Original Article

Effect of simple home exercise focused on timing and coordination on lower-extremity function in non-disabled older persons: A quasi-randomized controlled trial

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ABSTRACT

Introduction: Lower-extremity function is a predictor of subsequent disability in non-disabled older persons. The present study aimed to determine the effect of simple home exercise focused on timing and coordination of movement on lower-extremity function in community dwelling non-disabled older persons. Materials and methods: Study design was a single-blind quasi-randomized controlled trial. The participants were 66 non-disabled older persons aged 60 years or older who independent activity of daily living and walking indoor and outdoor. They were devilled into intervention group (n = 34) and control group (n = 32). Participants in the control group participated in routine activities. The intervention group participated in a 1-month of simple home exercise focused on timing and coordination of movement consisted of calf raise, pivot turn and front stepping. Lower-extremity function was assessed by measuring maximum walking speed, figure-of-8 walk test, 3-m zigzag walk test and chair stand five test at baseline and at 1month after starting the intervention. Results: The intervention improved chair stand five test (8.8sec to 7.5sec; $p < .05$). There was no significant change in maximum walking speed, figure-of-8 walk test and 3-m zigzag walk test. The mean adherence rate of home exercise was 76.1 ± 17.4%. Conclusion: Simple home exercise focused on timing and coordination of movement is effective to improve lower-extremity function in community dwelling non-disabled older persons.

Keywords: Non-disabled older persons; Lower-extremity function; Home based exercise; Health promotion.

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INTRODUCTION

Lower limb function is important for the independence of community-dwelling older people. It has been shown to predict the future functional decline of non-disabled older persons (Guralnik et al., 1995), and its maintenance and improvement are important if non-disabled older persons are to stay healthy and active within their local communities.

Guralnik et al. (1995) used walking speed and the ability to stand up from a chair to evaluate lower limb function. Walking speed has also been reported to be associated with falls (Quach et al., 2011), mortality (Studenski et al., 2011), basic activities of daily living (Green et al., 2012), and instrumental activities of daily living (Albert et al., 2015), and it is a useful indicator of the state of health of older people. Glaister et al. (2007) reported video analysis demonstrating that 35% of walking in a cafeteria and 50% in a supermarket involved turning, including changing direction. Walking in a curve is thus required during actual walking at home and in the community, and curved-path tests are therefore important for the evaluation of lower extremity function. One type of curved-path walking test, the figure-of-8 walk test(Hess et al.,2010), has been shown to be significantly correlated with the functional component of the Late-Life Function and Disability Instrument, which reflects difficulty in activities of daily living associated with movement at home and in the community(Hess et al.,2010).

The ability to stand up from a chair is often used as a proxy measure for lower extremity strength (Bohannon, 1995). One index used to assess the ability to stand up from a chair, the five-repetition chair stand test (CS-5), has been shown to be associated with knee extensor muscle strength(Lord et al.,2002), knee flexor muscle strength(Lord et al.,2002), and ankle plantar flexor muscle strength(Lord et al.,2002). Lord et al. (2002). also reported that the CS-5 was associated with the complex sensorimotor functions of lower limb proprioception, peripheral tactile sensitivity, and reaction time to a foot stimulus, as well as with the balance function of swaying on a foam rubber mat and stated that the CS-5 cannot simply be used as a proxy measure of lower limb strength. Because the CS-5 reflects a variety of different factors and curved-path walking tests measure actions required in real life, they are suitable for assessing the lower limb function of non-disabled older persons.

VanSwearingen et al. (2009) reported interventions with the objective of improving the lower limb function of older people, comprising the repetition of a range of step patterns and walking patterns with the aim of practicing the timing and coordination involved in these actions. They showed that practicing the timing and coordination required for particular movements is more effective than the usual exercise therapies (walking training, balance training, endurance training, and muscle strengthening exercises) in improving the efficiency and self-efficacy of walking. Walking efficiently helps ward off fatigue, enabling individuals to walk further and faster and become more active, leading to fewer subsequent reports of functional decline (VanSwearingen et al., 2011). This suggests that methods involving practicing the timing and coordination of the sorts of movements described in these previous studies may be effective in improving the lower limb function of non-disabled older persons and increasing their levels of activity and participation. However, in reality, interventions for community-dwelling older people may be hard to implement for reasons such as securing space to practice, the risk of falls during practice, and the difficulty of carrying out frequent individual or group interventions involving supervision by a physiotherapist. Exercises should therefore be designed with a view to home use in order to encourage their widespread use by older people in the community.

In this study, we built on the studies mentioned above and devised some simple exercises for non-disabled older persons to practice the timing and coordination involved in particular movements, with the objective of evaluating their effect on lower limb function when older people were instructed to perform them as a home exercise program.

MATERIALS AND METHODS

Participants

The study subjects were non-disabled older persons aged ≥60 years. They were recruited by the distribution of a printed invitation to participate in the study to community-dwelling older people by municipal governments. The 107 individuals who subsequently attended a meeting on the day baseline measurements were performed were provided with an explanation of the study, and those from whom consent was obtained were screened. The exclusion criteria were (1) certified as requiring long-term care, (2) hospitalized within the previous 6 months, (3) requiring assistance to walk, and (4) requiring assistance with activities of daily living, and the final study subjects were 96 community-dwelling older people(Twenty three males, seventy three females ; mean age ± SD 74.2 ± 6.2years) to whom none of these applied.

Measures

Measurements were evaluated at baseline and 1 month after the completion of the intervention. The parameters measured were maximum walking speed and the figure-of-8 walk test, 3-m zigzag walk test, and Five-repetition chair stand test. Each of these was measured twice, and the mean values were used. All the walking tests were measured at maximum walking speed. Maximum walking speed (MWS) (Salbach et al., 2001) was measured using a walking course of a total length of 11 m, comprising a 5-m measurement path with an additional 3-m section at either end. Maximum walking speed was calculated from the time taken to walk the measurement path. Figure-of-8 walking test (F8W) (Hess et al., 2010) was used as one indicator of the ability to walk a curved path. In the F8W, subjects are asked to trace a figure-of-8 course around two cones set approximately 1.5 m apart, and this test has been shown to have high reproducibility (ICC = 0.783) and inter-investigator reliability (ICC = 0.95–0.99) (Hess et al., 2010). In this study, we carried out measurements following the original method (Hess et al., 2010), and measured the time required to complete the test. 3-m zigzag walk test (3ZW) (Masuda et al., 2013) was used as one indicator of the ability to walk a curved path. The 3ZW was developed to simulate the frequent changes of direction required indoors and requires subjects to walk between cones while changing direction. Four cones were placed 60 cm apart between the starting point and goal on a straight 3-m walking course, and the time required to walk in a zigzag line between the cones was measured. This test is reported to have high intra-investigator reliability both for community-dwelling older people who have previously had a fall and those who have never fallen (ICC = 0.97 and 0.94, respectively) (Masuda et al., 2013). Five-repetition chair stand test (CS-5)(Whitney et al.,2005) evaluates the time required to stand up five times from a chair and has been shown to have high test reliability (ICC = 0.89)(Tiedemann et al.,2008). The subjects were asked to sit in a chair with arms folded in front of their chest to start the test. When instructed by the investigator, they stood up from the chair, and the time required to stand up and sit down again five times was measured.

Procedure

This was a single-blinded quasi- randomized controlled trial in which the investigators were blinded to patient characteristics. A study flow chart is shown in Figure 1. The participants were semi-randomly allocated to an intervention group (n = 48) and a control group (n = 48).

Subjects in the intervention group were asked to engage in a home exercise program for a one-month intervention period. For this study, we devised a home exercise program to improve lower limb function by practicing the timing and coordination involved in movements that was based on “timing and coordination in walking"(VanSwearingen et al.,2009), which depends on motor learning theory, with the aim of improving movement skills and autonomic motor control. This home exercise program included three components: (1) calf raises, (2) pivot turns, and (3) steps. The subjects were instructed to perform all three components on at least three days each week during the intervention period. The frequency of home exercising was recorded by giving the subjects calendars on which they were asked to record the date and content of each exercise session, which were collected at the final evaluation. A guidebook describing how to perform the home exercises was distributed, and a physiotherapist gave a demonstration and a full explanation of the purpose of the exercises and how to perform them properly. The program is described in detail below.

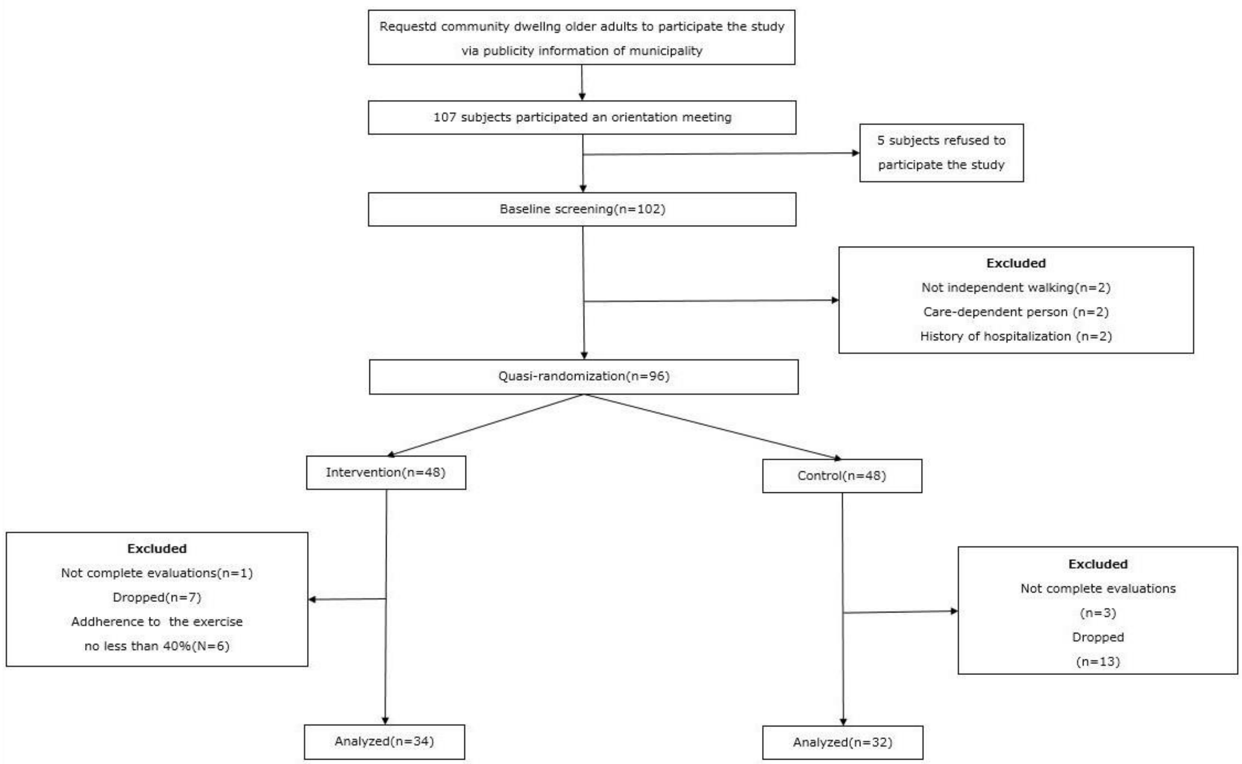

Figure 1. Flow chart of participants from the time of recruitment through study completion at 1 month.

Calf raises (Figure2A) was included in the program to strengthen the triceps surae muscles of the calf. These muscles act during the standing phase of walking (Judge et al., 1996) and are associated with the walking speed of older people (Suzuki et al., 2001). The exercise comprised raising and then slowly lowering the heel, with the hands placed lightly on a support. One set comprised 10 raises, and subjects were instructed to perform at least two sets. Because the bilateral symmetry of the lower limbs is associated with curved-path walking ability (Odonkor et al., 2013), they were also told to consciously place their weight evenly on both feet when performing the exercises.

Pivot turns (Figure2B) was included in the program to practice the movement of the lower limbs when changing direction, as pivot turning is reportedly a good strategy for changing direction (Thigpen et al., 2000). The exercise comprised standing with the feet slightly apart and making a 45º turn on the axis of the forefoot, with the hands placed lightly on a support. The direction of the trunk was also changed to match that of the legs. Changes in direction to both the left and right were practiced. The subjects were instructed to continue this exercise for at least 10 minutes each time. They were also told that once they had mastered the exercise, they could increase the angle of turn from 45º to 90º.

Steps (Figure2C) used one of the step patterns included in "timing and coordination in walking" (VanSwearingen et al., 2009). The aim was to practice weight control and the timing and coordination of leg muscle contraction during walking by repeating this type of step. The exercise comprised standing with the legs apart and stepping forward with one leg with the hands placed lightly on a support. The subject placed the foot that took the step on the ground heel-first, followed by the sole of the foot, and then transferred their weight toward the forefoot. They were instructed to be careful not to bend the hips, knees, or trunk during the exercise. The subjects were instructed to continue this exercise for at least 10 minutes each time. They were also told that once they had mastered the exercise, they could increase their speed or change the direction of the step to sideways or diagonal.

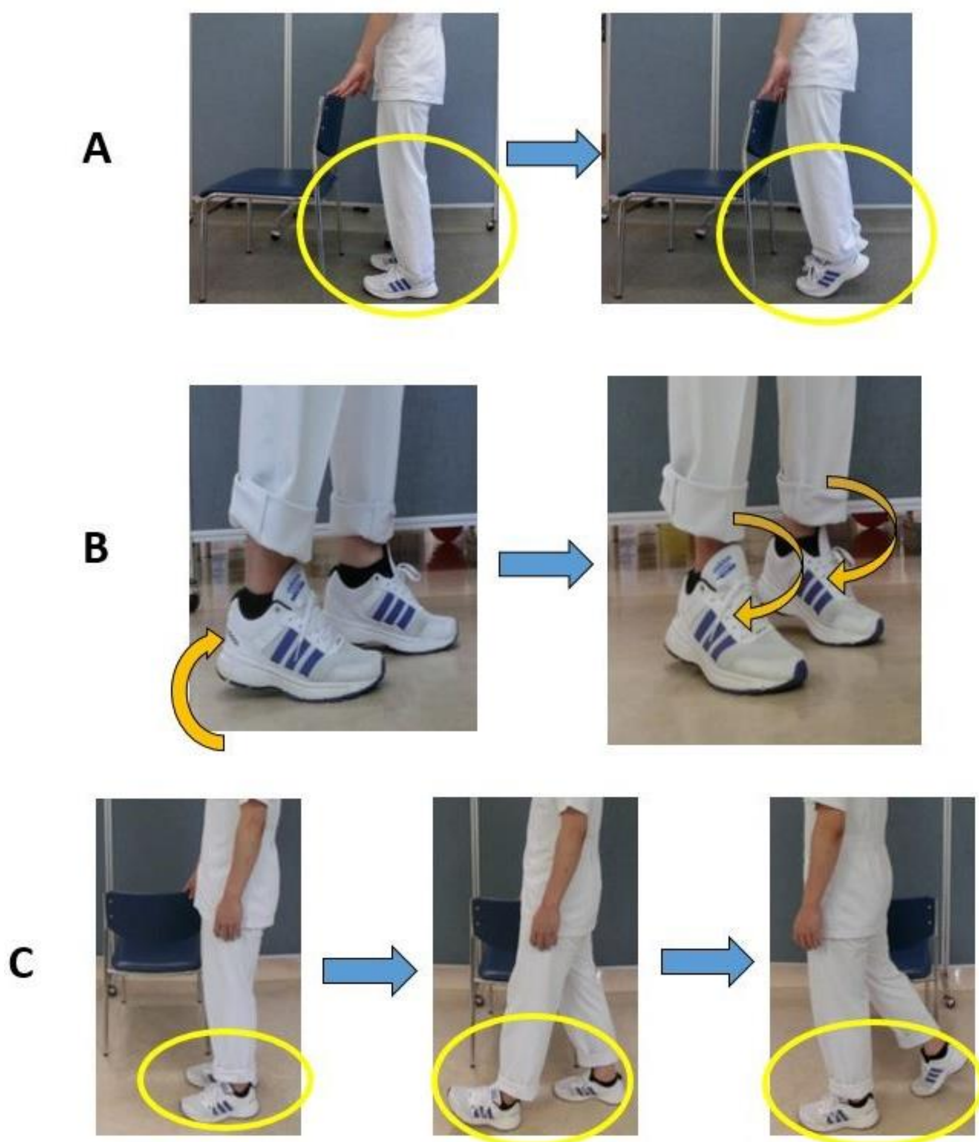

Figure 2. Home exercise program: (A) Calf raises, (B) Pivot turns, (C) Steps.

Subjects in the control group were instructed to carry out their normal activities during the intervention period, and no limitations were placed on movement.

The 2017 Tokyo Metropolitan University Arakawa Campus Research Safety and Ethics Committee (approval number 17043) approved this study, and we obtained written informed consent from all subjects.

Analysis

The intervention and control groups were compared at baseline using an unpaired t-test and Mann-Whitney U test for continuous variables and a χ^2 test for category variables. The results of the intervention were analysed by carrying out repeated-measures two-way analysis of variance (ANOVA) with age and sex as covariates, using data from the subjects who underwent all the evaluations before and after the intervention. Subjects in the intervention group who completed the home exercise program <40% of the required number of times were excluded. Multiple comparisons were performed for items for which interactions were observed, and the intrasubject and intersubject effects were both investigated. Bonferroni's method was used for multiple comparisons. We also calculated the effect sizes for the main effect and interactions (partial η^2). We used SPSS Statistics version 25.0 (IBM, Tokyo, Japan) for statistical analysis, and $p < .05$ was considered significant.

RESULTS

The analysis sets comprised 34 subjects in the intervention group and 32 in the control group. The mean implementation rates for the home exercise program by subjects in the intervention group were 76.1% ± 17.4% of the required number of times overall, 81.0% ± 17.6% for calf raises, 73.7% ± 17.5% for pivot turns, and 73.4% ± 22.1% for steps.

Table 1 shows the baseline data for all subjects and the subjects in each of the two groups. A comparison at baseline revealed significant differences in age (p = .018), sex (p = .015), MWS (p = .046), F8W (p = .001), and 3ZW (p = .022).

Table 1. Characteristics of all participants at baseline.

	Total (N = 66)	**Intervention** (n = 34)	**Control** (n = 32)	**p-value**	**Effect size**
Age（years)	74.2 ± 6.4	72.4 ± 6.0	76.2 ± 6.5	.018 a	d = 0.61
Sex (n ; %)					
Men	16 (24.2)	4 (11.8)	12 (37.5)	.015 b	
Women	50 (75.8)	30 (88.2)	20 (62.5)		
MWS (m/s)	1.80 ± 0.34	1.89 ± 0.32	1.72 ± 0.33	.046 c	d = 0.52
F8W (sec)	5.2 ± 1.2	4.7 ± 1.1	5.6 ± 1.2	.001 a	d = 0.78
3ZW(sec)	4.6 ± 1.1	4.3 ± 1.1	4.8 ± 1.0	.022 a	d = 0.47
CS-5 (sec)	8.6 ± 1.9	8.8 ± 2.2	8.4 ± 1.4	.608 a	d = 0.22

Data are presented as mean and standard deviation. aMann-Whitney U-test. bChi-squared test. c Unpaired t-test. MWS, maximum walking speed; F8W, figure-of-8 walk test; 3ZW, 3-m zigzag walk test; CS-5, five-repetition chair stand test.

Table 2 shows changes in outcomes after the intervention compared with baseline. A repeated-measures two-way ANOVA showed that CS-5 was the only outcome for which an interaction was present (F = 7.466, p

= .008). Multiple comparison testing revealed an intrasubject effect in CS-5 for subjects in the intervention group ($p = .015$, partial $\eta^2 = .099$) (baseline: 8.8 ± 2.2 s; post-intervention: 7.5 ± 1.6 s).

Table 2. Change in measurements from pre intervention to post intervention.

		Main effect			Interaction effect	
		Intervention (n = 34)	Control (n = 32)	Between effect	Interaction effect	Effect size (partial η2)
MWS(m/s)	Pre	1.89 ± 0.32	1.72 ± 0.33			.009
	Post	1.94 ± 0.29	1.75 ± 0.34	*		
	Time effect					
F8W(s)	Pre	4.7 ± 1.1	5.6 ± 1.2			.05
	Post	4.7 ± 1.1	5.3 ± 1.1			
	Time effect					
3ZW(s)	Pre	4.3 ± 1.1	4.8 ± 1.0			.002
	Post	4.1 ± 0.9	4.6 ± 1.0			
	Time effect					
CS-5(s)	Pre	8.8 ± 2.2	8.4 ± 1.4		**	.099
	Post	7.5 ± 1.6	8.1 ± 1.5			
	Time effect	*				

*Data are presented as mean and standard deviation. A post-hoc analysis of Bonferroni correction was applied. A repeated-measures analysis of covariance with covariates of age and sex was used. *p < .05, **p < .01. MWS, maximum walking speed; F8W, figure-of-8 walk test; 3ZW, 3-m zigzag walk test; CS-5, five-repetition chair stand test.*

DISCUSSION

In this study, we investigated the effect of a home exercise program to practice the timing and coordination involved in movements on the lower limb function of non-disabled older persons. The mean overall rate of implementation of the home exercise program in the intervention group was 76.1%, a rate that we consider to be high. The number of subjects excluded because they completed the home exercise program <40% of the required number of times was 6/48 (12.5%), indicating a good level of acceptance. These home exercises have the advantage that they do not require any special equipment, as subjects can practice them safely and easily while holding on to whatever is at hand. There were no reported falls while practicing during the implementation period, indicating that these exercises were safe to perform. As subjects could perform these exercises simply whilst standing, they were easy for the subjects to incorporate into their daily routines, and this may have contributed to the high implementation rate. This high implementation rate and the absence of any accidents during the implementation period suggest that our exercise program is a feasible intervention for community-dwelling older people.

The aim of our home exercises was to improve lower limb function by practicing the timing and coordination involved in movements. Accordingly, we hypothesized that the results of walking tests would improve. However, there was no significant improvement in the F8W or 3ZW. The level of performance in the F8W (time and number of steps required) is negatively correlated with step length variability (SLV) and stride width variability (SWV) during the F8W (Bland et al., 2019), suggesting that curved-path walking requires the abilities to adjust step length and stride width oneself and automatically use the step pattern required by the walking path (Bland et al., 2019). The aim of the step task in our home exercise program was to practice the timing of shifting the centre of gravity (COG) and contracting the muscles, but it lacked opportunities to practice the adjustment of step length and stride width. This may have accounted for its ineffectiveness in improving F8W time.

Our home exercise program also included pivot turns, to practice changing direction while walking, however, the kinematic characteristics of pivot turns (Taylora et al., 2005) reportedly consist of deviating the COG from the base of support toward the change of direction, thus encouraging the lower limb to pivot in the direction of movement. The aim of the pivot turns in our home exercises was to practice the coordinated movement of the lower limb required for a pivot turn while the COG was within the base of support. Thus, they did not extend to practicing the dynamic balance control involved in shifting the COG outside the base of support. This, there was no improvement in the ability to change direction while walking, and the subjects' F8W and 3ZW times did not improve.

An interaction was evident for the CS-5, and we observed a main effect in terms of time in the intervention group. In addition to lower limb muscle strength, the CS-5 is also reportedly associated with the complex sensorimotor functions of lower limb proprioception, peripheral tactile sensitivity, and reaction time to a foot stimulus, as well as with the balance function of swaying on a foam rubber mat (Lord et al., 2002). Proprioception can be defined as the cumulative neural input to the central nervous system from mechanoreceptors (joints, joint capsules, ligaments, muscles, tendons, and skin) (Ribeiro and Oliveira, 2007), and it is evaluated by testing the perception of joint position and limb movement (Hiemstra et al., 2001). Lower limb reaction time and the balance function of postural swaying are regarded as important functions for tasks that include shifts in the COG, such as body movements that require a rapid, accurate step reaction (Lord and Fitzpatrick, 2001). In our home exercises, calf raises were performed with subjects taking care to place their weight equally on both feet and noticing their ankle movements, while the aim of the step exercises was to practice muscle contraction and coordination in time with the placement of weight on the leg. The conscious repetition of these movements during our home exercise program may have improved proprioception and lower limb reaction time, leading to improved CS-5 time.

Despite the absence of improvement in curved-path walking tests, our home exercises did improve CS-5 time, suggesting that they may be effective for improving lower limb function in non-disabled older persons. The mean CS-5 times reported in previous studies are 11.4 s for individuals aged 60–69(Bohannon, 2006) and 12.6 s for those aged 70–79(Bohannon, 2006). In comparison with those values, our study subjects had better lower limb function. Thus, our home exercises may be a beneficial intervention for non-disabled older persons in terms of maintaining and improving high-level lower limb function.

Another possible reason for the comparative lack of improvement is the amount of practice performed. Previous studies have reported improvements in walking-related outcomes after a 12-weeks program of twice-weekly 60-minute interventions (24 sessions) (VanSwearingen et al., 2009) and group interventions comprising a 12-week program of twice-weekly 60-minute interventions (24 sessions) (Brach et al., 2016). As the intervention in this study was a home exercise program, the subjects were instructed to carry out the exercises for approximately 20 minutes three times a week for four weeks (30 days). As a result, although subjects maintained a high overall implementation rate of 76.1% and the continuation rate was good, with only seven dropouts (14.6%), the amount of exercise may have been insufficient for motor learning. Tasks must be gradually increased in stages to advance motor learning (VanSwearingen et al., 2014), and further studies are required to investigate whether or not combining home exercises with regular group exercises to learn elements not included in the home exercise program, ensuring a sufficient amount of exercise, and gradually increasing the difficulty of tasks will lead to improvements in F8W and 3ZW times.

One limitation of this study was the fact that although the subjects were semi-randomly allocated to the intervention and control groups, there were significant differences between the two groups at baseline. However, the differences between the values of the various indicators in the two groups were very small and were not considered to be clinically significant. Another limitation was the high level of walking ability of the subjects at baseline. In a previous study, the reference value for the time taken for older people who were independent in instrumental activities of daily living to walk 5 m as fast as they could was 2.86 s (a walking speed of 1.75 m/s) (Ando and Kamide, 2013). The mean age of our study subjects was 72.4 $\pm$ 6.0 years, and their mean MWS was 1.89 $\pm$ 0.32 m/s, meaning that they had high walking ability, even for community-dwelling older people. The reported mean F8W time for non-gait-impaired community-dwelling older people at maximum effort is 5.1 $\pm$ 1.2 s (Mizota et al., 2014), and compared with this value our study subjects also exhibited good curved-path walking ability. In this study, we investigated the improvement resulting from a one-month intervention, and further studies involving long-term follow-up are required to investigate whether or not this effect is maintained.

CONCLUSION

In this study, we investigated the effect of a home exercise program with the aim of practicing the timing and coordination involved in movements. A one-month intervention for non-disabled older persons significantly improved CS-5 time. This home exercise program including movement practice maintained both a high implementation rate and continuation rate, and there were no reported accidents during its performance. These results suggested that our home exercises can be safely introduced and improve lower limb function and are thus an effective intervention for non-disabled older persons. Further studies are required to investigate their long-term effect and the effect of combining them with group exercises.

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