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Regular Exercise in the Elderly Is Effective to Preserve the Speed of Voluntary Stepping under Single-Task Condition but Not under Dual-Task Condition

A Case-Control Study

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Key Words
Falls · Voluntary step execution · Balance · Late-life function · Exercises

Abstract
Background: Stepping response may be considered the most important postural reaction to prevent a fall because it is the inability to respond effectively to a loss of balance that ultimately determines whether a fall occurs. However, very little has been studied on the effect of exercising on step execution behavior in the elderly. ***Objectives:*** To explore whether older persons who exercise regularly have faster voluntary stepping times than sedentary elderly persons. Additionally, we investigated the association between step execution behavior, self-reported physical function, and balance performance. ***Methods:*** Case-control study of 48 elderly adults aged 65–91 years who live independently in retirement homes. Participants were classified as 24 exercisers (reporting >2 exercise training activities/week) and 24 age- and gender-matched inactive elderly individuals (who do not exercise regularly). The Voluntary Step Execution Test was performed as a reaction time task while standing on a force platform under single-task and dual-task conditions. Step initiation phase, foot off time, foot contact time, preparatory, and swing phases were extracted from center of pressure and ground reaction force data. Self-reported function was examined using Late-Life Function and Disability Instrument; Berg Balance Test was also performed. ***Results:*** Exercisers had significantly faster voluntary step times in single-task condition (959 vs. 1,158 ms) but not during dual-task condition (1,170 vs. 1,303 ms). Exercisers had a significantly higher Berg Balance Test (53.7 ± 3.6 vs. 49.8 ± 5.3), consumed less medication (3.3 ± 2.3 vs. 5.6 ± 2.9), and their lower extremity function scores were higher (88.61 ± 2.3 vs. 73.1 ± 2.7) than those of inactive subjects. ***Conclusion:*** Exercising regularly protects from physical functioning loss in older persons and against a decrease in voluntary step execution times during single-task but not during dual-task conditions. Lack of specificity (dual-task exercises) during the training may be the cause of insignificant differences in dual-task stepping performance. Thus, adding dual-task training may improve dual-task performance in the elderly.

Introduction

There are well-documented studies that show exercise is beneficial to people with heart disease [1] and that it reduces the risk of diabetes [2], stroke [3], hypertension [4], and osteoporosis [5], and increases muscle power [6],

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reduces frailty [7], and improves balance control [8] in the elderly. Research studies investigating exercise as a means of falls prevention in older adults have shown controversial results. Several studies show that exercise prevents falls [9–11], and others studies have shown no reduction [12–13]. This might be because of flaws in many balance training studies conducted to date. Even well-respected studies on balance training in the elderly population appear to have either ignored or misunderstood the importance of basic principles of physical training and exercise physiology, especially with respect to the concept of specificity. It is well-known that quick execution of a step is the most important protective postural strategy to avoid falling that can arise from large perturbations (e.g. slips, trips, and collisions), or from volitional movement (e.g. self-induced perturbation such as turning, bending, reaching) [14–15]. However, most training programs do not include step training and very little has been studied on the effect of exercising on step execution behavior in the elderly.

Melzer and Oddsson [14] found a significant increase in voluntary step reaction times in single and dramatic increase during dual-task condition (adding cognitive load) in older adults compared with younger ones, suggesting that elderly persons lacked the neural processing resources required for swift multitasking during a voluntary postural task. Thus, it is believed that some falls result from the inability to recover from a fall during an additional attention-demanding task during activities of daily living. A recent study by Melzer et al. [16] found that voluntary step execution was statistically significantly different between elderly nonfallers and fallers during dual-task conditions, participants with dual-task voluntary step execution times $\geq$1,100 ms had 5 times the risk of falling than participants with execution times <1,100 ms. Luchies et al. [17] showed reduced volitional step length in older adults compared to young adults, and Medell and Alexander [18] showed impaired step length in subjects with a history of falls. With respect to compensatory stepping responses, there was an increased frequency of collisions between the swing foot and stance leg during lateral perturbations [19], increased frequency of multiple-step responses [17–20], and an additional lateral second step following forward or backward compensatory step [20]. All the above results suggest that delayed stepping reactions, whether they were compensatory or voluntary in nature, may be a factor contributing to the large number of falls seen in elderly persons.

Thus, improved ability to step quickly under single- and dual-task conditions determines whether a fall occurs in elderly persons. Consequently, examination of whether exercising regularly improves/preserves the speed of stepping in elderly individuals is essential if we are to positively impact the health of the fastest growing population segment today.

The present study aimed to explore whether older persons who adopt an active lifestyle have faster voluntary stepping times than sedentary elderly persons. To date, only a few studies have examined the effects of exercising on step reaction times under single-task conditions [21], and others have suggested including step training during dual-task conditions [22, 23] in the elderly. An additional aim was to investigate the association between step execution behavior and self-reported physical function and balance performance in older persons. Based on previous work [24], we hypothesized that the voluntary step in single- and dual-task conditions would be faster and both would be related to the self-reported measure of function in exercisers.

Methods

Subjects

Forty-eight healthy subjects over 65 years old (age range 65–91 years) in protected retirement homes ('Omer's Gardens', Omer and Mediterranean Towers-Mishkenot Clal, Nordiya) were recruited to participate; 24 subjects were exercisers (i.e. exercised regularly) and 24 age- and gender-matched sedentary controls who did not exercise regularly. All the subjects were independent in daily living activities and no walking aids were required. Subjects completed medical histories, exercise histories, and information on lifestyles by questionnaire and physical examination before participation in the study to ensure they were free from exclusion criteria. The exclusion criteria were: (a) serious visual impairment, (b) inability to ambulate independently (cane/walker not acceptable), (c) score less than 24 on the Mini-Mental State Examination, (d) symptomatic cardiovascular disease, (e) neurological and orthopedic disorders, (f) peripheral neuropathy of the lower extremities, and (g) severe arthritis. After eligibility was determined and prior to their participation, subjects signed an informed consent form approved by the Institutional Review Board, Helsinki Ethics Committee of the Soroka University Medical Center, Beer-Sheva, Israel.

A sample size requirement of 48 was estimated to detect an effect size of 0.8, powered at 80%, and alpha of 5% was chosen for a clinically meaningful estimate. The estimation was performed two-sided. A paper published by Melzer et al. [16] found that step execution (foot contact times) during the execution of a cognitive task were 1,414 ± 417 ms for elderly fallers. Foot contact times of all 11 elderly fallers in this study were 1,050 ms or higher. Thus, it was estimated that at least 22 subjects are required to detect a significant change in foot contact from 1,414 to 1,050 ms.

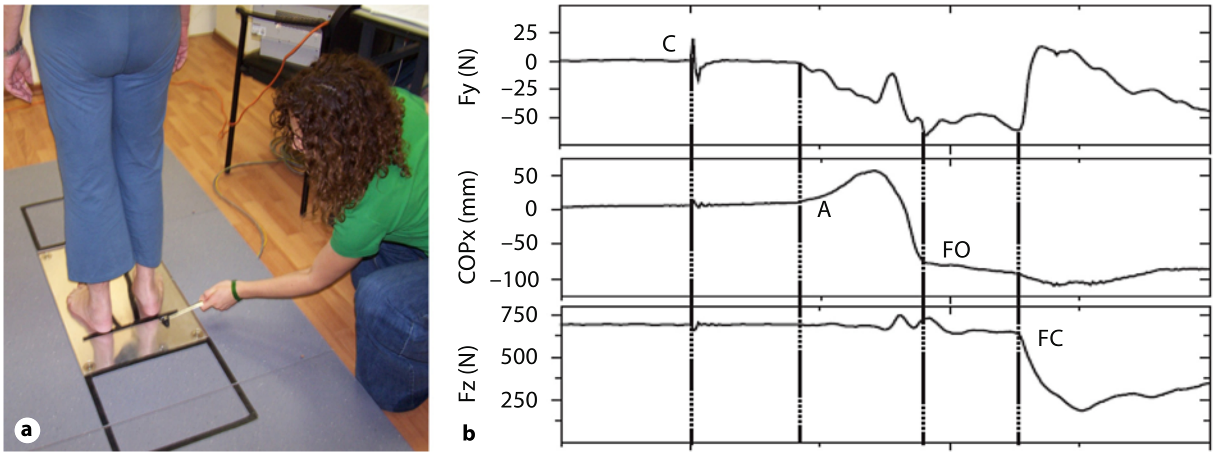

Fig. 1. a Photo of the experimental set up. Subjects were instructed to step as quickly as possible following a tap cue on the heel provided manually by the experimenter. After a short training period, subjects were instructed to step into a square that was drawn on the floor outside the force plate. **b** An example of step execution data. Fy = Ground reaction forces (shear forces) in anteroposterior direction; Fz = vertical ground reaction forces. The following events are marked with X; tap cue (C); initial deviation of COPx (A); foot off (FO); foot contact (FC). Note that the tap cue is detectable in any of the signals. See text for further details.

Exercise Programs

A convenient sample of 24 subjects was recruited in their protected retirement homes; they were elderly individuals who self-reported exercising regularly 3 times a week. The exercise included Tai Chi training once a week, Feldenkreis training and walking training session that contains aerobic exercises. The exercisers had participated in approximately 45-min exercise sessions, 3 times a week, for the last 3 years. The training programs were divided into five sections: a 5-min warm-up period, a 5-min stretching period, a 30-min training period (Tai Chi or Feldenkreis or Balance, aerobic and strength training), and a 5-min relaxation (cool down) period. The exercises were undertaken as group activities, with a major emphasis on social interaction and enjoyment.

Outcome Measures

Functional Balance Measurement

Elderly persons enrolled in the study also underwent the Berg Balance test (BBS) with a test-retest reliability correlation coefficient of 0.98 [25]. During the BBS, the participant was scored on 14 tasks graded on a 0–4 scale (maximum 56) to evaluate balance under different conditions; higher score indicates higher levels of balance function.

Voluntary Step Execution Test

Subjects were instructed to stand upright and barefoot on a force platform and to step as quickly as possible following a tap cue on the heel provided manually by the experimenter. Step execution trials were roughly 60 cm long into a square that was drawn on the floor out of the force plate (fig. 1a). The Voluntary Step Execution Test was always performed with the dominant leg as chosen by the subject. After short training period, a total of 9 trials were conducted for each of the two test conditions (e.g. single- and dual-task conditions), forward, sideways, and backward (three trials in each direction) for a total of 18 step trials. For the single task, subjects viewed an 'X' displayed on a screen 3 m in front of them. During the dual task, they were viewing the same screen while performing a modified Stroop task and awaiting the somatosensory cue. The modified-Stroop task was projected at eye level onto a wall 3 m in front of the subject. The task consisted of reading colors from a printout showing 25 colored words, representing names of colors that were different from the printed ink. For example, the word yellow was printed in red ink. The subjects were asked to step as quickly as possible from the force plate while concurrently reading out loud the color of the ink as quickly as possible until the end of the procedure. They were instructed not to stop reading while stepping, and did not receive any feedback concerning their performance in the two tasks. The modified Stroop test [26] was used because the test requires considerable focused attention and few instructions to perform. Subjects were allowed a brief learning period in a sitting position prior to start of the experiment. Subjects were instructed to stand evenly on both feet and to step as quickly as possible following a tap cue on the heel of the preferred stepping foot provided manually by the experimenter (fig. 1a). The center of pressure (COP) and ground reaction force data during trials were collected with a Kistler 9287 force platform (Kistler Instrument Corp., Winterthur, Switzerland) and sampled at a frequency of 100 Hz.

Force platform data were analyzed using a code written in Matlab (Math Works Inc., Cambridge, Mass., USA) to extract five different temporal parameters: step initiation, preparation and swing phases, foot off time and foot contact time (fig. 1b). The tap cue (C) was detected as a spike (>3 standard deviations from the average baseline noise) in the ground reaction forces in the anteroposterior direction. Step initiation was defined at the first mediolateral deviation of COP (COPx) towards the swing leg (>4 mm from the average baseline sway prior to tap). Foot off was defined by a sudden change in the slope of COP towards the stance foot in the mediolateral direction (COPx). Foot contact was defined as the onset of unloading in the vertical ground reaction forces when the subject stood with the swinging leg out of the force platform. The step initiation phase was calculated as the time from tap onset to step initiation. The preparation phase was defined as the time from step initiation to foot off, and swing phase was calculated as the time from foot off to foot contact. Foot contact time (the stepping time) was calculated as the time from tap cue to foot contact [14, 16, 24]. An average of each of the five temporal parameters event across 9 trials during two different conditions: single task and dual task was used to represent each subject.

Self-Reported Measure of Function

The Late-Life Function and Disability Index (LLFDI) tests were administered [27]. The LLFDI is a scale specifically designed to be sensitive to differences in physical function and disability. The English version of LLFDI showed intraclass correlation coefficients of 0.91–0.98 for the function component [27]. Similarly, the Hebrew version [28] showed test-retest ICCs ranged from good to excellent (0.77–0.90) for the functional component. The function component evaluates self-reported difficulty in performing 32 physical activities in three dimensions: upper extremity, basic lower extremity, and advanced lower extremity. Subscales are each scored on a 0–100 scale, with higher scores indicating higher levels of functioning. LLFDI Overall Function scores were moderately associated with BBS and TUG ($r = 0.48$, $p < 0.001$) [28].

Data and Statistical Analyses

The analysis of step execution data extracted specific temporal events using a program written in MatLab (Math Works). The dependent variables included the average step execution times in single- and dual-task conditions: (a) time to step initiation; (b) time to foot off; (c) time to foot contact; (d) preparatory phase; (e) swing phase. For each parameter, the mean dependent variables (step reaction times) were calculated with SPSS (Chicago, Ill., USA).

Descriptive statistics consisted of group means and distributions for each of the measurements. Differences in means between elderly persons who exercised and those who did not were analyzed using a two-way analysis of variance that included group (exercisers – sedentary elderly) as the between-subjects factor with repeated measures on the within-subjects factors of task (single-dual). In the case the variables were not normally distributed (Shapiro-Wilk statistics), the nonparametric Wilcoxon signed rank test and Mann-Whitney U tests were performed.

Student's t test for independent measures was used to evaluate the differences between exercisers and sedentary elderly in the BBS and overall function, basic upper and lower extremity function, and advanced lower extremity function scores in LLFDI. Pearson correlation was used to find associations between all five step parameters, in single- and dual-task condition BBS, and LLFDI scores. A significance level of 0.05 was used.

Table 1. Comparison of 24 elderly persons who self-reported exercising regularly vs. 24 age- and gender-matched subjects that did not exercise regularly (mean ± SD)

Characteristic	Exercisers	Non-exercisers	p value
Age, years	78.1 ± 6.19	78.9 ± 5.11	0.625
Mini-Mental Test score	28.6 ± 1.1	28.6 ± 1.0	0.96
Medications/day	3.3 ± 2.3	5.6 ± 2.9	0.003
Diseases	1.7 ± 1.4	2.6 ± 1.6	0.05
Weight, kg	64.9 ± 10.7	64.8 ± 13.3	0.99
Berg Balance Score	53.7 ± 3.6	49.8 ± 5.3	0.05
LLFDI functional component			
Overall function	69.2 ± 11.4	61.9 ± 9.9	0.02
Upper extremity	86.5 ± 14.6	80.4 ± 11.7	0.11
Basic lower extremity	88.6 ± 12.3	73.1 ± 2.7	0.0001
Advanced lower extremity	66.4 ± 14.0	51.1 ± 15.7	0.001

p values compare means ± 1 SD in the two groups and, unless otherwise indicated, are based on t test or Wilcoxon signed rank test.

Results

There were no significant differences in age, gender, weight, and Mini-Mental Test scores between exercisers and sedentary controls (table 1); however, there were significant differences in BBS (53.7 ± 3.6 vs. 49.8 ± 5.3), number of medications taken (3.3 ± 2.3 vs. 5.6 ± 2.9) and number of diseases (1.7 ± 1.4 vs. 2.6 ± 1.6). Subjects from both groups suffered from diseases such as hypertension, diabetes mellitus, osteoporosis, OA in the lower limb joints. No subject reported acute inflammatory condition or pulmonary diseases (e.g. COPD or emphysema) which also may affect performance.

Voluntary Step Execution Test

There were statistically significant differences between exercisers and sedentary older adults across all step execution parameters during the single-task condition (fig. 2a). The average step initiation times during the single-task condition were 207 ms for exercisers and 251 ms for sedentary ($p = 0.03$). Statistically significant differences were observed in foot off and foot contact times between exercisers and sedentary (625 vs. 759 ms, $p = 0.002$, and 959 vs. 1,158 ms, $p = 0.002$, respectively). The preparatory phase and swing phase durations under single-task condition were also significantly different between groups (417 vs. 507 ms, $p = 0.002$, and 334 vs. 399 ms, $p = 0.01$, respectively).

Adding cognitive load to the Voluntary Step Execution Test (the dual-task condition) revealed no statistically significant differences between groups, apart from the preparatory phase duration that was approximately

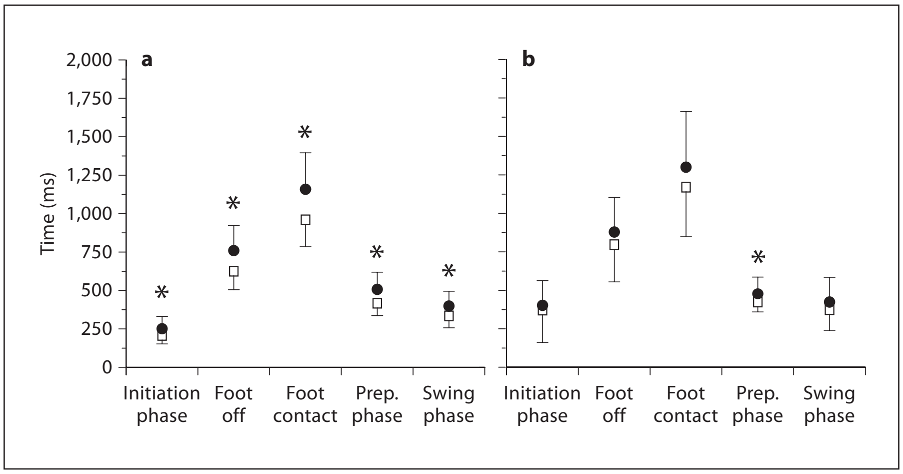

Fig. 2. Average voluntary step execution parameters for exercisers (□) and nonexercisers (●) in both single-task condition (**a**) and dual-task condition (**b**). Placement of symbols indicates mean values and the whiskers of each plot indicate ±1 standard deviation of the mean. * $p < 0.05$, significant differences between groups.

Table 2. Associations between voluntary step execution parameters, subject characteristics, BBS, and LLFDI functional component

	Initiation phase		Preparation phase		Swing phase		Foot off time		Foot contact time	
	ST	DT	ST	DT	ST	DT	ST	DT	ST	DT
Mini-Mental Test score	–0.17	–0.39**	–0.27	–0.24	–0.27	–0.16	–0.27	–0.40**	–0.29*	–0.34*
Medications/day	0.42**	0.08	0.38**	0.36*	0.34*	0.25	0.45**	0.25	0.45**	0.25
Berg Balance score	–0.47**	–0.14	–0.49**	–0.37**	–0.54**	–0.25	–0.54**	–0.26	–0.59**	–0.28
LLFDI functional component										
Overall function	–0.28*	–0.20	–0.22	–0.09	–0.22	–0.11	–0.28	–0.19	–0.28	–0.17
Upper extremity	–0.23	–0.23	–0.32*	–0.36*	–0.32*	–0.29*	–0.32	–0.33*	–0.35*	–0.35*
Basic lower extremity	–0.57**	–0.25	–0.48**	–0.29*	–0.50**	–0.29*	–0.58**	–0.31*	–0.60**	–0.34*
Advanced lower extremity	–0.47**	–0.22	–0.34*	–0.17	0.30*	–0.11	–0.44**	–0.24	–0.43**	–0.21

ST = Single-task condition; DT = dual-task condition. * $p < 0.01$; ** $p < 0.001$.

11% faster ($p = 0.04$) in exercisers compared with sedentary subjects (424 vs. 477 ms; fig. 2b).

Late-Life Function Index

Lower extremity functional components of the LLFDI were significantly higher for exercisers compared with sedentary elderly persons (table 1), especially basic lower extremity function of LLFDI (88.6 ± 12.3 vs. 73.1 ± 2.7, $p = 0.0001$), with no significant differences in upper extremity function (86.5 ± 14.6 vs. 80.4 ± 11.7, $p = 0.11$).

Correlations of Voluntary Step Execution Parameters and Other Outcome Measures

As shown in table 2, moderately strong and significant negative correlations are seen between BBS and step times (foot contact time) in single-task condition ($r = -0.47$ to -0.59); the higher the score in BBS, the faster the step times. Lower but still significant positive correlations were found between the number of medications taken and step times in single-task condition ($r = 0.34$–0.45); fewer medications consumed correlated with faster step times. With respect with self-reported function, moderately strong correlations were found between step times during single-task condition and basic lower extremity function ($r = -0.48$ to -0.60), and lower but still significant correlations with advanced lower extremity function ($r = -0.34$ to -0.47). Not surprisingly, the associations between step times and upper extremity function score were poor. Weaker correlations were found between voluntary step reaction times during attention-demanding tasks, BBS, and the function components of LLFDI.

Discussion

A quick step execution, whether it is compensatory [15] or voluntary [16], is an important skill that can serve to alter the base of support and preserve stability and prevent a fall. In fact, a delayed initiation and completion of a voluntary step may well be a marker for increased risk of falling and has been linked as a causal factor in the incidence of falls in the elderly population [16, 17]. Using an inverted pendulum model, Van den Bogert et al. [29] predicted a faster response time to be the most important factor for successful balance recovery. In the optimal control model of compensatory stepping, Maki and MacIlroy [15] claimed that in order to 'capture' the center of mass and keep it from falling, a step must be completed within approximately 1,100 ms. Furthermore, Melzer et al. [16] found that foot contact times were not significantly different between fallers and nonfallers (1,113 vs. 986 ms). However, statistically significant differences were found when an attention-demanding task was added to the Voluntary Step Execution Test – 1,414 ms for fallers vs. 1,168 ms for nonfallers ($p = 0.037$). Elderly persons with dual-task step execution times $\geq$1,100 ms had 5 times the risk of falling than participants with execution times $<$1,100 ms [16].

Age and lack of physical activity may both be responsible for poor stepping responses and increased risk of falls in the elderly. The present study suggests that consistently exercising may well preserve the voluntary step reaction times during single-task condition (959 ms in exercisers vs. 1,158 ms in sedentary) in fairly active older, and may not be statistically significant in dual-task condition (1,170 ms in exercisers vs. 1,303 ms sedentary). This finding is somehow surprising, since falls often occur in situations when attention has to be shared between more than one task, and it is conceivable that physical fitness helps to reduce the risk of falling especially in those rather demanding situations [16]. Thus, it is possible that sedentary elderly adults focused their attention more strongly on the Voluntary Step Execution test in the dual-task situation, whereas the exercisers had the tendency to invest their resources into the cognitive task (e.g. tried to perform as well as possible in the Stroop test), since the Voluntary Step Execution test was not as difficult for them as for the inactive participants. This potential differential emphasis behavior might explain the finding that group differences in the step test did not reach significance any more under dual-task conditions. The explanation is supported by age-comparative laboratory research on cognitive-sensorimotor dual-task situations which has shown that older participants have larger dual-task-related performance decrements than young adults, and tend to focus their attention more strongly on the sensorimotor task when both tasks are very resource demanding [30–33]. Another explanation might be that the traditional exercise regimes emphasize training balance under single-task condition; this might improve function in single-task conditions only. This is supported by Silsupadol et al. [34] who found that older adults may be able to improve their balance under dual-task conditions only following dual-task balance training. Also, it might be that the study sample was small to reveal significant differences in dual-task stepping.

The step reaction gains in exercisers was associated with preserved: (1) step initiation phase, that is mainly dependent on peripheral sensory detection, afferent and efferent nerve conduction velocity, and central neural processing speed; (2) preparation phase/anticipatory postural adjustments phase are executed, and (3) swing phase, that is mainly dependent on neuromotor mechanisms related to the build-up of muscle force and power to execute the task of taking the step.

Since there is no scientific evidence that supports the idea that sensory detection thresholds and nerve conduction velocity of older adults are modulated by training [35], it appears that a faster step initiation phase is largely due to a faster central neural processing time in elderly adults who train regularly. This is supported by Rossini et al. [36], who suggested that neural redundancy and plastic remodeling of brain networking might be secondary to physical training. Also, Pensini et al. [37] concluded that the joint torque gains observed after training were associated with central adaptations.

The results show faster preparation phase/anticipatory postural adjustments (APAs) in exercisers in both task conditions, similarly to Forrest [38] who found counterintuitive reductions in the APAs of several muscle groups while the stability of standing improved in elderly subjects who were practicing Tai Chi. Hass et al. [39] found that Tai Chi training improved the mechanism by which forward momentum is generated and improved coordination during gait initiation, suggesting improvements in postural control. We suggest that the mechanisms related to the faster swing phase in fairly active older in the present study are due to the more effective build-up of muscle force and power to execute the step. This is supported by Scaglioni et al. [35] and Rice et al. [40] who found that strength training significantly improves maximum voluntary contraction by 18–20% and decreased twitch contraction time by 8–10%, respectively. Furthermore, 12 weeks of resistance training [41] found that step time was positively influenced ($p < 0.03$). Rogers et al. [21] found that a 3-week period of either voluntary or waist-pull-induced step training reduced step initiation time in older and younger adults. However, the findings of previous studies regarding the effects of exercise on step/gait initiation reaction times are inconsistent. Endurance and aerobic or resistance training regimes [42] had no effect on reaction times in older adults. Differences in the mode and intensity of the exercises, lack of specificity of the training programs or differences in the contents of measurement in different studies may also explain the inconsistencies.

A direct link was found in the present study between physical activity and the number of different medications taken; 3.3 per day in exercisers compared with 5.6 in sedentary elderly. Since frequency of falls is associated with treatment by ≥ 5 kinds of medications [43], exercisers in the present study are in a lower risk of fall. The present study also proves a mutual dependency between exercising regularly and self-reported functional status of the elderly community dwellers. Maintaining regular physical activity was found to provide benefits including protection from decreased physical function especially in the lower limbs (tables 1 and 2). Other studies also found that exercise predicted a better self-rated health, physical functioning, fewer physical role limitations, and greater energy in elderly bereaved persons [44]; exercising is predictive of fewer IADL limitations, greater longevity, positive affect, and meaning in life 8 years later among the old old [45], and during a comprehensive rehabilitation program in chronically ill elderly. Similarly to our findings, Brach et al. [46] found in a cross-sectional study that lower extremity performance was positively related to physical activity; inactive elderly individuals are most likely to have impaired performance. In a Cohort study with a 4.5-year follow-up, Visser et al. [47] found that inactive persons had twice the risk of incident mobility limitation as exercisers. For the lifestyle active and inactive, absence of walking activity conferred an additional risk of mobility limitation.

Results of the present study suggest that by consistently exercising, independent elderly adults may well preserve physical performance and the ability to step rapidly, both related to reduce risk of falls in the elderly. However, this study has several limitations. First, the allocation or assignment of the exercise and control subjects was not under control of the investigator. It is possible that those participants who are still rather fit tend to engage more in physical exercise, and that those who already have severe health problems tend to remain inactive, such that some of the superior performances in the exercisers are not a direct consequence of the exercise regime, but were present in the sample even before. In an observational study, the combinations are self-selected or are 'experiments of nature'. Observational case-control studies provide weaker empirical evidence than do experimental studies (randomized controlled trials). Thus, there is unknown association between genetic influence and the outcomes. Second, the symmetry of other unknown confounders cannot be maintained. Third, the data came from a fairly small sample that was drawn from a defined relatively healthy community-based population; these results cannot be generalized to extremely weak or institutionalized elderly persons, because data were assessed in a group of relatively healthy elderly persons. Further study should involve larger sample sizes, controlled designs, and less healthy populations of older adults. Falls follow-up studies are needed to determine if the benefits for stepping behavior can reduce the risk of falls in elderly populations. In the hierarchy of research designs, the results of randomized controlled trials are considered to be evidence of the highest grade, whereas observational studies are viewed as having less validity because they reportedly overestimate treatment effects. However, Concato et al. [48] compared the results of randomized clinical trials and observational studies that examined the same clinical topics. They found that the average results of the observational studies were remarkably similar to those of the randomized, controlled trials.

In conclusion, participation in a regular exercise programs is an effective modality to reduce/prevent a number of functional declines associated with falls. Physical activity preserves skills (e.g. voluntary stepping and BBS) and elicits a number of favorable responses that contribute to healthy aging. As more individuals live longer, it is imperative to determine the extent and mechanisms by which exercise can also improve stepping responses during dual-task conditions. The results suggest that the ability to adapt and respond to physical training is well preserved in the elderly and that active lifestyle could be an effective approach to ameliorate the risk factors for falls and to reduce risk of falls in community-dwelling elders.

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