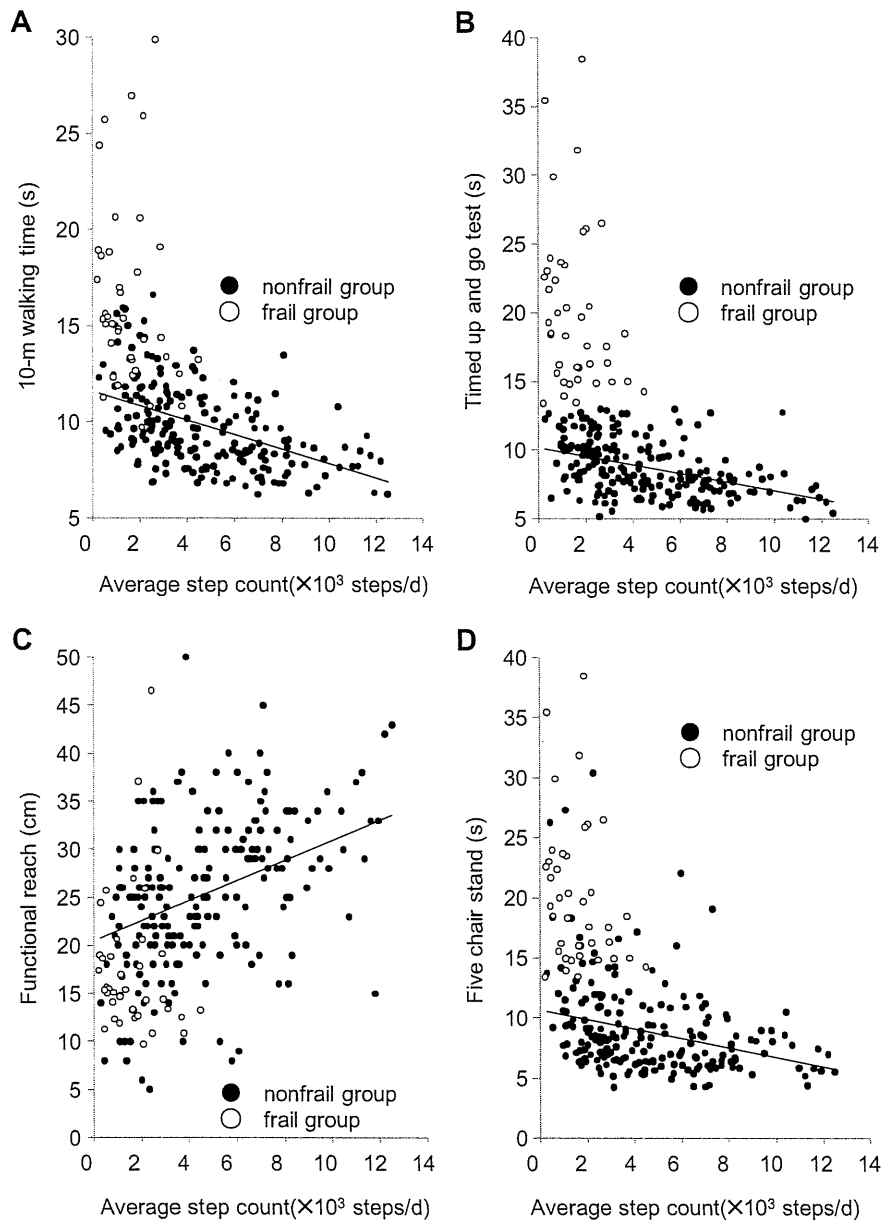


Fig. 1. Relationships between average daily steps and physical function. The physical function was associated with physical activities in nonfrail but not in frail elderly. (A) 10-m walk test; (B) Timed up and go test; (C) Functional reach; (D) Five-chair stand test.