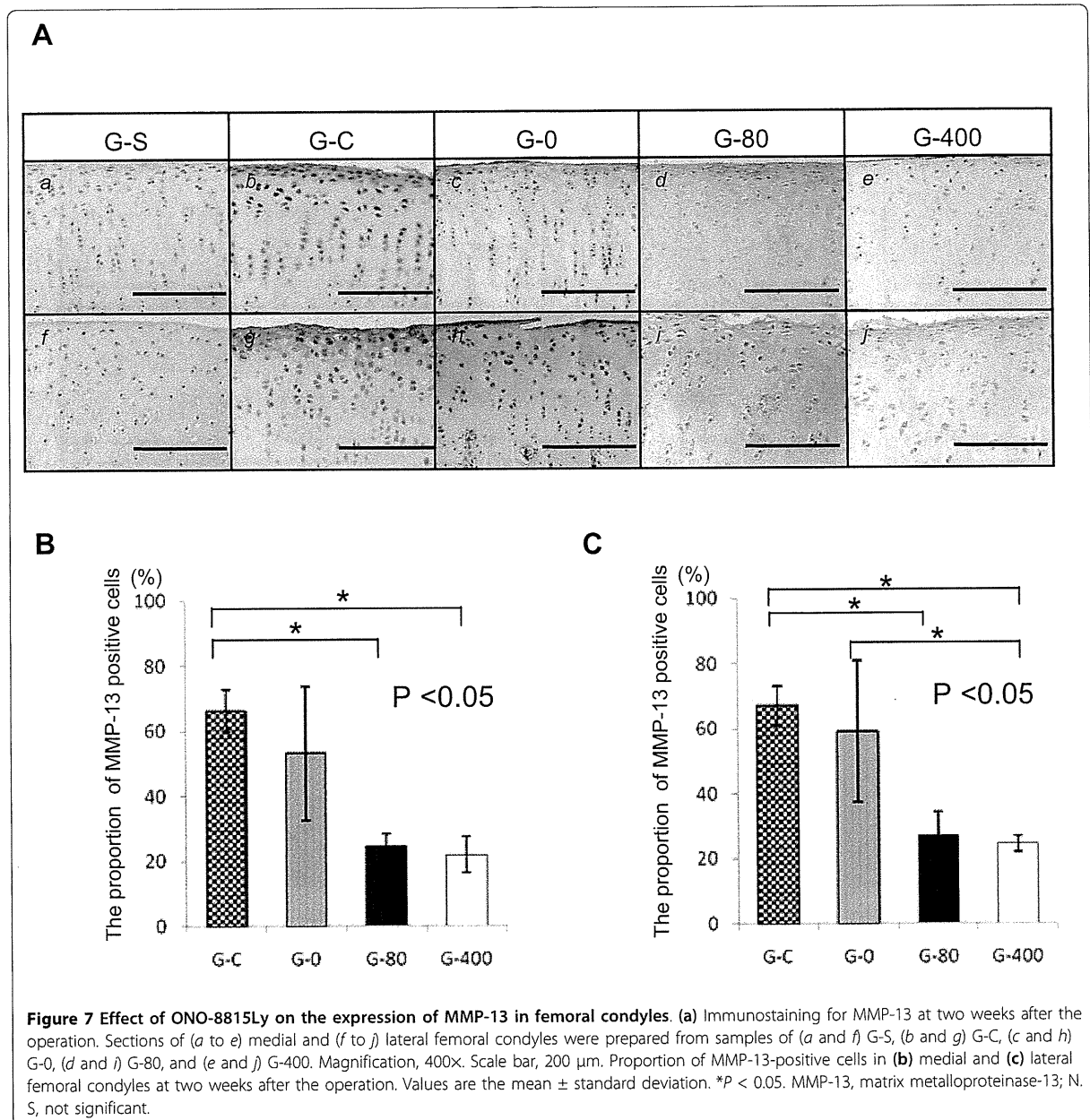


Previously, we showed that EP2 signaling enhances the growth of chondrocytes [18,19] and promotes the regeneration of articular cartilage in rabbits with cartilage defects by an EP2-selective agonist [19]. However, in the current study, EP2 signaling failed to promote chondrocyte proliferation (Figure 5). The differences may result from differences in the animal models. In the previous study, the effect of EP2 signaling on articular cartilage was evaluated using the chondral and osteochondral defect models. In that model, cartilage defects are present before initiation of the treatment with an EP2 agonist. Thus, EP2 signaling may promote cartilage regeneration by inducing proliferation of cartilage chondrocytes and,

consequently, contributing to ECM reconstruction. On the other hand, in the present study, the articular chondrocytes appeared normal immediately after the ACLMT operation, and EP2 signaling reduced cartilage degeneration caused by traumatic instability of the knee joint. These differences in models might be the cause of difference in the results.

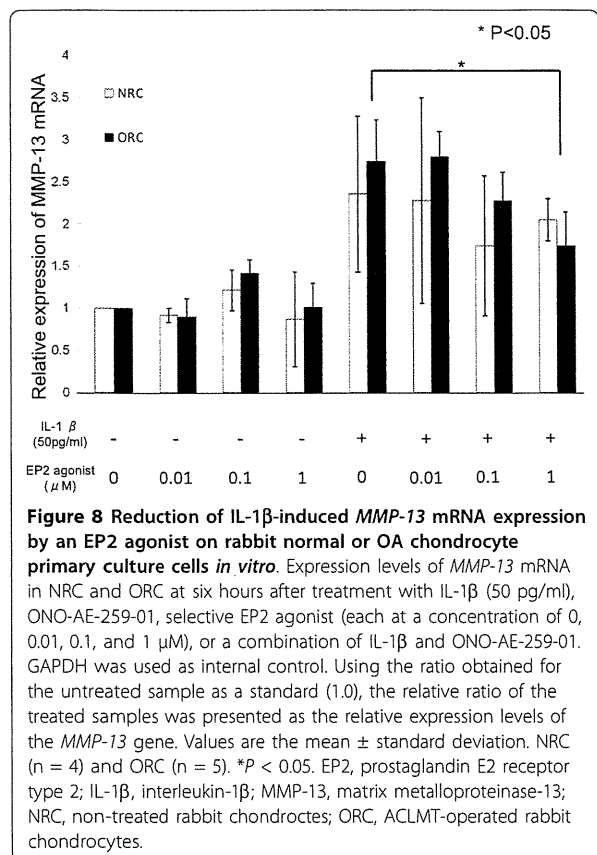
In the present study, the abnormal stress on cartilage tissues induced by joint instability was the main cause of degeneration. The degeneration was more remarkable in the lateral (Figures 2d and 3d) than in the medial components (Figures 2c and 3c), wherein partial meniscectomy was performed. We have no clear explanation for this



result. A study has shown that the lateral components of the rabbit knees were more susceptible to degeneration than the medial components in the ACLMT model [31]. The rabbit knee joints are physiologically in the valgus position, causing excess load on the lateral side, which might explain the susceptibility.

The grade of degeneration at 12 weeks was less prominent than we expected (Figure 4). In this injury model, cartilage degeneration will be induced by abnormal stress due to joint instability. Such abnormal stress takes place during

weight-bearing movements of the knee joints. Therefore, to enhance such stress, Park et al. forced the rabbits to move in a confined space (5 m \times 5 m) for one hour twice a day, from three days after ACLMT onward [22], which increased the Mankin's score up to 12 points at eight weeks after the operation. Restriction in a small cage in the knee-flexed position, as in our study, may minimize such stresses. In addition, both knees were operated on, which may further decrease the activities of the rabbits. These may cause almost no progression of the disease after two weeks.



Generally, cartilage degeneration in OA is due to the induction of MMP expression. MMP-13 is a product of chondrocytes that reside in cartilage and has a stronger effect than MMP-1 on type II collagen [32]. Some insisted that PGE2 exerts direct inhibitory effects on the expression of MMP-1 [33,34] and MMP-13 [28,33,34] in arthritic chondrocytes, and Sato et al. demonstrated that EP2 signaling was responsible for the down-regulation of MMP-13 *in vitro*, although they used a different agonist [28]. Taken together, EP2 signaling regulates MMP-13 production. In agreement, we showed that production of MMP-13 in articular chondrocytes was reduced when treated with an EP2 agonist *in vivo* (Figure 7) and *in vitro* (Figure 8). Controversially others studies show that PGE2 plays a crucial role in the induction of MMP-13 and MMP-3 in chondrocytes in response to IL-1 β in microsomal prostaglandin E synthase-deficient mice [35] or that of PGE2 inhibits chondrocyte maturation [36]. In the current study model, EP2 signaling was shown to inhibit the expression of MMP-13 mRNA, suggesting that EP2 signaling protects the articular cartilage from degeneration.

MMP-3 is a protease expressed in OA specimens at an early stage [37,38]. MMP-3 cleaves a variety of ECM components such as proteoglycans, collagens, and procollagens

[39]. In the current study, ONO-8815Ly had no effect on the production of MMP-3 (Figure 6). Although there is still much to be done, the current study suggested that an EP2 agonist may exert a protective effect on articular cartilage by inhibiting MMP-13.

It is important to clarify whether an EP2 agonist caused inflammation either systemically or locally. PGs are pro-inflammatory lipid mediators whose levels increase in the synovial membrane and synovial fluid of patients with OA. We previously reported that intra-articular administration of an EP2 agonist did not affect the mRNA expression of the MMP-3, TIMP-3, and IL-1 β genes in the synovium, or the amounts of TNF- α and C-reactive protein (CRP) in joint fluids. As in our previous study, we found no severe inflammatory changes in the synovium, and no change in the levels of CRP (data not shown), suggesting that this EP2 agonist caused no inflammation either systemically or locally.

The effect of an EP2 agonist did not last long (Figure 4), yet this may be rectified by developing a suitable drug-delivery system. Continuous administration of an EP2 agonist using such a newly developed system could provide a novel therapeutic modality to treat OA.

Conclusions

Stimulation of PGE2 via EP2 prevents degeneration of the articular cartilage during the early stages. The current study suggests that EP2 agonists may exert a protective effect on articular cartilage by inhibiting MMP-13. With a long-term delivery system, the EP2 agonist could be a new therapeutic tool for OA.

Abbreviations

ACLMT: anterior cruciate ligament and menisectomy transaction; COX: cyclooxygenase; CRP: C-reactive protein; DMEM: Dulbecco's modified Eagle's medium; ECM: extracellular matrix; EP2: prostaglandin E2 receptor type 2; FBS: fetal bovine serum; GAPDH: glyceraldehyde 3-phosphate dehydrogenase; H&E: hematoxylin & eosin; IGF: insulin-like growth factor; IL: interleukin; MMP: matrix metalloproteinase; OA: osteoarthritis; PBS: phosphate-buffered saline; PCNA: proliferating cell nuclear antigen; PG: prostaglandin; PLGA: poly(lactic-co-glycolic acid); SD: standard deviation; TNF: tumor necrosis factor.

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Authors' contributions

HM performed animal experiments, carried out analysis and interpretation of the data, and drafted the manuscript. TA conceived this study, designed the study, carried out analysis and interpretation of the data, and drafted the manuscript. MF and JY performed animal experiments and carried out analysis of the data. KI performed animal experiments. TM was the chief investigator in the development of materials, and conceived this study. TK designed and performed animal experiments. SF performed animal experiments and obtained samples from animals. HS was responsible for providing materials. NA was responsible for the development of drug delivery system. TO carried out administrative and financial support and helped to draft the manuscript. TN carried out administrative and financial support and helped to draft the manuscript. JT conceived this study, provided financial support, designed experiments, interpreted the data, and drafted the manuscript. All authors have read and approved the manuscript for publication.

Competing interests

Takayuki Maruyama, Toshiya Kanaji, Shinsei Fujimura, Hikaru Sugihara, and Akio Nishiura are employees of Ono Pharmaceutical Co. Ltd. All other authors have no conflicts of interest.

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Tailor-Made Programs for Preventive Falls that Match the Level of Physical Well-Being in Community-Dwelling Older Adults

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*Kyoto University,
Japan*

1. Introduction

Falls are relatively common in the elderly, with approximately 30% of individuals aged 65 and older falling at least once a year and approximately half of them experiencing repeated falls (Tinetti et al., 1988). Falls and fractures have a major impact on elderly individuals, their caregivers, health service providers, and the community. Sherrington et al. reported that up to 42% of falls can be prevented by well-designed exercise programs that target balance and involve a good amount of exercise (Sherrington et al., 2008).

In daily life, locomotion occurs under complicated circumstances, with cognitive attention focused on a particular task, such as watching the traffic or reading street signs, rather than on performing a simple motor task such as walking. A seminal study demonstrating that the characteristic “stops walking when talking” could serve as a predictor of falls introduced a novel method for predicting falls based on dual-task (DT) performance (Lundin-Olsson et al., 1997). Our recent study indicated that different factors may be related to fall incidents depending on the level of frailty of the community-dwelling elderly adults (Yamada et al., 2011a). These findings suggest that fall prevention programs should be tailored to the elderly adult’s level of physical well-being. The purpose of this review is to review approaches to fall prevention tailored to an individual’s level of physical well-being.

2. What is “Dual-task”?

Recently, several investigators have reported that DT gait is associated with fall incidents in elderly adults. A summary of these DT studies is shown in Table 1.

3. How can we use DT to assess fall risk in the elderly?

3.1 Game-based fall risk assessment

DT performance may be a reliable predictor of falls in elderly adults. The Nintendo Wii Fit program requires the distribution of attention to the motor task and the monitor (cognitive task). Thus, it is assumed that this program includes a constituent of DT. We examined whether the Wii Fit program’s Basic Step can be used for fall risk assessment in healthy,

	Primary task	Secondary task	Fall related
Beauchet et al., 2008	Walk	Cognitive task	○
Beauchet et al., 2008	Walk	Cognitive task	○
Kressing RW et al, 2008	Walk	Cognitive task	○
Beauchet et al., 2007	Walk	Cognitive task	○
Faulkner KA et al, 2007	Walk	Cognitive task	○
Toulotte C et al, 2006	Walk	Manual task	○
Springer S et al, 2006	Walk	Cognitive task	×
Bootsma- vander Wel A et al, 2003	Walk	Cognitive task	×
Verghese et al., 2002	Walk	Cognitive task	○
Stalenhoef PA et al, 2002	Walk	Cognitive task	×
Lundin-Olsson L et al, 1997	Walk	Cognitive task	○

○, related to falls; ×, non-related to falls

Table 1. Effect of dual tasking on falls.

community-dwelling elderly adults (Yamada et al., 2011b). The results suggested that game-based fall risk assessment has a high generality and is very useful for assessing community-dwelling elderly adults (Fig. 1).

This study included a Wii Fit Balance Board, which was placed under the participants' feet. A score of 111 points on Basic Step was used to classify 88.6% of the cases correctly ($p < 0.001$). The horizontal demonstrates the cutoff point.

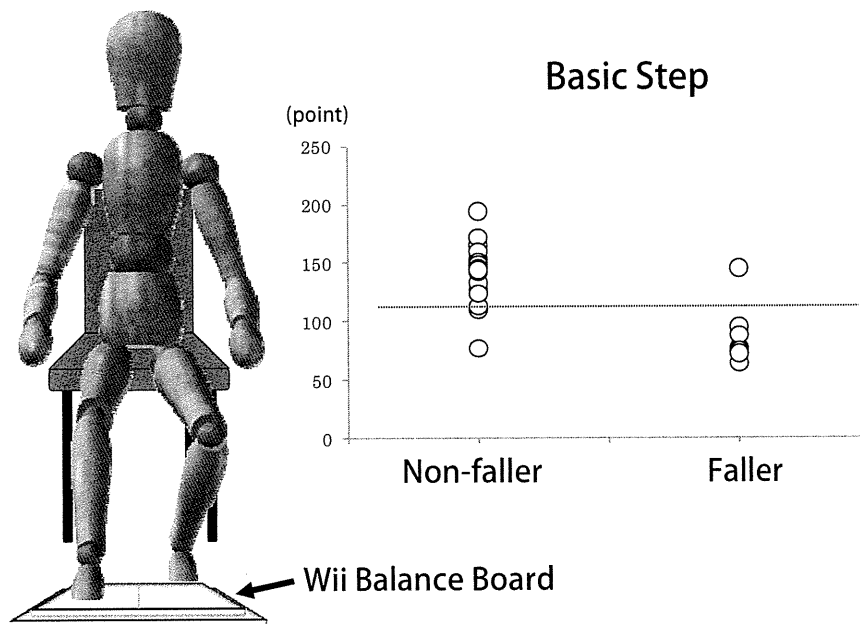


Fig. 1. Schematic diagram of Basic Step as played in a sitting position and scatter chart.

3.2 Smartphone-based fall risk assessment

The Android-based Smartphone can be used to develop applications freely. These applications can then be disseminated across the world via the internet. 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. We 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 angle of the phone is determined by triaxial accelerometers (Fig. 2). The Android application also calculates a score on the basis of the coordinate data of the ball on the circle; higher scores indicate that the blue ball is closer to the center of the circle. The application was based on the “walking while carrying a ball on a tray” task. We previously examined whether the score determined by the Android application for DT-based fall risk assessment was related to falls in a population of community-dwelling elderly people (Yamada et al., 2011c). The results suggested that the Android application is very useful for fall risk assessment in elderly adults (Fig. 2).

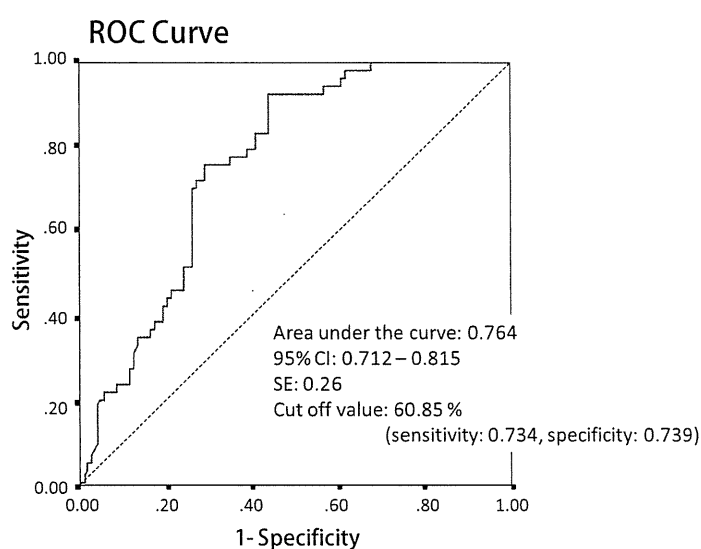
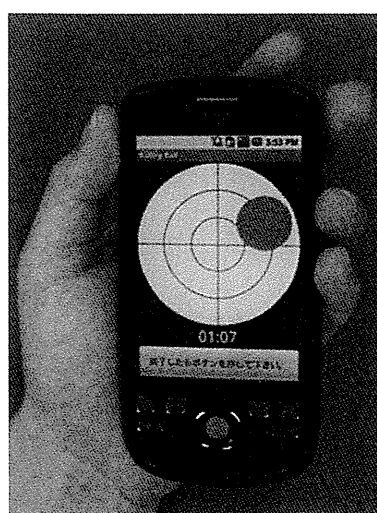


Fig. 2. An Android application allows users to control the position of a small blue circle (1.5 cm in diameter) on a large white circle (4 cm in diameter). Scores are automatically calculated on the basis of coordinate tracking data for the blue circle.

ROC (receiver operating characteristic) curve of the dual tasking (DT) total cost for the classification of fall risk. The area under the curve was 0.764. For the DT total cost, the cut-off value was 60.85% (sensitivity = 73.4%, specificity = 73.9%). CI, confidence interval

3.3 Multitarget Stepping Test (MTST)

We developed a walking test, the multitarget stepping test (MTST) (Yamada et al., 2011d). During the test, stepping and avoidance failures were measured while participants walked along a 10-m walkway and stepped on multiple targets. The MTST was performed on a black elastic mat (10 m long × 1 m wide). Forty-five 10 cm × 10 cm squares were on the mat (see Fig. 3). These squares were arranged into 3 rows (15 cm between each row) and 15 lines (61 cm between each line). Each square was marked with red, blue, or yellow tape. Each line had one of the 3 colored squares in a random order. One square (blue or yellow) was the

footfall target, whereas the others were distracters. The color of the footfall target was counterbalanced among the participants and announced to each participant before he or she began walking.

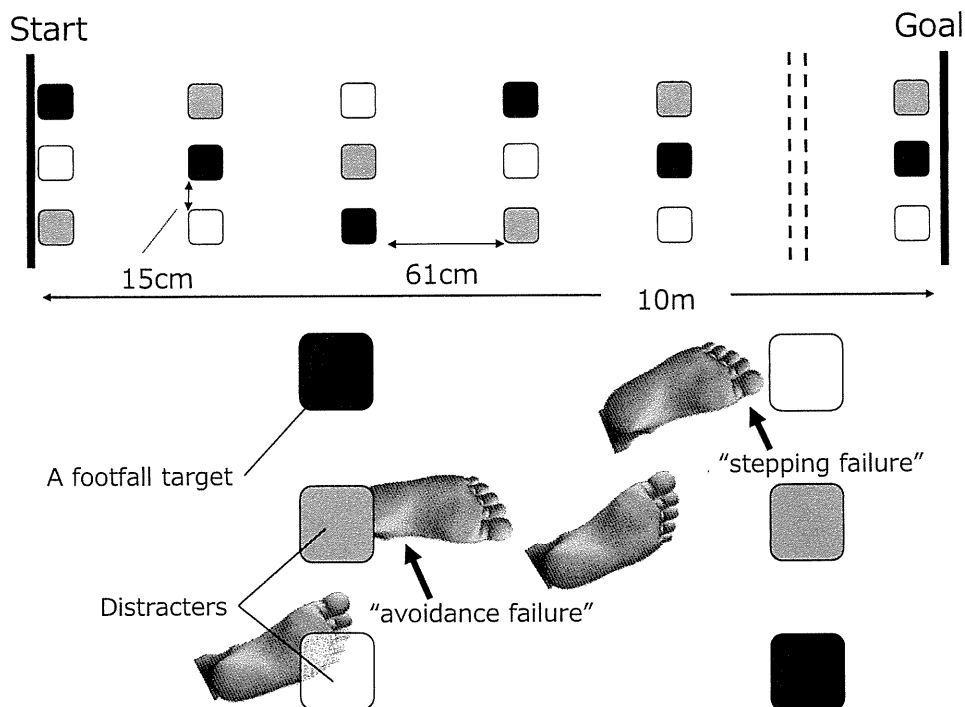


Fig. 3. The 10-m walkway used in the multitarget stepping test (MTST): Each square was made of red, blue, or yellow tape. The MTST measured 2 types of failure. A participant intended to step on footfall targets (displayed in white). Failure to step on the footfall target was regarded as a stepping error. Failure to avoid a distracter was regarded as an avoidance failure. As shown in this figure, avoidance failure was always the result of an accidental step as the participant walked from target to target; it did not occur because of selecting the wrong target out of the 3 squares on the line on which the participant intended to step.

The participants walked on the mat at a self-selected pace while stepping on the target square placed on each line. The participants were instructed (a) to step on a footfall target with either side of the foot and any part of the sole, (b) to take as many steps as necessary while walking between the lines to comfortably walk toward the next footfall target, and (c) to not step on the distracters. The main dependent measures were 2 types of failure indicating less accurate stepping performance: a stepping failure (i.e., failure to step on the footfall target) and an avoidance failure (i.e., failure to avoid distracters).

The results demonstrated that the stepping failure was independently associated with falling (odds ratio [OR] = 19.365, 95% confidence interval [CI] = 3.28–113.95; $p < 0.001$). Hence, measurements of stepping accuracy while performing the MTST, particularly precise stepping failure, could help identify elderly individuals at high risk for a fall.

3.4 Questionnaire-based fall risk assessment

As discussed, DT walking, game-based assessment, Smartphone assessment, and/or MTST can be used to identify elderly adults at high risk of falling. However, more simple and reliable assessment methods are necessary for community-dwelling elderly people. We previously examined whether a newly developed index we had designed to assess complex-task locomotion was related to falls in a robust elderly population (Yamada et al., in press a). The results suggested that a score of more than 1 point on the new index can predict falls in elderly adults (Table 2, Fig. 4).

	Item	0	1
1)	Can you stand up without a support?	Yes	No
2)	Can you turn in the opposite way, while holding an empty glass?	Yes	No
3)	Can you walk without dropping a glass of water?	Yes	No
4)	Have you ever tripped over an obstacle while going to the bathroom or picking up the telephone?	No	Yes

Table 2. Newly developed index

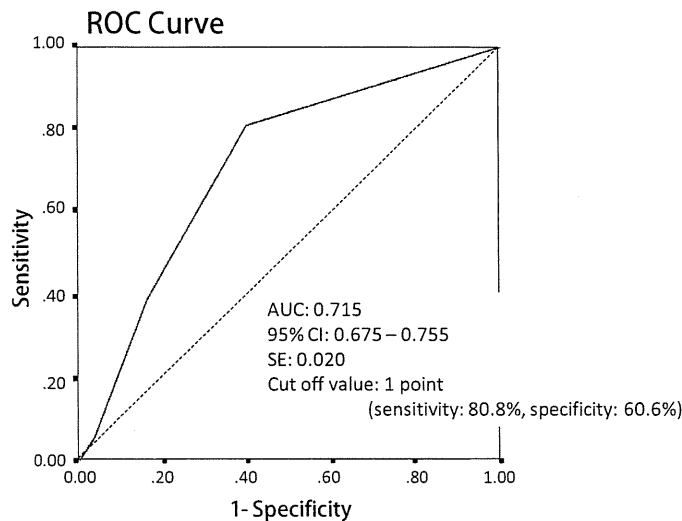


Fig. 4. The ROC (receiver operating characteristic) curve for the total points used for the classification of fall risk: The area under the curve (AUC) was 0.715. Concerning the total points, the cut-off value was determined at 1 point (sensitivity, 80.8%; specificity, 60.6%). CI, confidence interval

4. Different factors related to fall incidents

Our research has indicated that different factors may be related to fall incidents depending on the level of frailty in community-dwelling elderly adults.

One study population consisted of 1038 elderly Japanese subjects aged 65 years or older living in a community (401 men, 637 women; mean age, 77 ± 8 years). We assessed 6 items of physical functioning: timed up and go (TUG), functional reach, 5-chair stand, single-task (ST) 10-m walking time, and DT (CT [cognitive task], MT [manual task]) 10-m walking time.

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 (Podsiadlo et al., 1991). Functional reach was measured using a simple clinical apparatus consisting of a yardstick secured to the wall at right acromion height as previously described (Duncan et al., 1990). In the 5-chair stand, participants were asked to stand up and sit down 5 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 (Guralnik et al., 1994). In ST walking, the participants were asked to walk as fast as possible along a 10-m straight line, with a 1-m approach at both ends, for a total length of 12 m. The time required was measured. 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: $DT \text{ cost } [\%] = 100 \times (DT \text{ walking time} - ST \text{ walking time}) / ([ST \text{ walking time} + DT \text{ walking time}] / 2)$.

Information on fall incidents over the following year was collected from participants via a monthly telephone interview. A fall was defined as any event that led to unplanned, unexpected contact with a supporting surface during walking.

For analysis, we divided the TUG test results into quartiles (fastest, faster, slower, and slowest). A multivariate analysis by means of logistic regression using a stepwise-forward method was performed to investigate which of the 5 measures of physical functioning (i.e., ST walking time, CT cost, MT cost, functional reach, or 5-chair stand test) was independently associated with falls.

A total of 20% in the fastest group, 18.2% in the faster group, 34.1% in the slower group, and 44.1% in the slowest group experienced falls over the following year. In the fastest group ($n = 230$), the regression analysis indicated that the MT cost ($OR = 1.068$, $95\% \text{ CI} = 1.04\text{--}1.10$; $p < 0.001$) was an independent variable that remained in the final step of the regression model. In the faster group ($n = 258$), the regression analysis indicated that the CT cost ($OR = 1.03$, $95\% \text{ CI} = 1.01\text{--}1.04$; $p < 0.001$) was an independent variable. In the slower ($n = 264$) and slowest ($n = 286$) groups, the 5-chair stand test (slower group: $OR = 1.11$, $95\% \text{ CI} = 1.03\text{--}1.19$; $p < 0.001$; slowest group: $OR = 1.05$, $CI = 1.01\text{--}1.09$; $p < 0.045$) was found to be a significant and independent variable of falls. A summary of these results is shown in Fig. 5.

5. Fall prevention programs tailored to levels of physical well-being

Fig. 5 shows that different factors may be related to fall incidents depending on one's level of physical well-being. DT walking is associated with falls in the robust elderly population, and thus this population should be given the rhythmic stepping exercise (Yamada et al., 2011e). DT walking and muscle strength are associated with falls in the intermediate elderly population, and thus this population should be given the seated stepping exercise (Yamada et al., 2010a). Muscle strength and DT walking are associated with falls in the pre-frail elderly population (Yamada et al., 2010b) and thus this population should be given the trail walking exercise. Finally, muscle strength is associated with falls in the frail elderly population, and thus this population should be given resistance exercise (Yamada et al., 2011f).

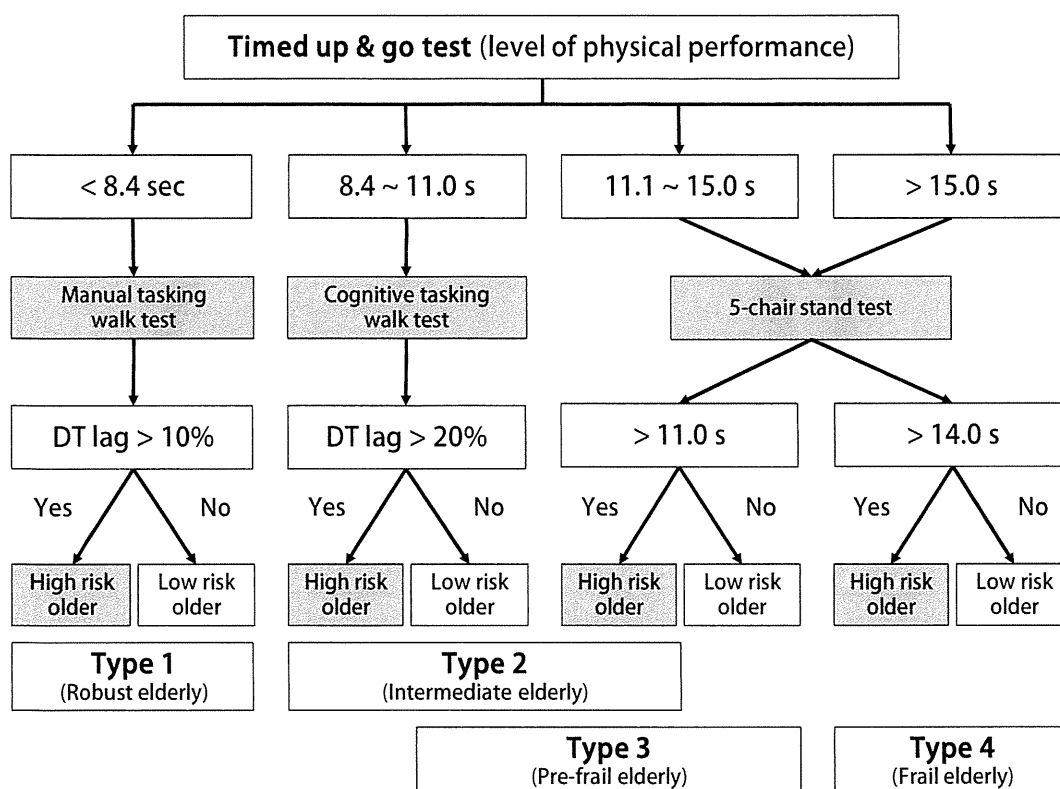


Fig. 5. Flow chart showing that the different factors may be related to fall incidents depending on an individual's level of physical well-being; DT, dual tasking

5.1 Rhythmic stepping exercise

Rhythmic stepping exercises were performed on a thin elastic mat (150 × 150 cm) that was partitioned into 5 squares (50 cm each) to form a cross (Fig. 6). The stepping exercises included forward, backward, and sideways step patterns. The participants were required to step at a tempo of 60-120 beats/min along with the accompanying rhythm sound and to step into the square indicated verbally by the supervisor (e.g., "right," "forward," "back"). Cognitive functioning (reaction, short-term memory, etc.) and motor functioning (stepping in multiple directions) were simultaneously required of the participants. In order to change the level of difficulty, the instruction method transposed not only direction but also color (e.g., "red," "blue") or number (e.g., "3," "7"). The participants completed 5 sets of 1 min per set of stepping exercises between weeks 1 and 8, which was then increased to 3 sets of 3 min per set between weeks 9 and 16 and 3 sets of 5 min per set between weeks 17 and 24. The instructions given at the beginning of each class were as follows: "Please step as correctly as possible, and avoid making mistakes as much as you can."

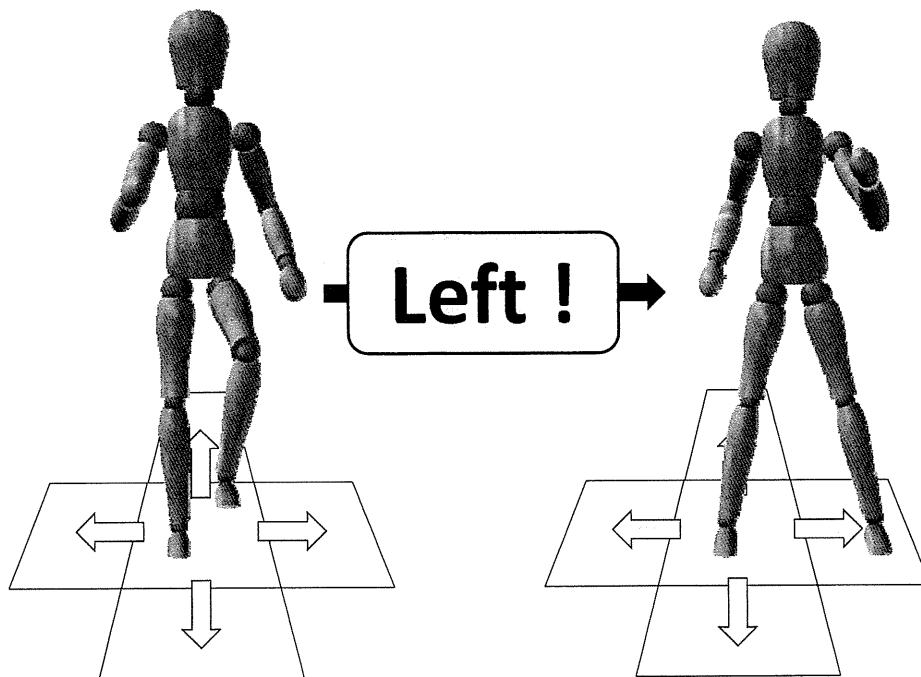


Fig. 6. Schematic representation of the stepping exercises.

The stepping exercises were performed on a thin elastic mat that was partitioned into 5 squares (50 cm each) to form a cross shape. The stepping exercises included forward, backward, and sideways step patterns.

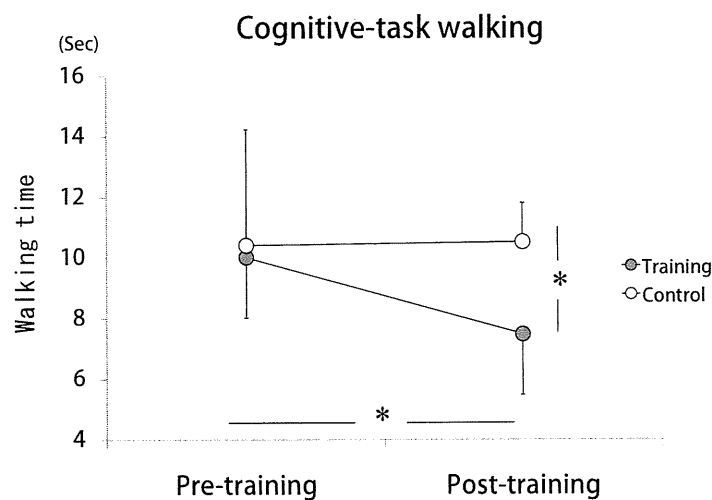


Fig. 7. Cognitive task walk time in training (rhythmic stepping exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

We evaluated whether a 24-week rhythmic stepping exercise program would effectively improve physical functioning and reduce fear of falling in community-dwelling elderly

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.”

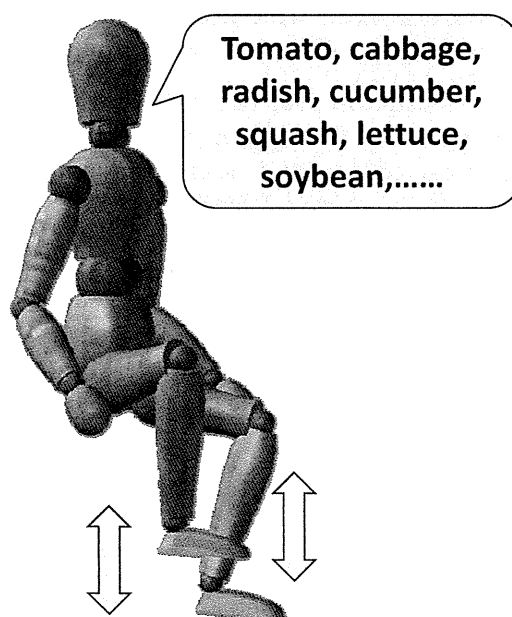


Fig. 8. Schematic representation of the seated stepping exercise

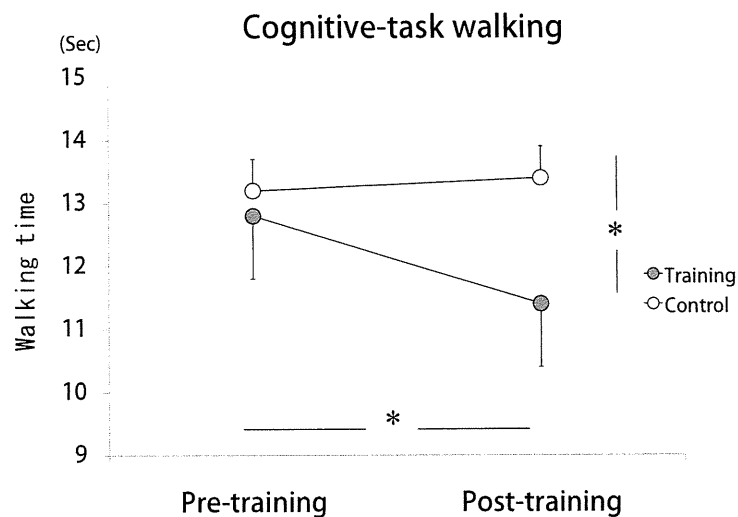


Fig. 9. Cognitive task walk time in training (seated stepping exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

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:

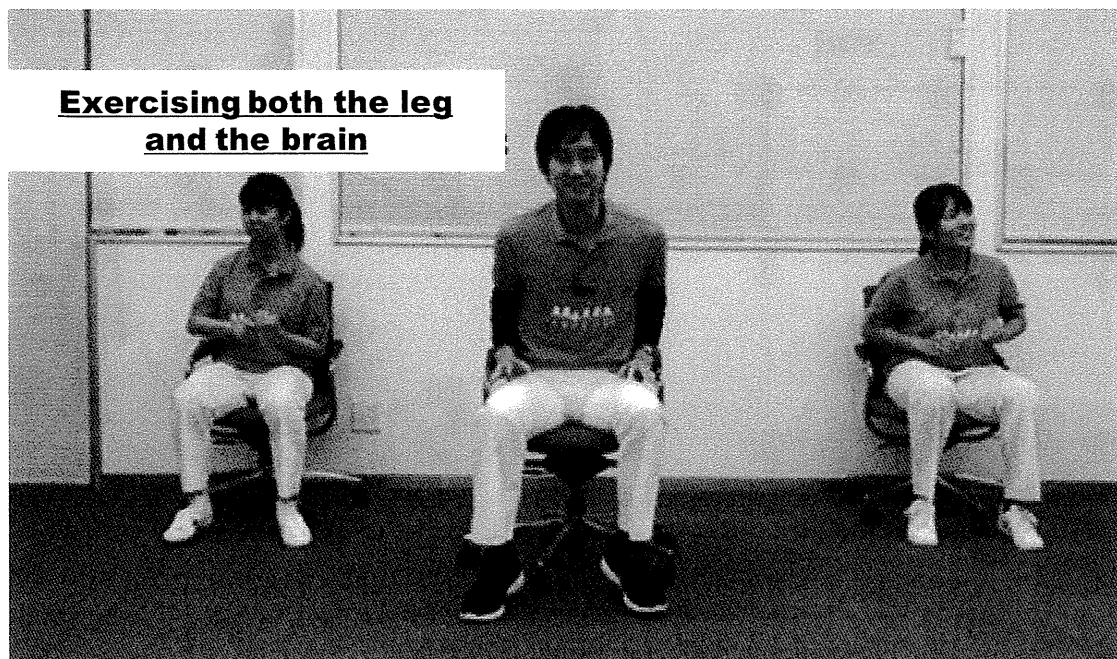
<http://www.youtube.com/watch?v=1391kzEYMJM>

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.

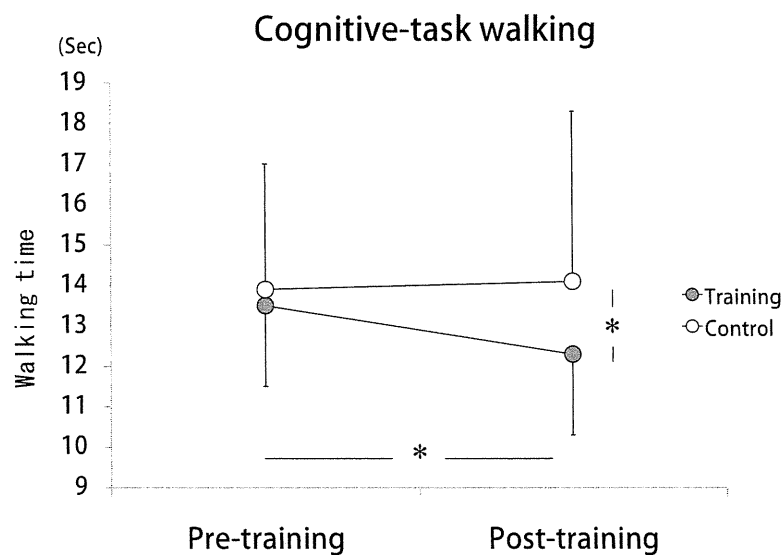


Fig. 11. Cognitive task walk time in training (DVD-based seated stepping exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

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.

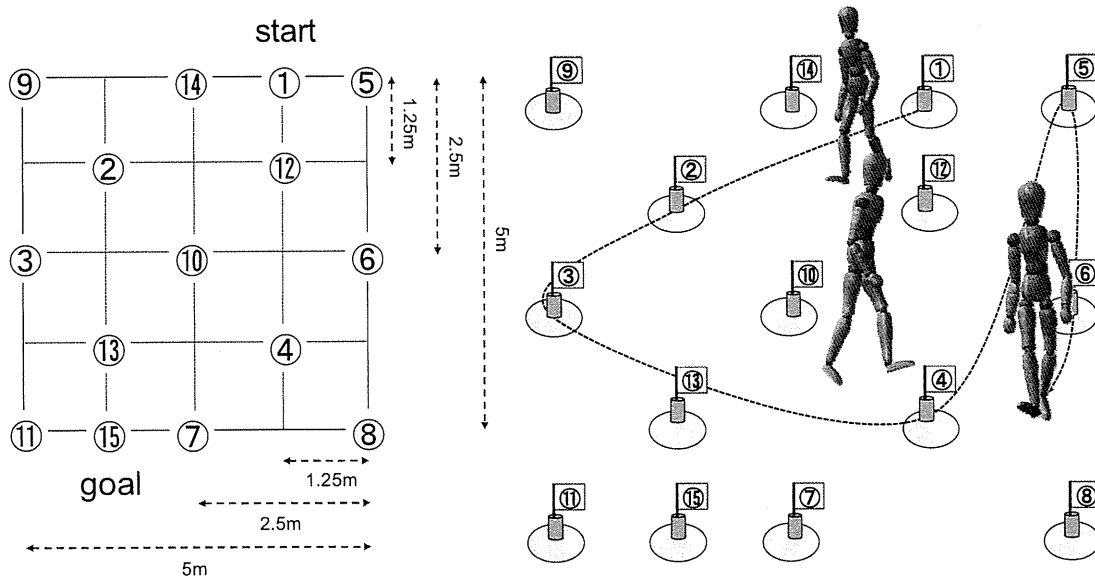


Fig. 12. Schematic representation of the trail walking exercise

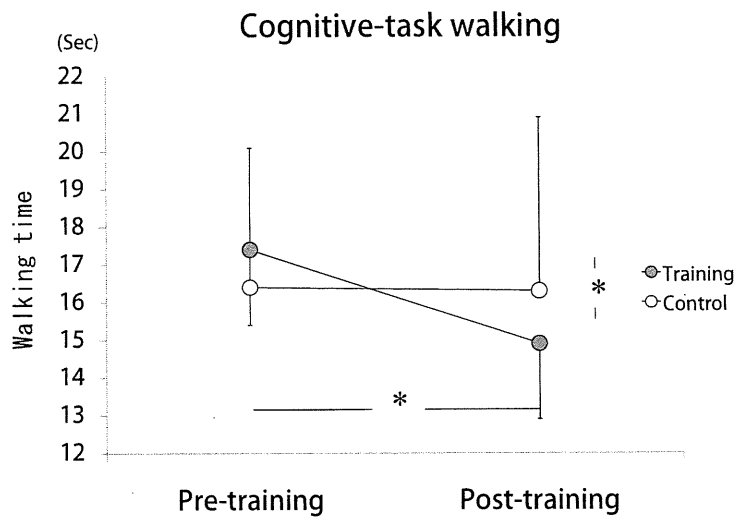


Fig. 13. Cognitive task walk time in training (trail-walking exercise) and control groups during pre- and post-training. Significant differences were observed between the 2 groups ($p < 0.05$).

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).

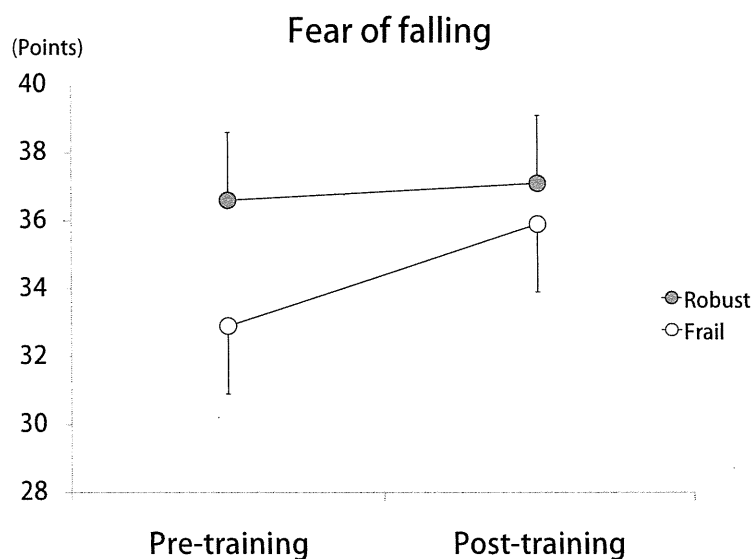


Fig. 14. Fear of falling in robust and frail groups during pre- and post-resistance training. Significant differences were observed between the 2 groups ($p < 0.05$).

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.

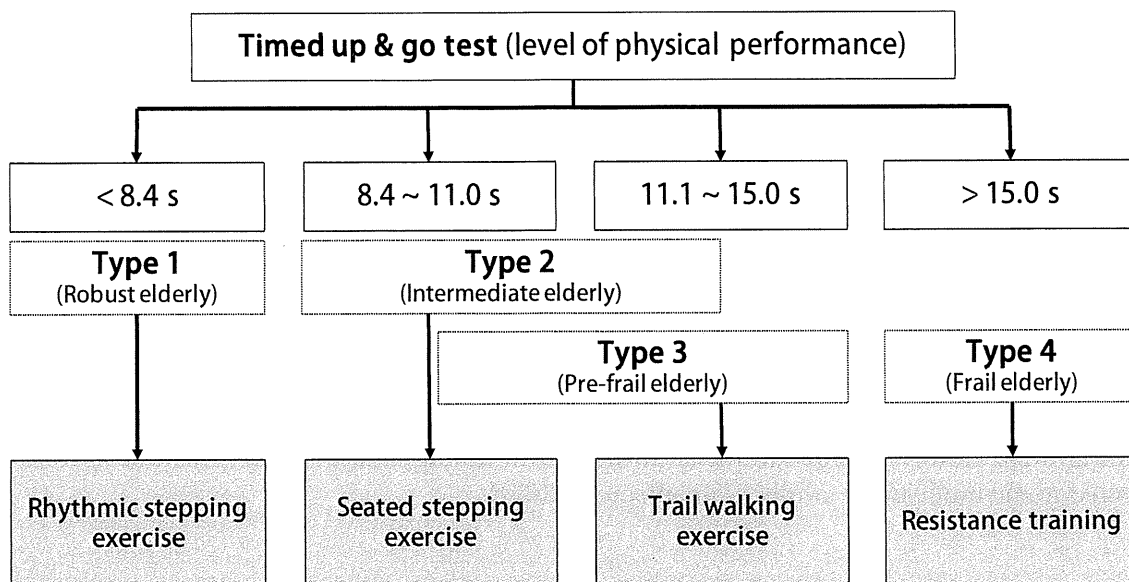


Fig. 15. Flow chart showing interventions tailored to levels of physical well-being.

7. Acknowledgments

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