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Original Article

Effect of increased daily physical activity on lower-extremity physical function during an exercise program for older adults

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Abstract:

During an exercise program for older adults, it is important that participants exercise not only in the exercise classroom but also in their daily lives. The present study investigated how goal-setting aimed at increasing daily physical activity by 1,000 steps per day, influenced lower-extremity physical function during the exercise program. The participants were non-randomly allocated to two groups: with goal-setting (n = 19, mean age: 68.9 ± 3.3 years) and without goal-setting (n = 13, mean age: 69.9 ± 4.2 years). Participants in the group with goal-setting were encouraged to increase their physical activity by 1,000 steps/day above their baseline step counts. All of the subjects in both groups participated in a square-stepping exercise program for 90 min once a week for 9 weeks. To determine the lower-extremity physical function benefits of the program, six types of test were performed before and after the program. There was a significant group-by-time interaction on daily physical activity ($p < 0.001$). The group with goal-setting significantly increased their physical activity, and the group without goal-setting did not change their physical activity. There were significant time effects in the 5-m habitual walk, choice stepping reaction time, and 6-min walk. There was a significant group-by-time interaction in the five-repetition sit-to-stand test ($p = 0.006$), and only the group without goal-setting improved their performance. Although we successfully increased daily physical activity using goal-setting, we could not confirm the effect of goal-setting on lower-extremity physical function.
Key words: square-stepping exercise, step counts, feedback, goal-setting

Introduction

Care needs due to lower levels of physical function in older adults are a global health issue. Maintaining lower-extremity physical function (LEPF) is a key factor in helping older adults to prevent care needs and to maintain the quality of life (Guralnik et al., 1995; Moreland et al., 2004; Shinkai et al., 2000). Exercise programs for improving LEPF have been conducted across many fields of research (Howe et al., 2007; Liu & Latham, 2009).

On the other hand, exercise training in elderly individuals has been reported to cause a compensatory decline in non-training physical activity (PA) (Meijer et al., 1999, 2001). Furthermore, another study reported that effects can only be expected when participants maintain their daily PA during an exercise program (Jindo et al., 2016). Therefore, it is important for participants to perform exercise not only in the classroom but also in their daily lives. To maintain the participants' daily PA during the program, PA enhancement, such as goal-setting (GS), self-monitoring, and feedback, is an effective method for increasing PA (Baker et al., 2008; Kolt et al., 2012; Petersen et al., 2012). Petersen et al. (2012) reported that combining the use of a pedometer with GS increased PA in older adults. However, it is still unclear as to whether the combination of exercise programs with the encouragement of daily PA by GS is linked to an increase in daily PA and improvement in LEPF.

Previous studies have reported that increased PA may induce falls in older adults (Ebrahim et al., 1997; Lawton et al., 2008) and have suggested that PA enhancement should include a fall prevention component (Tiedemann et al., 2015). In the present study, we used a fall prevention exercise program called the square-stepping exercise (SSE), which is effective in improving LEPF (Shigematsu & Okura, 2006). The combination of SSE with the encouragement of daily PA by GS may represent a multi-component solution for health issues in older adults. The purpose of the present study was to investigate the effects of GS aimed at increasing daily PA

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by 1,000 steps/day on LEPF during a SSE exercise program. We hypothesized that increasing daily PA would augment the effects of the exercise program on LEPF in older adults.

Material and methods

Participants

We conducted the present study from May to August 2015 in Ibaraki prefecture, rural Japan. Participants comprised 35 independently living older adults aged 65 years and older who were recruited through local advertisements or leaflets, which were distributed to participants who attended a health promotion event. The participants were non-randomly allocated to two groups: with GS (n = 20) and without GS (n = 15). The two programs were conducted at different times, and the participants selected the program based on the desired time. To avoid selection by program content, the participants had not been informed of the difference between the two programs by the end of the program. The participants were required to meet the following inclusion criteria for the study: (1) aged 65 years or older, (2) able to walk, and (3) living independently. Two participants who did not attend the post-test measurements and one participant who did not attend more than half of a session were excluded. The remaining 19 participants in the group with GS (mean age: 68.9 ± 3.3 years) and 13 participants in the group without GS (mean age: 69.9 ± 4.2 years) were included in the analysis.

All participants provided a signed, informed consent. The Ethics Committee of University of Tsukuba approved the present study (registration no. tai 26-131).

Exercise program

All subjects participated in an exercise program, which utilized SSE (Shigematsu & Okura, 2006). This program was conducted separately for the group with GS and that without GS. The program was conducted at a community center once a week for 90 min over a total of 9 weeks. Experienced instructors supervised the exercise program. SSE is performed on a thin felt mat (250 × 100 cm), which is divided into 40 small squares (25 × 25 cm). The exercise technique includes forward, backward, lateral, and oblique steps, with a progressive increase in the step pattern complexity. SSE has been applied as the main exercise in voluntary exercise salons for healthy elderly individuals (Mitsuishi et al., 2013), exercise programs that are aimed at preventing care needs for older adults (Jindo et al., 2015), and rehabilitation programs for post-stroke patients (Túbero et al., 2014). The SSE program consisted of a warm-up activity (15 min), SSE (40 min), a recreational activity (20 min), and a cool-down period (15 min). Short breaks were taken between each activity and at halftime. A previous study has described this program in detail (Jindo et al., 2016).

Measurement variables

Measurement testing was performed before and 1 week after the exercise program period. The demographic variables included age, gender, clinical history, and body mass index. In addition, the fall history during the last year and during the exercise program was evaluated. To determine the LEPF benefits of the program, we measured six physical function tests: single-leg balance with eyes open (balance) (Rikli & Busch, 1986) five-repetition sit-to-stand (muscle strength; STS) (Guralnik et al., 1994), timed up and go (mobility) (Shumway-Cook et al., 2000), 5-m habitual walk (walking ability, HW) (Shinkai et al., 2000), choice stepping reaction time (reaction speed; CSRT) (Lord & Fitzpatrick, 2001), 6-min walk (endurance power; 6MW) (ATS statement, 2002).

Physical activity

The participants daily PA during the exercise program was measured using pedometers (Kenz Lifecorder; Suzuken, Nagoya, Japan), and they were instructed to wear the pedometer on their waists at all times while they were awake, except when swimming or bathing (non-wear time). All of the participants began to wear the pedometer when they had finished the pre-test, and they were asked to maintain their usual lifestyles for a week to ascertain their regular PA (regular step counts).

For the group with GS, the first session of the program was extended by 45 min, and a GS session was conducted. The aim of GS was to increase the mean step count of the first week by 1,000 steps/day. For physical activity motivation, two visual goal-setting sheets were made. The first was a line graph that confirmed whether the participants' PA had increased or not based on the mean step counts of the first week (Fig. 1). The usage was as follows: (1) put the regular step counts into the middle brackets, (2) put ±7,000 steps/week and ±14,000 steps/week above or below the regular step counts, and (3) confirm a weekly total step count and put it on the graph. The participants were encouraged to reach or surpass the line of the goal (+1,000 steps/day), i.e., above the middle line. The second was a map to confirm the progress of GS (Fig. 2). This was a real map of Japan (SHIROTIZU KenMap, Ver 9. 11, http://www5b.biglobe.ne.jp/~t-kamada/CBuilder/kenmap.htm), and the scale on the map indicated approximately 10 km for each division (e.g., Point 1 indicates 50 km from the starting point). Each participant's step length was supposed to be 60 cm, and the individual goal was set as when a participant increased the step count by 1,000 steps/day based on the mean steps count of the first week. The participants selected a preferred map out of the three maps. The instructor painted the scales according to the participant's weekly total step counts. At that time, the instructor provided feedback as to whether their step counts were enough to accomplish the goal. Before each session, the PA enhancement techniques were provided on an individual basis by an experienced instructor. To reevaluate GS, it was conducted again half way through the program.

Fig. 1 and 2 show the visual representation of GS. The aim of GS was to increase the mean step count of the first week (regular step counts) by 1,000 steps per day. Fig. 1 can confirm whether there is an increase in the participants' PA or not based on the regular step count. Fig. 2 shows the progress of GS on a real map of Japan.

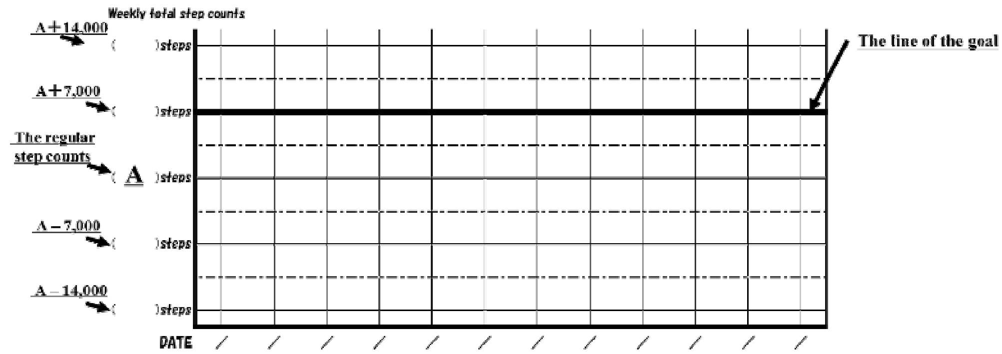


Fig. 1. Goal-setting: a line graph


Fig. 2. Goal-setting: maps

The participants in the group without GS were able to see their daily step counts; however, they did not receive feedback on their step counts, and they were not provided with any supporting tools such as GS. The exercise program, which included a baseline test and post-test period, was divided into four periods as follows: baseline (1st week) early (2nd–4th session), middle (5th–8th session), and late (9th–11th session), and the average daily step counts were calculated for each period (Jindo et al., 2016). Lifelyzer05 Coach ver. 2.1 (Suzuken) was used to analyze the downloaded data.

Statistical analysis

Data were analyzed using mean and standard deviation. The participants' characteristics were compared between the two groups using independent *t*-tests and chi-square tests. Two-way analysis of variance was used to confirm the interaction between the two groups and the time effects before and after the program. A post-hoc test was used on the variables that showed a significant group-by-time interaction to determine which groups had more improvement. Regarding PA, the time factors for two-way analysis of variance were the four points. To calculate effect sizes, Cohen's *d* (Cohen, 1988) was used with 0.30 indicating a small effect, 0.50 a medium effect, and 0.80 or greater a large effect (Cohen, 1988). IBM SPSS Statistics 23 for Windows was used for the statistical analysis, and the level of statistical significance was set at $p < 0.05$.

Results

As shown in Table 1, there were significant differences at baseline in the fall history in the last year and HW between the two groups. The participants in the group with GS had a fewer number of falls and better scores on HW. The mean percentages of classes that were attended were 95.9% ± 8.5% (range: 77.8%–100.0%) for the group with GS and 94.0% ± 10.7% (range: 66.7%–100.0%) for the group without GS, without a significant group difference ($p = 0.582$).

Table 1. Comparison of baseline characteristics between two groups

Baseline characteristics	SSE with GS (n = 19) Mean ± SD	SSE without GS (n = 13) Mean ± SD	*p*- value
Demographic items			
Age, y	68.9 ± 3.3	69.9 ± 4.2	0.470
Women, n (%)	15 (78.9)	11 (84.6)	0.687
Education, y	12.0 ± 1.9	12.3 ± 1.3	0.623
Heart disease, n (%)	1 (5.3)	0 (0.0)	0.401
Stroke, n (%)	0 (0.0)	0 (0.0)	-
Low back disease, n (%)	4 (21.1)	3 (23.1)	0.892
Knee disease, n (%)	1 (5.3)	3 (23.1)	0.135
Fall in the last year, n (%)	0 (0.0)	4 (30.8)	0.010
Fall during the exercise program, n (%)	1 (12.5)	0 (0.0)	0.401
Body mass index, kg/m2	23.4 ± 3.1	24.3 ± 2.6	0.413
Physical activity			
Daily step counts, steps/day	8,312 ± 3,759	7,796 ± 2,708	0.696
LEPF items			
Single-leg balance with eyes open, sec	39.5 ± 19.9	47.1 ± 22.2	0.315
5 repetition sit-to-stand, sec	6.6 ± 0.6	7.2 ± 1.1	0.119
Timed up and go, sec	5.1 ± 0.5	5.5 ± 0.8	0.128
5 m habitual walk, sec	3.2 ± 0.5	3.6 ± 0.3	0.040
Choice stepping reaction time, msec	1,025 ± 105	1,027 ± 64	0.932
6-min walk, m	575 ± 72	560 ± 62	0.534

GS: goal-setting, LEPF: lower-extremity physical function, SD: standard deviation, SSE: square-stepping exercise

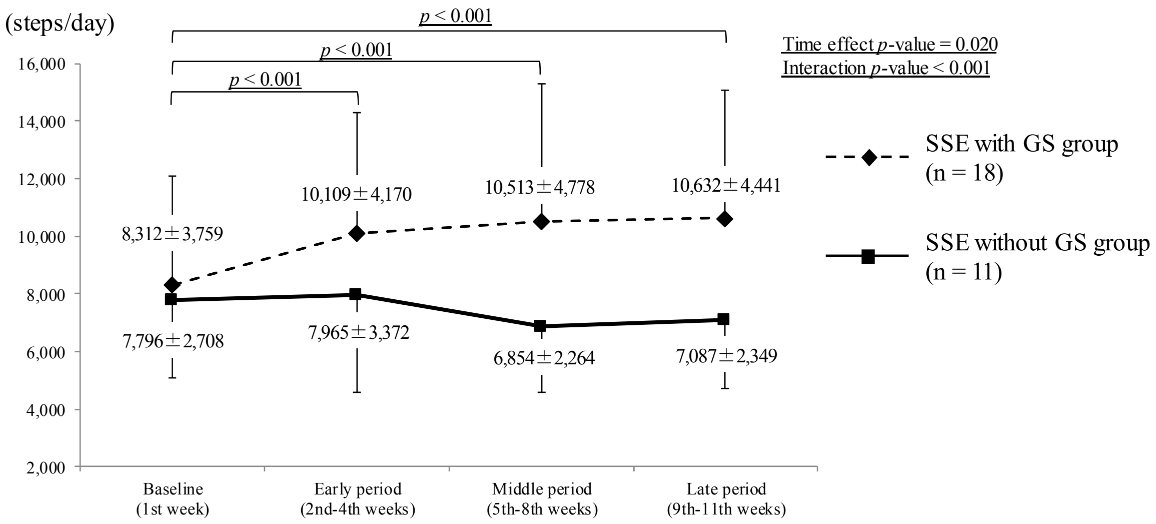
As shown in fig. 3, there was a significant group-by-time interaction on PA ($p < 0.001$). The group with GS significantly increased their PA from baseline to the three other periods, whereas the group without GS did not change their PA. There were significant time effects in HW, CSRT, and 6MW, with both groups improving their performances (table 2). There was a significant group-by-time interaction in STS ($p = 0.006$) with only the group without GS improving performance. Although significant group-by-time interaction in STS was confirmed, on post-hoc testing, there were no significant differences in the six physical function tests between the two groups.

Table 2. Physical function items by group at baseline and post-test

Lower-extremiy physical function items	Baseline-test Mean ± SD	Post-test Mean ± SD	Time effect *p*-value	Effect size (Cohen's *d*) Baseline vs. Post-test	Interaction *p*-value	Post hoc test	Comparison of post-test score With GS vs. Without GS *p*-value
Single-leg balance with eyes open, sec							
SSE with GS	39.5 ± 19.9	44.7 ± 19.7	0.367	0.27	0.417		0.717
SSE without GS	47.1 ± 22.2	47.4 ± 21.1		0.01			
5 repetition sit-to-stand, sec							
SSE with GS	6.6 ± 0.6	6.8 ± 0.9	0.154	0.23	0.006	0.241	0.750
SSE without GS	7.2 ± 1.1	6.7 ± 1.4		0.40		0.007	
Timed up and go, sec							
SSE with GS	5.1 ± 0.5	5.2 ± 0.6	0.360	0.14	0.914		0.223
SSE without GS	5.5 ± 0.8	5.6 ± 1.0		0.11			
5 m habitual walk, sec							
SSE with GS	3.2 ± 0.5	3.1 ± 0.5	0.024	0.27	0.469		0.273
SSE without GS	3.6 ± 0.3	3.3 ± 0.6		0.49			
Choice stepping reaction time, msec							
SSE with GS	1,025 ± 105	1,016 ± 83	0.030	0.10	0.149		0.274
SSE without GS	1,027 ± 64	984 ± 73		0.64			
6-min walk, m							
SSE with GS	575 ± 72	589 ± 86	0.035	0.17	0.477		0.939
SSE without GS	560 ± 62	587 ± 60		0.44			

GS: goal-setting, PA: physical activity, SD: standard deviation, SSE: square-stepping exercise

Fig. 3 presents physical activity (PA) by group during the three periods. Participants in the group with goal-setting (GS) were encouraged to increase their PA by 1,000 steps/day above their baseline step counts. The group with GS significantly increased their PA, whereas the group without GS did not change their PA.



GS: goal-setting, SSE: square-stepping exercise
Three participants had wearing times that did not reach the criteria for calculating step counts.

Fig. 3. Physical activity by group during the four periods

Discussion

In the present study, we conducted an exercise program and compared its effects on LEPF between participants with GS aimed at increasing PA by 1,000 steps/day and those without GS. The graph and map, which were used in the present study, were visually understandable and were able to motivate participants to achieve their goal. However, although the group with GS significantly increased their daily PA compared with the group without GS, we were unable to confirm the effect of GS on LEPF.

Both groups significantly improved in HW, CSRT, and 6MW from baseline to post-testing. A previous study has suggested that SSE, consisting of multidirectional steps in the forward, backward, lateral, and oblique directions, led to a better LEPF (Shigematsu et al., 2008). This may explain why we were able to confirm significant improvements in HW and CSRT. Moreover, regardless of the daily PA, it is possible that the SSE program in itself is effective in improving 6MW in older adults. The SSE program may be as effective as walking programs in improving endurance power (Okubo et al., 2015).

On the other hand, there was a significant group-by-time interaction in STS, and only the group without GS improved their performance. A previous study showed that older adults with a low level of physical fitness at baseline are more likely to improve their physical fitness with a period of exercise program (Arai et al., 2009). In the present study, the without GS group had a comparatively lower level of physical performance than the group with GS. This indicates that the group without GS had greater room for improvement in their LEPF. In addition, Aoyagi et al. (2009) reported that walking speeds were positively associated with daily step counts of up to 7,000–8,000 steps per day but that there was no association for more than 8,000 steps per day. The group without GS maintained approximately 7,000 steps, whereas the group with GS exceeded 10,000 steps per day by the late period. Although we successfully increased PA using GS, the participants in the group with GS may have had a ceiling effect of increased PA for improving LEPF.

The present study had several limitations. First, it included only a small sample size and was not a randomized controlled trial. Having only a few male subjects in each group was also a limitation. Secondly, PA and LEPF of our study participants were equal or slightly higher than Japan's general values (Seino et al., 2014). Therefore, there may have been a ceiling effect for improving LEPF and step counts. We need to investigate whether our findings apply to other populations, such as sedentary older adults or those with poorer LEPF. Finally, the present study was a short-term program, and a long-term program is needed to confirm the effects of GS in increasing daily PA.

Conclusion

We conducted the SSE program and compared its effects on LEPF between participants with GS aimed at increasing PA by 1,000 steps/day and those without GS. The group with GS increased their PA; however, we could not confirm the effect of GS on LEPF. A long-term program is needed to confirm the effects of GS in increasing daily PA. Even so, because the without GS group tended to decrease the daily PA during the program, the GS techniques were useful to prevent decrease in daily PA due to the participation in an exercise program.

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