Relationship Between Physical Activity and Locomotive Syndrome After a 3-Month Exercise Intervention of Walking and Stair Climbing in Elderly Japanese Individuals

TOMOHARU KITADA*1, HAYAO OZAKI*2, TAKASHI NAKAGATA*2, MASAYOSHI ISHIBASHI*3, SHUICHI MACHIDA*1, HISASHI NAITO*1

*1) Graduate School of Health and Sports Science, Juntendo University, Chiba, Japan, *2) Faculty of Health and Sports Science, Juntendo University, Chiba, Japan, *3) Juntendo University Center of Innovation Program, Juntendo University, Tokyo, Japan

Objective: This study aimed to investigate the relationship between physical activity (PA) and locomotive syndrome after a 3-month exercise intervention of walking and stair climbing in elderly Japanese individuals.

Design: Eighteen elderly participants (mean age 68±5 years) were equally assigned to a normal walking and stair climbing (WS) group or a WS and walking with blood flow restriction (WS+BFR) once a week group. Both the groups were instructed to walk at a faster pace than usual for more than 30 min per day and climb more than 5 flights of stairs per day, for more than 4 days per week in the WS group and for more than 3 days per week in the WS + BFR group for 3 months.

Methods: PA was measured using a wristband type acceleration sensor. Locomotive syndrome risk tests (the two-step test, the stand-up test, and 25-question risk assessment) were performed before and after the intervention.

Results: No significant difference was found between the groups considering the PA. Step counts over 3 metabolic equivalents (METs) per day increased by exercise intervention \( p=0.014 \). Increase in vigorous PA \( \geq 6 \) METs was positively correlated with the stand-up test score \( r=0.490, p<0.05 \), but not the two-step test score and 25-question risk assessment.

Conclusions: These results suggest that increase in vigorous PA via walking and stair climbing might lead to improving locomotive syndrome risk in elderly Japanese individuals, regardless of walking with blood flow restriction once a week.

Key words: vigorous physical activity, locomotive syndrome risk test, lower limb muscle strength

Introduction

In Japan, along with the increasing lifespan, the number of elderly individuals who need care has increased as the population ages. Age-related loss of skeletal muscle mass was defined as sarcopenia\(^1\), while the Japanese Orthopedic Association proposed the term “locomotive syndrome” in 2007\(^2\). Locomotive syndrome represents a high-risk condition in the locomotor apparatus such as the skeletal muscles, bones, joints, cartilage, or intervertebral discs. Recently, tests for the assessment of locomotive syndrome risk were designed by the Japanese Orthopaedic Association (2013)\(^3\). The tests consist of three subtests (the two-step test, the stand-up test, and the 25-question risk assessment), and the two-step test and the stand-up test, which is able to easily assess the ability of the lower limb muscle, are expected to be useful for screening the need for nursing care. However, most previous studies that focused on locomotive syndrome were performed using the cross-sectional design\(^4\)–\(^9\).
while only few studies have been performed using the longitudinal design such as an exercise intervention for locomotive syndrome\textsuperscript{10, 11}.

Motion in daily activities is restricted by muscle reduction, particularly in the lower limb muscles. Therefore, it is important for individuals to be extremely active in the lower limbs in order to prevent progression of locomotive syndrome and to maintain the lower limb muscle volume and strength. Abe \textit{et al.}\textsuperscript{12} reported that daily physical activity (PA) at moderate and vigorous intensity was associated with a higher muscle thickness in the lower leg and the anterior thigh in women. Moreover, Kubo \textit{et al.}\textsuperscript{13} reported that muscle thickness and strength of the lower limb muscle in elderly individuals increased by moderate walking training. In addition, the muscle activity level is higher in stair climbing than in walking\textsuperscript{14}. Thus, increased PA via walking and stair climbing at moderate or vigorous intensity may prevent or improve the risk of locomotive syndrome in elderly individuals. Although a previous study summarized the evidence for PA via walking or stair climbing as an exercise intervention for metabolic syndrome\textsuperscript{15}, the relationship between the changes in PA resulting from exercise intervention of walking and stair climbing and the changes in the test scores for the assessment of locomotive syndrome risk is unknown. Moreover, walking with blood flow restriction in the lower limb muscle increases muscle size and strength\textsuperscript{16}. This method enhances the lower limb muscle function and may lead to an additional beneficial effect for treating locomotive syndrome.

We hypothesized that increased moderate and vigorous PA resulting from walking and stair climbing or walking with blood flow restriction improves locomotive syndrome test scores. The purpose of this study was to investigate the relationship between the changes in PA and the changes in locomotive syndrome risk test scores in elderly Japanese individuals after a 3-month walking and stair climbing intervention program.

Materials and methods

1. Participants

Eighteen elderly participants (age, 68 ± 5 years; height, 1.64 ± 0.08 m; weight, 63.6 ± 2.4 kg) volunteered to participate in this exercise intervention study. They were recruited through printed advertisements. None of the participants had undergone any regular aerobic or resistance training for the previous 1 year. All participants provided informed consent before participating in this study. The participants were randomly assigned into the two following groups: normal walking and stair climbing (WS group; n = 9, 8 men and 1 woman) and a WS and walking with blood flow restriction once a week (WS+BFR group; n = 9, 6 men and 3 women). This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of Juntendo University, Japan.

2. Exercise intervention program

Both the groups wore an acceleration sensor on the wrist and were instructed to walk at a faster pace than usual for more than 30 min per day, and climb more than 5 flights of stairs per day, for more than 4 days per week in the WS group and for more than 3 days per week in the WS + BFR group. Moreover, the WS + BFR group performed 20 minutes of treadmill walking with blood flow restriction at a pre-determined exercise intensity of 70–85\% of the age-predicted maximum heart rate (220 - age). In the WS + BFR group, nylon cuffs (105-mm wide, MT-870 Digital Tourniquet; Mizuho, Tokyo, Japan) were applied tightly at the most proximal portion of both the legs during walking with blood flow restriction. The target pressure was calculated for each participant based on the circumference of the right thigh (33\% of the distance from the inguinal crease to the top of the patella) as follows: <50 cm = 100 mmHg, and 50–55 cm = 120 mmHg. This is because arterial occlusion pressure is largely influenced by the thigh circumference\textsuperscript{17}. The cuff air pressure was released immediately after completing each session.

The acceleration sensor measured PA during the 3-month exercise intervention. Subtests of the locomotive syndrome risk test (the two-step test, the stand-up test, and the 25-question risk assessment) were performed before and after the 3-month exercise intervention.

3. Acceleration sensor

A 3-axis wristband–type acceleration sensor
wristband type life recorder UW-301, A&D Company Limited, Japan) was worn by each participant to evaluate PA for 7 consecutive days. The data criteria were defined as having more than 5 days of wear time in 7 days\(^{18,19}\) and 10 hours of wear time in 24 hours\(^{20,21}\). The average daily step count and step counts over 3 metabolic equivalents (METs) per day were measured, and PA levels were calculated from the obtained data at each time. PA levels were classified as Ex1 (< 1.1 METs), Ex2 (≥1.1 to <1.5 METs), Ex3 (≥1.5 to <3.0 METs), Ex4 (≥3.0 to <6.0 METs; moderate PA), and Ex5 (≥6 METs; vigorous PA).

4. Locomotive syndrome risk tests

Locomotive syndrome risk tests composed of the following three subtests: the two-step test, the stand-up test, and the 25-question risk assessment.

5. The two-step test

This test measures the stride length to assess walking ability, including muscular strength, balance, and flexibility of the lower limbs. First, the starting line was decided, and participants were asked to stand behind the line, with the toes of both feet behind it. Second, participants were instructed to take two steps with the maximum possible stride and then align both feet. After the steps, the length of double strides was measured. The formula for calculating the test score was the maximal length of the double stride (cm)/height (cm).

6. The stand-up test

This test measures the height of standing to assess leg strength. After preparation of 4 seats of 40, 30, 20, and 10 cm, the participants folded their arms and leg at an angle of 70 degrees to the floor. First, if the participant could stand up from a height of 40 cm on one leg for both the right and left leg, without leaning back to gain momentum, and maintain this position for three seconds, then, the participant passed the height. Second, the participant tried the same thing from lower heights at 10-cm decrements. If the participant was unable to stand up on one leg from the height of 40 cm, the participant was considered to have failed the height and challenge to stand up on both legs from the height of 10 cm.

7. The 25-question risk assessment

This test consists of 25 items that include questions regarding body pain and usual daily life for the last one month. These 25 items are graded with a 5-point scale, and then arithmetically added to obtain a total score (0-100 points). A higher score is associated with worse locomotive function.

8. Statistical analysis

All statistical analyses were performed using SPSS Version 17.0 (SPSS Inc., Chicago, IL). Data are presented as mean ± standard error. A two-way (group × time) analysis of variance (ANOVA) with repeated measures was used to analyze the PA. The relationship between the changes in PA and the changes in locomotive syndrome risk test scores after a 3-month walking and stair climbing intervention program was analyzed using Pearson’s correlation coefficient. A value of p < 0.05 was considered significant in all analyses.

Results

1. Physical activity

After the 3-month exercise intervention, the average daily step count (WS: 7,407 ± 1,276 to 9,031 ± 1,587, WS+BFR: 9,412 ± 1,597 to 10,550 ± 1,907; p = 0.024, Figure-1) and step count over 3 METs (WS: 3,998 ± 1,240 to 5,700 ± 1,432, WS+BFR: 5,706 ± 1,543 to 6,650 ± 1,759; p = 0.014, Figure-2) were significantly increased when compared to baseline in both the WS and WS+BFR groups. There was no significant difference between the groups and no significant group × time interaction considering the average daily step count and the step count over 3 METs per day. Changes in PA levels are shown in Table-1. In comparison with the baseline, Ex1 increased significantly (p < 0.05) and Ex3 decreased significantly (p < 0.01); no significant changes found in Ex2, Ex4, and Ex5 for both the groups after the 3-month exercise intervention. Moreover, the change in Ex3 was negatively correlated with the change in Ex5 (r = -0.546, p < 0.05).

2. Relationship between physical activity and locomotive syndrome risk test scores

The change in Ex3 after exercise intervention
was negatively correlated with the changes in the stand-up test score ($r = -0.612, p < 0.01$; Figure-3). Meanwhile, the change in Ex5 with exercise intervention was positively correlated with the changes in the stand-up test score ($r = 0.490, p < 0.05$), but not the two-step test score and 25-question risk assessment (Figure-4). However, no other PA was significantly correlated with locomotive syndrome risk test scores.

**Discussion**

The main findings of this study were that the step count over 3 METs as well as the average daily step count increased through walking and stair climbing intervention and that the increased Ex5 was correlated with the stand-up test score for the assessment of the locomotive syndrome risk.

According to the Compendium of Physical Activities, Ex3 and Ex5 in this study correspond to standing to walking at a slow pace and brisk walking or climbing, respectively. The results of decreases in Ex3 and increases in Ex5 suggest that PA levels increased through exercise intervention. The rectus femoris muscle is a two-joint muscle, crossing both the hip and knee joint, and Ericson et al. indicated that the rectus femoris muscle contributed to accelerating the lower limb forward during the start of the swing phase. Abe et al. investigated the relationship between PA and muscle thickness in elderly women in a cross-sectional study and reported that a higher muscle mass of the anterior thigh and lower leg was associated with more moderate and vigorous PA. Moreover, Kubo et al. reported that muscle thickness and strength of the lower limb muscle increased...
Figure 3  Relationship between the changes in Ex3 and changes in the score of (A) the stand-up test, (B) the two-step test and (C) 25-question risk assessment for the assessment of locomotive syndrome risk (n=18)
Closed circles represent the participant who was observed the largest changes in vigorous activity.

Figure 4  Relationship between the changes in vigorous PA and changes in the score of (D) the stand-up test, (E) the two-step test and (F) 25-question risk assessment for the assessment of locomotive syndrome risk (n=18)
Closed circles represent the participant who was observed the largest changes in vigorous physical activity.
significantly after 6 months of walking training in elderly individuals. These previous studies indicated that increase in PA at moderate to vigorous intensity may lead to improved locomotive syndrome risk, according to enhancing lower limb muscle function. In fact, a longer Ex5 was correlated with stronger muscle strength of knee extension at 60 degrees per second (r = 0.780, p < 0.01; unpublished data). Thus, a significant correlation might be found between improvement in the stand-up test score for assessment of the leg strength and the increase in Ex5.

Meanwhile, no significant correlation was observed between the increase in PA and the changes in the two-step test score and the 25-question risk assessment. The relatively high baseline scores on the two-step test score and the 25 question risk assessment may have limited the amount of change possible with the 3-month walking and stair climbing program.

Certain limitations of this study should be mentioned. First, the sample size in this study was small (n = 18). Second, owing to the lack of a control group considering the study design, it is unclear if the changes in PA were because of the exercise intervention. Moreover, as we did not sub-classify participants considering only walking and walking and stair climbing, it remains unclear whether walking or stair climbing has a more beneficial effect. Therefore, additional research is need.

In summary, increases in the stand-up test score for the assessment of the locomotive syndrome risk was positively correlated with increases in PA at vigorous intensity after the 3-month exercise intervention of walking and stair climbing in elderly Japanese individuals, regardless of walking with blood flow restriction once a week. These results suggest that walking and stair climbing at a vigorous intensity might lead to improving locomotive syndrome risk.

Acknowledgement

This research was supported by the Center of Innovation Program from Japan Science and Technology Agency, JST.

Conflict of interest

No conflicts of interest, financial or otherwise, exist.

References

16) Abe T, Kearns CF, Sato Y: Muscle size and strength are increased following walk training with restricted venous blood flow from the leg muscle, Kaatsu-walk training. J Appl Physiol (1985), 2006; 100: 1460-1466.