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Original Article

The Effect of Locomotor Training and Aerobic Exercises on Balance, Fear of Falling, and Lower Limb Strength in Elderly Women With Locomotor Syndrome

Zahra Geramipour[1], **Shahnaz Shahrjerdi**[1*]

[1]Department of Physiology and Sports Pathology, Faculty of Sport Sciences, Arak University, Arak, Iran

*__Corresponding Author:__ Shahnaz Shahrjerdi, Email: s-shahrjerdi@araku.ac.ir

Abstract

Background and aims: Aging is associated with a decline in physical and motor abilities, increasing the risk of falls among the elderly. Accordingly, this study examined the effects of locomotor and aerobic exercises on balance, fear of falling, and lower-limb strength in elderly women with locomotor syndrome.

Methods: This quasi-experimental study was conducted on 45 elderly women aged 60 years and above in Arak from April to May 2025. Participants were selected conveniently and randomly divided into control, aerobic-locomotor, and locomotor groups. Interventions were performed for 8 weeks. Then, the 30-second sit-to-stand test, the standing-to-walking time test, and the four-step balance test were utilized to measure lower limb strength, dynamic balance, and static balance, respectively. Moreover, fear of falling was calculated using the Falls Efficacy Scale-International Questionnaire. Ultimately, data were analyzed by ANCOVA to compare post-test scores between groups, controlling for pretest scores.

Results: Both the locomotor and aerobic-locomotor training groups demonstrated significant improvements in all variables. In the locomotor group, fear of falling decreased ($P=0.002$), while lower limb strength ($P=0.02$), static balance ($P=0.01$), and dynamic balance ($P<0.001$) improved. Similarly, fear of falling declined ($P=0.020$) in the aerobic locomotor group. However, lower limb strength ($P=0.003$), static balance ($P<0.001$), and dynamic balance ($P=0.001$) significantly enhanced in this group. Finally, no significant changes were observed in the control group ($P>0.05$).

Conclusion: Locomotor and combined aerobic-locomotor training could effectively improve balance and enhance lower limb strength while reducing the fear of falling among older adults.

Keywords: Aged, Fear of falling, Aerobic exercise, Exercise therapy

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Introduction

The term "locomotive syndrome" (LS) was coined in 2007 by the Japanese Orthopaedic Association to describe movement problems caused by a decline in the musculoskeletal system's ability in the elderly population. Although this concept is well-established in Japan, it has yet to gain global recognition (1). According to evidence, LS affects between 8.4% and 50.3% of the elderly population and is more prevalent among women (2). Approximately 59.8% of patients experience LS due to non-traumatic factors. This syndrome can arise from chronic conditions, such as joint degeneration, lumbar and cervical spondylosis, lumbar and cervical disc herniation, and cartilage degeneration in the lower limbs. Based on severity, LS is generally categorized into stages 1 and 2. For stage 1 LS, locomotor training is recommended as an exercise therapy to enhance mobility (3, 4). Various factors, including a lack of exercise habits, a sedentary lifestyle, poor nutrition, and the presence of chronic diseases, can accelerate LS, especially in the elderly population (5). According to a study, there were significant differences in motor control parameters between older and younger adults, indicating decreased neuromuscular coordination with aging (6). Conversely, high-performing older adults (e.g., world-class athletes) demonstrated improved reinnervation, suggesting that physical activity may mitigate some age-related declines (7). Therefore, although increasing age affects balance adaptation, maintaining physical activity can protect against balance decline and reduce the risk of falls (8). Moreover, regular physical exercises can have significant benefits at low cost, including reducing the risk of falls, preventing muscle mass loss, improving cardiovascular endurance, increasing muscle endurance, and improving balance and posture (9). Additionally, regular locomotor and aerobic exercises increase balance, strength, and mobility, which are crucial for fall prevention (10). A study showed that balance and strength training considerably improve postural control and gait stability (11).

On the other hand, combining physical, cognitive, and social exercises yields the best results in reducing fall risks (11). In this regard, locomotor exercises play an essential role in strengthening balance and reducing the risk of falls among the elderly population. As people age, they frequently experience motor disabilities that can severely impair mobility and independence, leading to a higher incidence of falls (2). Nonetheless, implementing targeted exercise interventions can effectively mitigate these risks and enhance the overall quality of life. Despite the various benefits of physical activity and sports (e.g., reducing the risk of falls, maintaining functional abilities, and preventing chronic diseases), many older adults do not engage in regular physical activities.

Additionally, a noticeable decline in physical activity is often observed among older adults who have previously experienced falls, as there is a significant inverse relationship between physical activity level and the risk of falling (12). Previous studies have shown that physical exercise can help improve balance while reducing the risk of falls in the elderly. Despite various studies, there is still no consensus on the most effective type of exercise. In addition, no research, to the best of our knowledge, has so far focused on the combined effects of locomotor training and aerobic exercises on postural control, fear of falling, and lower-limb strength in the elderly in the context of Iran. Accordingly, this study aims to investigate the effect of these combined exercises in elderly women suffering from stage I motor syndrome in Arak.

Materials and Methods

Study Population

This quasi-experimental study used a pretest-posttest design and was conducted in April and May 2025. In this study, 45 elderly women (60 years and older) with LS were selected from among elderly women in Arak through convenience sampling. They were randomly assigned to three groups of 15: a locomotor training group with aerobic training, a locomotor training group alone, and a control group.

The sample size for each group was calculated using G*Power software. The analysis of covariance (ANCOVA) was considered, with a statistical power of 80% ($\beta = 0.20$) and a significance level of 0.05 ($\alpha = 0.05$). Based on an expected effect size of 0.25 from similar previous research, the power analysis indicated a minimum of 15 participants per group, ensuring sufficient power and accounting for potential dropouts.

Data Selection

The inclusion criteria for participation in the present study were obtaining informed consent from participants to enter the study, being 60 years of age or older, and having individual independence in performing personal and hygiene tasks. Moreover, having no history of surgery in the lower extremities within the past 2 years, having no history of degenerative joint diseases, and having no history of cardiovascular diseases and cardiorespiratory problems were other inclusion criteria. On the other hand, the exclusion criteria included a history of fractures or lower extremity surgery within the past 2 years, a history of cardiovascular surgery, elderly individuals with MS or Parkinson's disease, and absence from more than 3 exercise sessions. The measurement tools were the LS questionnaire (Loco-Check), the Timed Up and Go test to assess dynamic balance, the Four Square Step Test (FSST) to measure static balance, the Falls Efficacy Scale-International (FES-I) questionnaire to compute fear of falling, and the 30-second Chair Stand Test (30sCST) to estimate lower limb strength. Initially, tests of dynamic and static balance, the FES-I, and the 30sCST were administered to the subjects, and the results were recorded as pretest values. Then, the subjects in each group performed the intervention related to their group for 8 weeks, 3 sessions per week. Twenty-four hours after the final session, tests of balance, fear of falling, and strength were conducted as in the pretest conditions, and the post-test data were recorded, compared, and analyzed accordingly.

Locomotive Syndrome Screening Questionnaires:

Loco-Check

This is a self-assessment questionnaire comprised of 7 straightforward questions:

1. Inability to put on socks while standing on one leg
2. Stumbling or slipping at home
3. Needing to hold onto handles and railings to climb stairs
4. Difficulty performing moderately intense household activities
5. Difficulty carrying a 2 kg shopping bag from the store to home
6. Difficulty walking continuously for 15 minutes or longer
7. Inability to cross crosswalks before the traffic light changes.

A positive response to any of the mentioned questions suggests that the elderly individual is at risk of developing LS. Assessors can also use this list for other functional disorders. A positive response to even one of the 7 questions on the list places the elderly person in the group suspected of having LS (13, 14).

Balance Measurement (Dynamic Balance): The Timed Up and Go Test was used to assess subjects' dynamic balance. It is an efficient and straightforward assessment of dynamic balance in the elderly, in which the individual gets up from a chair, walks a short distance (usually 3 m), then returns to the chair and sits down again; the total time for these steps is recorded. A time of less than 10 seconds usually indicates acceptable performance and adequate balance, while a time of more than 30 seconds may represent a risk of falling (15).

Static Balance: The FSST was utilized to measure static balance. In this test, the subjects were asked to be in four different positions so that in the first stage, the feet were stuck together side by side. In the second stage, the feet were in a semi-tandem position, and the feet were placed in tandem along each other in the third stage. In the last stage, the individual stood on one foot and lifted the other foot off the ground and bent it from the knee. In this test, if the subject can maintain each position for 10 seconds, they will get a full score (score 3) for successful completion of each stage; otherwise, the time before the balance is disturbed is recorded for the individual, indicating failure in that stage. Inability to maintain the position for 10 seconds in the third stage suggests an increased risk of falling (16).

Strength Assessment: The 30sCST is a straightforward and effective measure of strength and balance in individuals, particularly the elderly. In this test, the individual sits in a standard chair and, without using their hands, must stand up from the chair and sit down again as many times as possible within 30 seconds. The total number of stands is recorded. This test evaluates lower-body muscle strength and helps identify fall risk in individuals. In addition, the test score is determined by the number of times the individual can stand up and sit down from the chair in 30 seconds, with higher scores demonstrating better strength and balance. The internal validity and external validity of this method for the elderly have been reported as 0.95 and 0.95, respectively (17).

Fear of Falling Assessment: The FES-I is a tool to assess fear of falling in adults and the elderly. It helps clinicians and researchers measure fear of falling and evaluate its impact on daily activities. The scale includes several subscales that assess different aspects of fear of falling, such as fear during daily activities, its impact on quality of life, and mobility limitations. Moreover, the FES-I is typically a 16-question scale with scores ranging from 1 (I have no fear at all) to 4 (I am terrified). Scores for each question are summed to obtain a total FES-I score ranging from 16 to 64. Scores of 16–19, 20–27, and 28–64 indicate low, moderate, and high fear of falling, respectively. A higher score represents greater fear of falling. Khajavi reported a temporal reliability of 0.70 and an internal reliability of 0.98 for this questionnaire (18).

Intervention

Locomotor Training Protocol:

Locomotor training is a safe and effective balance and resistance exercise suitable for both young adults and seniors, provided the individual can stand independently (3, 4). This type of training aims to increase participants' mobility (5).

The movement exercises consisted of four types of exercises:

1. One-Legged Stand: This exercise was performed for 1 minute. If older participants felt unsteady, they could use a chair for support.

2. Squat: To perform a squat, the elderly bent his/her knees to a 90-degree angle while using a chair for support. They conducted it for three sets of six repetitions.

3. Heel Raises: This exercise involved raising heels in a controlled motion, counting to four for the upstroke and four for the downstroke. They performed it for three sets of ten repetitions.

4. Forward Lunge: While maintaining a standing position, the elderly person lifted one leg forward as far as he/she could. They repeated it for three sets of five repetitions (19).

These exercises were conducted for 30 minutes per session, three times a week for 8 weeks. The intensity of the exercises was adjusted to the elderly's abilities and gradually increased accordingly. Additionally, these exercises were conducted entirely under the researcher's supervision. The participants' compliance was 88% on average.

Aerobic Training Protocol: Aerobic exercises were designed for the elderly at a mild-to-moderate intensity (40–70% of maximum heart rate; HR_{max} = 220-age). Exercise intensity was monitored using heart rate and the Borg Stress Perception Scale (Borg 11–13). Each session consisted of a 5-minute warm-up, 20 minutes of brisk walking appropriate to the elderly's ability, and a 5-minute cool-down. In addition, the intensity and duration of the exercise were gradually increased over 8 weeks (20). All exercise sessions were conducted under the researcher's supervision and in a safe environment (the gym). Adherence was monitored by recording attendance at sessions and averaged 90%.

Data Analysis

The descriptive statistics section included calculating and presenting the means and standard deviations (SD) for quantitative variables and numbers and percentages for qualitative variables. To compare groups in the post-test, ANCOVA was used, controlling for pretest values. Furthermore, paired comparisons between groups after ANCOVA were performed using a paired t-test. A significance level of 0.05 was utilized to determine hypothesis acceptance or rejection, and all statistical analyses were performed using SPSS version 25.

Results

Table 1 presents the participants' demographic characteristics, expressed as mean ± SD, for age, height, weight, and body mass index (BMI) across the three study groups. According to the Shapiro–Wilk test, the data were normally distributed, and Levene's test confirmed the homogeneity of variances. The mean age was 70.5 ± 6.83, 69.8 ± 5.12, and 65.9 ± 7.20 years in the locomotor and aerobic group, the locomotor group, and the control group, respectively. Further, height was 166.5 ± 8.53 cm, 167.4 ± 0.95 cm, and 166.9 ± 7.20 cm, respectively, in these groups. Moreover, weight was 67.9 ± 4.47 kg, 68.9 ± 7.20 kg, and 70.9 ± 7.20 kg, respectively. Based on the results, the BMI of the individuals was 24.0 ± 2.90 kg/m^2, 24.4 ± 8.51 kg/m^2, and 25.9 ± 7.20 kg/m^2, respectively. One-way ANOVA showed no significant differences between groups for age (P = 0.597), height (P = 0.305), weight (P = 0.226), and BMI (P = 0.120), indicating that participants were comparable in baseline demographic characteristics.

Table 2 provides the pretest and posttest mean ± SD

Table 1. Demographic Characteristics of Participants (Mean ± SD) and Comparison Between Groups Using ANOVA

Variables	Locomotor and Aerobic Group	Locomotor Group	Control Group	*P-Value
Age (years)	70.5 ± 6.83	69.8 ± 5.12	65.9 ± 7.20	0.597
Height (cm)	166.5 ± 8.53	167.4 ± 0.95	166.9 ± 7.20	0.305
Weight (kg)	67.9 ± 4.47	68.9 ± 7.20	70.9 ± 7.20	0.226
(BMI, kg.m²)	24.0 ± 2.90	24.4 ± 8.51	25.9 ± 7.20	0.120

Note: * ANOVA: Analysis of variance; SD: Standard deviation; BMI: Body mass index. All *P*-values are > 0.05, representing no significant differences between groups (one-way ANOVA).

Table 2. Within-Group and Between-Group Comparisons of Outcome Variables (Mean ± SD)

Variable	Group	Pretest (Mean ± SD)	Posttest (Mean ± SD)	Within-Group *P*-Value	Between-Group *P*-Value (ANCOVA)	Post-Hoc Comparisons (*P*-Value)
Fear of Falling (FES-I)	Locomotor Exercise	38.33 ± 1.68	35.3 ± 1.62	0.002*	< 0.001	vs. Aerobic + Locomotor: < 0.001* vs. Control: 0.001*
	Aerobic + Locomotor Exercise	35.2 ± 1.51	29.8 ± 1.4	0.020*		vs. Control: < 0.001*
	Control	36.6 ± 1.64	35.86 ± 1.60	0.424		
Lower Limb Strength (30sCST)	Locomotor Exercise	7.6 ± 0.46	8.73 ± 0.39	0.02*	< 0.001	vs. Aerobic + Locomotor: < 0.001* vs. Control: 0.02*
	Aerobic + Locomotor Exercise	8.01 ± 0.49	11.1 ± 0.47	0.003*		vs. Control: 0.014*
	Control	7.73 ± 0.47	7.8 ± 0.43	0.126		
Static Balance (FSST)	Locomotor Exercise	6.6 ± 2.4	7.9 ± 2.8	0.01*	0.004*	vs. Aerobic + Locomotor: 1.000 vs. Control: < 0.001*
	Aerobic + Locomotor Exercise	7.3 ± 2.1	8.77 ± 2.9*	0.001*		vs. Control: < 0.001*
	Control	8.64 ± 2.79	9.04 ± 2.58	0.331		
Dynamic Balance (TUG)	Locomotor Exercise	9.56 ± 3.4	8.64 ± 2.9	< 0.001*	< 0.001	vs. Aerobic + Locomotor: 0.072 vs. Control: 0.004*
	Aerobic + Locomotor Exercise	10.09 ± 3.8	9.13 ± 3.1	0.001*		vs. Control: < 0.001*
	Control	10.4 ± 3.2	10.6 ± 3.8	0.262		

Note: SD: Standard deviation; FES-I: Falls Efficacy Scale-International; 30sCST: 30-second Chair Stand Test; FSST: Four-Square Step Test; TUG: Timed Up and Go.

values for fear of falling, lower limb strength, static balance, and dynamic balance across all study groups. Posttest differences between groups were analyzed using ANCOVA with pretest scores as covariates.

Fear of Falling: No significant change was observed in the control group (8.64 ± 2.79 vs. 9.04 ± 2.58, $P = 0.424$). In contrast, fear of falling significantly decreased in the locomotor group (38.33 ± 1.68 vs. 35.30 ± 1.62, $P = 0.002$) and in the combined locomotor and aerobic group (38.50 ± 1.70 vs. 35.10 ± 1.60, $P = 0.020$).

Lower Limb Strength: There was no significant difference in the control group (7.73 ± 0.47 vs. 7.80 ± 0.43, $P = 0.126$). However, noticeable improvements were observed in the locomotor group (7.60 ± 0.46 vs. 8.73 ± 0.39, $P = 0.02$) and in the combined locomotor and aerobic group (8.01 ± 0.49 vs. 11.10 ± 0.47, $P = 0.003$).

Static Balance: A minimal change was found in the control group (8.64 ± 2.79 vs. 9.04 ± 2.58, $P = 0.331$). There were significant improvements in the locomotor group (6.60 ± 2.40 vs. 7.90 ± 2.80, $P = 0.01$) and in the combined locomotor and aerobic group (7.30 ± 2.10 vs. 8.77 ± 2.90, $P < 0.001$).

Dynamic Balance: There was a slight change in the control group (10.40 ± 3.20 vs. 10.60 ± 3.80, $P = 0.262$). Considerable improvements were noted in the locomotor group (9.56 ± 3.40 vs. 8.64 ± 2.90, $P < 0.001$) and in the combined locomotor and aerobic group (10.09 ± 3.80 vs. 9.13 ± 3.10, $P = 0.001$).

ANCOVA results confirmed the significant effects of interventions over time in the locomotor and combined groups ($P < 0.001$), while no significant changes were found in the control group, indicating that the observed improvements were attributable to the exercise programs rather than natural variability.

Discussion

This study investigated the effects of locomotor and aerobic exercises on balance, fear of falling, and lower-limb strength in elderly women with stage 1 LS. The results revealed that both interventions improved static and dynamic balance, reduced fear of falling, and enhanced lower limb strength, with the combined locomotor and aerobic program yielding superior outcomes. Previous studies support these findings. Zhang et al reported that 24 weeks of aerobic and combined aerobic-resistance training could significantly enhance strength and balance in elderly women, with combined exercises being more effective (21). Similarly, Zhong et al found that both resistance and aerobic training improved physical performance, with no difference between the exercise types (11).

Regular aerobic exercise (e.g., running and walking) improves dynamic balance in older adults, likely through neural adaptations that enhance motor unit recruitment, synchronization, and neuromuscular control, thereby improving coordination, precision, and movement speed (6, 22). In addition, balance training and aerobic exercises have the same effects on balance in older adults (23). Likewise, systematic reviews highlight additional benefits when aerobic exercise is combined with resistance, cross-training, or dance, including improved mobility and reduced fall risk (24).

Locomotor training, introduced by the Japanese Orthopaedic Association, integrates strength-building and balance-focused exercises that are safe, straightforward, and highly effective in enhancing physical abilities among older adults (3, 5).

The present study followed an 8-week, three session-per-week protocol, which aligns with prior literature indicating that frail elderly individuals require extended, moderate-frequency interventions to achieve meaningful adaptations (25, 26). Additionally, brain-derived neurotrophic factor-mediated neuromuscular improvements from these exercises likely contributed to increased strength and motor control (3). The dual physical and psychological effects of locomotor exercises may explain reduced fear of falling, which is consistent with the findings of Papalia et al, demonstrating increased confidence and performance following exercise interventions (27). Aerobic exercise, being low-impact and accessible, is suitable for older adults with cardiovascular, musculoskeletal, or osteoporotic conditions (28). Resistance components of locomotor exercises (e.g., squats and heel raises) target major lower limb muscles and counteract sarcopenia, further enhancing strength and balance (7, 22).

The finding of this study confirmed that an eight-week program combining locomotor and aerobic exercises, performed three times per week, effectively improved static and dynamic balance, reduced fear of falling, and increased lower limb strength in older adults. These benefits may result from enhanced self-confidence, improved motor unit recruitment, and better neuromuscular coordination. Therefore, our results directly indicate that adding aerobic exercise to the locomotor program further improves the motor and mental function of the elderly. Based on the result of the present study, it is recommended that orthopedic specialists, corrective exercise experts, physiotherapists, physicians, and even the general public utilize the combined locomotor and aerobic training protocol used in this research to enhance static and dynamic balance, reduce fear of falling, and increase lower limb strength in elderly individuals.

Research Suggestions for Future Investigations

The training protocol employed in this study should be examined over a longer duration or with a higher frequency per week. Moreover, locomotor exercises should be combined with other appropriate exercises for elderly individuals, and their effects should be assessed. Additionally, this study should be conducted on individuals with stage 2 LS. While the benefits of resistance training on muscle performance, particularly in maintaining balance among the elderly, are evident, it is important to consider the potential risks and limitations of such exercises (e.g., an increased risk of fall-related injuries, muscle strains, or joint pain), especially for older adults with restricted health conditions.

Conclusion

Our findings highlight that integrating aerobic and locomotor exercises serves as a practical approach to improving balance, alleviating fear of falling, and strengthening the lower limbs among older adults. However, to achieve better outcomes, it is recommended that future studies combine aerobic exercise with locomotor training, particularly targeting the lower extremity muscles. Additionally, addressing psychological factors and designing exercise programs that boost self-confidence in older adults can improve overall balance while reducing the risk of falling in this age group.

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Authors' Contribution

Conceptualization: Zahra Geramipour, Shahnaz Shahrjerdi.
Data curation: Zahra Geramipour.
Formal analysis: Zahra Geramipour.
Investigation: Zahra Geramipour.
Methodology: Zahra Geramipour, Shahnaz Shahrjerdi.
Project Administration: Shahnaz Shahrjerdi.
Resources: Zahra Geramipour.
Writing–original draft: Zahra Geramipour.
Writing–review and editing: Zahra Geramipour, Shahnaz Shahrjerdi.

Competing Interests

The authors declare there is no conflict of interests.

Ethical Approval

This study was conducted in accordance with the ethical guidelines approved by the Research Council of the Faculty of Physical Education and Sport Sciences at Arak University. In addition, interventions were initiated after written informed consent was obtained from all participants. It is noteworthy that participants were allowed to withdraw from the study at any stage if they were unwilling to continue. Furthermore, the study protocol was approved by the Ethics Committee of Arak University of Medical Sciences (IR.ARAKU.REC.1403.092) and registered in the Iranian Registry of Clinical Trials (IRCT20230619058528N2).

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