

Original Article

Effects of the Otago Exercise Program in older hypertensive patients with pre-frailty

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Abstract. [Purpose] We aimed to investigate the effects of the Otago Exercise Program in older hypertensive patients with pre-frailty. [Participants and Methods] Participants were randomly divided into the (Otago Exercise Program OEP) group (n=37) and the control group (n=38). The OEP group completed the exercise step 3 times during hospitalization. For 12 weeks, the OEP group exercised at home and the control group completed daily walking activities ≥ 3 times per week. [Results] There were significant differences in FRAIL scale score, 10-meter gait speed, one-leg standing test results, and functional reach test results between the two groups. In addition to the above indicators, the differences in diastolic blood pressure were also statistically significant between the two groups before and after intervention. [Conclusion] The OEP can improve frailty and the ability to perform activity in older hypertensive patients with pre-frailty. Diastolic blood pressure decreases significantly after intervention.

Key words: Otago exercise, Pre-frailty, Hypertension

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INTRODUCTION

Older patients with essential hypertension and frailty often have multiple co-existing diseases; a high risk of adverse events, such as falls, disability, and hospitalization; and a high risk of death. Chinese Guidelines for the Management of Hypertension in the Elderly 2019 recommend that physical exercise for 30 minutes five times per week is recommended for older patients with hypertension¹⁾. Exercise therapy for hypertension mainly includes aerobic exercise and resistance training. A meta-analysis showed that aerobic exercise reduces systolic blood pressure by 5.3 mmHg and diastolic blood pressure by 3.7 mmHg in older patients with hypertension²⁾. Another meta-analysis of 28 randomized controlled studies examined the effect of resistance training on hypertension. It was concluded that resistance training decreases both systolic and diastolic blood pressure by 3.9 mmHg in patients without hypertension or prehypertension³⁾. A previous study⁴⁾ also confirmed that exercise and physical activity are important interventions to delay and improve the frailty state, and physical training is important to maintain and improve physical strength and function in older individuals with frailty. Lack of exercise reduces muscle function, flexibility, and strength, and in older adults, loss of muscle strength is greater in the lower body than in the upper body⁵⁾. When standing, decreased muscle strength in the lower extremities causes the body to sway on a weight-bearing surface, leading to loss of balance. Pre-frailty is a state in which the health status is relatively poor but has not yet reached significant frailty. The results of a systematic review show that the incidence of pre-frailty among the older

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in the community ranges from 19%–53%⁶), and the number of people is considerable. Due to its reversibility, pre-frailty is considered a key condition that must be recognized and addressed in clinical practice⁷). Many studies have focused on exercise interventions for frail older adults, but few studies not on pre-frailty.

The Otago Exercise Program (OEP) originated in New Zealand in the 1990s and was developed by Campbell et al. of the Otago School of Medicine. It is an evidence-based exercise program that can be performed at home and mainly exercises lower limb muscle strength and balance. It was initially applied to community-dwelling older females aged >80 years, with improvements in the mean fall rate, relative risk of falls, and sense of balance after the intervention⁸). It is now widely used in Nordic countries and worldwide⁹). In recent years, Chinese scholars have applied the OEP to stroke^{10, 11}), in the perioperative period of joint replacement^{12–14}), and in elderly care facilities¹⁵), amongst other contexts, but whether the OEP is effective in hypertensive patients with debilitating disease is unknown. In this study, we investigated whether the OEP improves blood pressure, degree of frailty, mobility, and balance in older hypertensive patients with pre-frailty over 12 weeks.

PARTICIPANTS AND METHODS

Seventy-five hypertensive patients with pre-frailty aged ≥ 65 years (mean age 73.4 ± 5.3 years), who were hospitalized at the Department of Cardiology from August 2020 to September 2021, were selected and divided into the intervention group (OEP; $n=37$) and the control group (daily walking activities ≥ 3 times per week; $n=38$) according to the random number table. The study was approved by the hospital ethics committee, (hospital ethics number: 2021-09) and all participants provided written informed consent.

The inclusion criteria were as follows: 1) met the diagnostic criteria for hypertension according to the Guidelines for Prevention and Treatment of Hypertension in China¹⁶); 2) FRAIL scale score of 1–2 points; 3) hospital stay of ≥ 7 days; 4) ability to walk independently without an assistive device; 5) voluntary participation and informed consent. The exclusion criteria were as follows: 1) visual or hearing impairment that would affect communication and training; 2) unstable blood pressure or other clinical symptoms; 3) history of lower back and leg pain or lumbar and/or lower limb fracture; 4) history of stroke, psychosis, epilepsy, vertigo, or extrapyramidal disease.

During the study, seven patients withdrew in the intervention group (one patient left the local area and six patients could not adhere to active exercise withdrawal), and eight patients withdrew in the control group (four left the local area, one died, and three were readmitted). There was a total of 30 patients in the intervention group and 30 patients in the control group.

The members of the established study team included the investigators, eight nursing staff (including one head nurse), and one associate chief physician. The investigators trained the members of the research group, including training on the OEP, data collection methods, and communication skills; provided specific guidance of the intervention process; supervised the entire study; and recorded the OEP video at our hospital before the intervention. The nursing staff assisted the investigator in collecting data, guiding exercises, and conducting return visits. The physicians were responsible for dealing with emergencies and related consultations that arose during the intervention.

To describe the OEP and its role, the intervention process, how to cooperate, and the intervention duration during hospitalization, a video of the Otago exercises was played in the ward corridor every afternoon. One member of nursing staff was also available to provide on-site guidance and assessment. Patients were required to complete ≥ 3 exercises before discharge and be able to complete all exercise steps under the guidance of a nurse. An OEP instruction manual outlining the action steps, muscle strength training requirements, and balance training requirements, as well as an exercise diary form, was distributed before discharge. The patients were instructed to immediately call the researchers if they experienced any discomfort during home training.

The control group received nursing and health education according to the general nursing routine of the cardiology department during hospitalization. The control group underwent routine walking activities for 20–30 minutes ≥ 3 times per week according to the living habits of the study participants after discharge. In the first week after discharge, a telephone interview was conducted, mainly to inquire about daily activities and to provide health education guidance, such as guidance on the disease and medication.

After discharge, in the intervention group, all participants were required to exercise at home and to keep an exercise diary. Most of the Otago exercise steps were completed ≥ 3 times per week for 40–50 minutes, and routine walking activities were performed ≥ 3 times per week for 20–30 minutes. Telephone follow-ups were conducted at weeks 1 and 8 and home visits at weeks 4 and 12. For the home visits, two research group members visited the homes of the participants to complete the collection of functional data. Follow-up was mainly intended to guide movement standardization, urge the participants to adhere to the Otago exercises, examine the feelings experienced during movement, determine whether the participants had experienced falls or injuries, check the movement diary, enhance participants' confidence and compliance in performing the exercises, provide guidance on the disease, and answer patients' questions.

In the intervention group, the OEP was performed on the basis of routine care measures. To conduct the OEP, two 0.5 kg ankle cuffs were obtained free of charge for each participant. Part I of the OEP consisted of three parts: warm-up exercises (5 actions), muscle strengthening exercises (5 actions), and balance training (12 actions). The warm-up exercises were performed before the muscle strengthening exercises, and each action of head movement, neck movement, body extension, and trunk movement was repeated five times, while ankle movement was repeated 10 times.

The warm-up exercises were followed by muscle strengthening exercises, including knee extension, knee flexion, hip extension, tiptoe, and tiptoe heel. During the first three movements of the practice, the 0.5 kg ankle cuffs were tied to the ankles of both lower limbs, 10 times each for the left and right feet and 20 times each for the tiptoe and tiptoe heel.

Finally, balance training included 12 items, as follows: knee flexion, walking upside down, “8” walking, walking side down, toe-heel standing, toe-heel walking, one-leg standing (OLS), toe-walking, heel walking, toe-heel walking upside down, sit-to-stand exercise, and stair climbing.

Part II of the OEP involved walking ≥ 3 times per week for 20–30 minutes each time in addition to Otago exercises.

The FRAIL scale score, blood pressure, mobility, and balance were assessed in both groups. Baseline data collection was performed before the physician assessed that each patient was stable during hospitalization and was able to perform OEP training. After 12 weeks of intervention, the assessment was performed at each patient’s home by the investigator and head nurse, who carried a tape measure, stopwatch, sphygmomanometer, stethoscope, and FRAIL score sheet, amongst other items.

The FRAIL scale was developed by the International Association of Nutrition and the Elderly and consists of five components: fatigue, resistance, ambulation, illness, and loss of weight^{17, 18}). Scores range from 0 to 5, with a score of ≥ 3 indicating frailty, 1–2 indicating pre-frailty, and 0 indicating a robust health status. Fatigue was measured by asking the patients how often in the past 4 weeks they had felt tired, answering 1 point for “all the time” or “most of the time”; 1 point for difficulty climbing a floor alone without rest and assistance; 1 point for difficulty walking 100 meters alone without assistance; 1 point for reporting ≥ 5 of the listed conditions; and 1 point for weight loss of $\geq 5\%$ in the past 12 months.

Blood pressure was measured at the upper arm after the patient had rested quietly for at least 5 minutes. The upper arm was placed at the level of the heart in the sitting position. The brachial artery is level with the midaxillary line in the supine position. A mercury column sphygmomanometer was used to meet the measurement standard. The measurement was repeated 1–2 minutes apart, and the average value of the two readings was used. If the two readings of systolic blood pressure and diastolic blood pressure differed by >5 mmHg, blood pressure was measured again, and the average of the three readings was used.

The ward corridor was used as the 10-meter walkway, and a 5-meter distance was marked at the beginning and end of the corridor to give the participant room to accelerate and decelerate outside of the data collection area to reduce the gait variability resulting from these stages^{19, 20}). Ten-meter gait speed was measured twice and averaged. An average pace of <0.8 m/s was considered a slow pace^{21, 22}). Some scholars have proposed that gait speed should be regarded as the sixth vital sign²³). Some studies have shown that a single measure of gait speed is superior to other multi-component frailty scales in predicting outcomes²⁴).

For the OLS test, the patients stood with both eyes open with their arms by their sides. They chose one leg to stand on, bent their knees, took one foot off the ground, and stood independently on one leg for as long as possible. The assessor recorded the time in seconds and determined whether the patient was able to maintain their balance for ≥ 5 seconds. The timer was stopped if the patient maintained their balance for more than 60 seconds²⁵). Each leg was tested twice and averaged. As previously described, the OLS test result is a simple predictor of nociceptive falls and debilitation²⁵).

For the FRT, the patients stood with one side of their body against a wall, a mark is made at the level of the acromion, and leant the upper body forward as far as possible under the premise of maintaining their own balance. Both upper limbs were extended horizontally, and the heels were kept on the ground. The examiner records the maximum distance (in cm) from the acromion marked on the wall to the extension of the upper extremity, and a greater distance indicated better dynamic balance²⁶). According to previous cross-sectional study data, the FRT is a practical tool that is more closely related to physical frailty than to age²⁷).

All statistical tests were performed using SPSS 25.0 statistical software. Categorical variables are described as number of cases (%), and comparisons between groups were made using the χ^2 test or the exact probability method (Fisher’s test). Continuous variables were first tested for normality. Where the variance is equal between the two groups, mean \pm SD is used, and the t-test was used for comparisons between groups. Non-normally distributed data are presented as median (interquartile range), and were compared using the non-parametric Mann–Whitney U test to produce Z scores. A p value of ≤ 0.05 was considered statistically significant for all tests.

RESULTS

There were no significant differences in demographic data between the two groups ($p > 0.05$) (Table 1). Before the OEP, there were no significant differences in systolic blood pressure, diastolic blood pressure, FRAIL scale score, OLS test results, and FRT results between the two groups; however, there was a significant difference in 10-meter gait speed ($p \leq 0.05$). After 12 weeks, there were significant differences in FRAIL scale score, 10-meter gait speed, OLS test results, and FRT results between the two groups ($p \leq 0.05$), but there was no significant difference in systolic blood pressure or diastolic blood pressure ($p > 0.05$) (Table 2). There were significant differences in diastolic blood pressure, FRAIL scale score, 10-meter gait speed, OLS test results, and FRT results between the two groups at baseline and after OEP ($p \leq 0.05$) (Table 3).

Table 1. Comparison of demographic data between the two groups

Variable	Intervention group (n=30)	Control group (n=30)
Age (years), mean \pm SD	72.3 \pm 4.8	74.4 \pm 5.6
Gender, n (%)		
Male	10 (33.3)	10 (33.3)
Female	20 (66.7)	20 (66.7)
Marital status, n (%)		
Widowed	7 (23.3)	5 (16.7)
Married	23 (76.7)	25 (83.3)
Education level, n (%)		
Illiteracy	10 (33.33)	11 (36.7)
Primary school	16 (53.3)	14 (46.7)
Junior high school	4 (13.33)	5 (16.7)
Weight (kg), mean \pm SD	62.6 \pm 8.5	61.6 \pm 10.2
Height (m)	1.6 (1.6, 1.6)	1.6 (1.6, 1.6)
BMI (kg/m ²), mean \pm SD	24.5 \pm 3.7	23.9 \pm 2.9

Age, weight and BMI: Independent-samples t-test. Gender and marital status: χ^2 test. Education level: Fisher test. Height: Mann-Whitney U test. $p > 0.05$ in all of variables between two groups.

Table 2. Comparison of each index before and after the intervention between the two groups

Variable	Time point	Intervention group (n=30)	Control group (n=30)
SBP (mmHg)	Pre-intervention	141.2 \pm 19.5	145.3 \pm 18.3
	Post-intervention	136.0 \pm 11.5	141.6 \pm 11.3
DBP (mmHg)	Pre-intervention	89.1 \pm 14.9	87.0 \pm 12.7
	Post-intervention	80.1 \pm 10.1	83.7 \pm 11.3
FRAIL scale score	Pre-intervention	1.6 \pm 0.5	1.6 \pm 0.5
	Post-intervention	0.6 \pm 0.6	1.7 \pm 0.7***
Ten-meter gait speed (m/s)	Pre-intervention	0.8 \pm 0.2	0.8 \pm 0.2
	Post-intervention	1.1 \pm 0.2	0.7 \pm 0.2***
OLS (s)	Pre-intervention	3.5 (2.6, 4.7)	4.9 (2.5, 7.5)
	Post-intervention	9.3 \pm 3.6	4.9 \pm 2.6***
FRT (cm)	Pre-intervention	77.5 (72.2, 81)	76 (70, 90.8)
	Post-intervention	86 (84, 90)	75 (65, 85.5)***

*** $p \leq 0.001$. SBP: systolic blood pressure; DBP: diastolic blood pressure; FRAIL scale: Fatigue, Resistance, Ambulation, Illness, and Loss of Weight Scale; OLS: one-leg standing test; FRT: functional reach test.

Table 3. Comparison of various indicators before and after the intervention between the two groups

Variable	Intervention group (n=30)	Control group (n=30)
SBP (mmHg)	-9 (-10.8, -2.5)	-3.5 (-9.8, 3.8)
DBP (mmHg)	-6.5 (-17, -3)	-4 (-6, 0.8)*
FRAIL scale score	-1.0 \pm 0.5	0.1 \pm 0.7**
Ten-meter gait speed (m/s)	0.2 \pm 0.1	0.0 \pm 0.1***
OLS (s)	4.75 (1.99)	-0.01 (0.40)***
FRT (cm)	9.5 (6, 12)	-3.5 (-5, -2)***

* $p \leq 0.05$, ** $p = 0.001$, *** $p < 0.001$.

DISCUSSION

In this study, we examined the effect of the OEP on dynamic and static balance according to two indicators: the FRT and OLS. The median difference in OLS was +4.75 s, and the median difference in FRT was +9.5 cm after OEP. Moreover, balance significantly improved after OEP in patients with pre-frailty ($p \leq 0.05$). Son et al.²⁸ showed that after 12 weeks of intervention in older females in the community, Otago exercise and traditional martial arts (Tai chi) significantly improved balance and lower limb strength, but Otago exercise improved FRT more significantly. Yang et al.²⁹ performed a 6-month OEP intervention in participants with mild balance impairment, and the results showed a mean difference of 2.9 cm in the FRT after compared with before the intervention (95% CI 1.75–4.15). Otago exercise increased the angle of joint motion in the lower limbs and prevented adhesion of collagen tissue. Increased muscle strength and joint flexibility enable older adults to respond quickly and reduce gait disturbances when their gait changes⁵. Dynamic and static balance exercises with gait and walking training may also promote the generation of vestibular compensation and facilitate the brain to re-establish good balance.

Walking speed is a commonly used indicator to examine physical function, sarcopenia, and frailty. Li suggested that a reduction in gait speed is an independent risk factor for falls in older patients with essential hypertension (OR 2.88, 95% CI 1.26–6.56, $p < 0.05$)³⁰. Gait speed has also been shown to predict morbidity and mortality in various populations, including in older patients with cardiovascular disease. In a previous study, the muscle actions most strongly correlated with gait speed were non-dominant hip abduction (comfortable speed) and knee extension (maximum speed)³¹. Otago exercises mainly target the lower limbs, including the ankle joint, knee joint, and hip joint, and ankle cuff weight-bearing also enhances the muscle strength of the knee extensors and flexors, hip abductors, and ankle plantar flexors and back flexors²⁸. These exercises increase the synthesis of myofibrillar proteins, improve the function of muscle fibers, and enhance muscle strength. This study showed that the mean difference between the two groups after 12 weeks of OEP was significantly different ($p \leq 0.05$). Other studies have shown a correlation between muscle strength and gait speed in debilitated patients^{32, 33}. Therefore, patients with frailty who participate in the OEP will also demonstrate an improvement in pace as muscle strength increases.

In this study, there was a significant decrease in systolic and diastolic blood pressure after the OEP compared with baseline, but there was no significant difference between the OEP group and the control group ($p > 0.05$). However, in terms of the change in diastolic blood pressure after the intervention compared with baseline, there was a statistically significant difference between the two groups ($p \leq 0.05$), with diastolic blood pressure decreasing to a greater degree in the OEP group. The American College of Sports Medicine recommends that patients with hypertension perform dynamic aerobic endurance training for at least 30 minutes each day, preferably supplemented by dynamic resistance training. A previous meta-analysis showed that endurance, dynamic resistance, and isometric resistance training reduce systolic and diastolic blood pressure, while combined training only reduces diastolic blood pressure³⁴. Otago exercises include resistance, balance, and aerobic exercises, which are supplemented by walking, and their effects on blood pressure have rarely been reported; thus, multi-center large-sample studies are needed.

Exercise intervention for frailty has been shown to delay frailty progression³⁵. Liang et al.¹⁵ used Fried's frailty phenotype criteria as an assessment tool to study the effects of Otago exercises on frailty in older adults at old-age institutions. They found that after undergoing 3 months of Otago exercises, the intervention group had a milder frailty status and fewer frailty phenotypes (all $p < 0.05$) than the control group who did not undergo Otago exercise. Individuals in the control group had a comparably worse frailty status and a significantly worse frailty phenotype (all $p < 0.05$). A previous study suggested that the OEP can reduce the risk of falls and that older, more frail participants may benefit more from enhanced body balance and strength than young elders who have better balance and strength at baseline³⁶. In this study, frailty status was assessed using the FRAIL scale score. After the intervention, there was a significant difference in the FRAIL scale score between the two groups ($p < 0.001$). Moreover, the mean change in FRAIL scale score after compared with before the intervention was significantly different between the two groups ($p < 0.001$). Different frailty assessment tools and sample sizes may lead to inconsistent study results, and whether Otago exercise has an effect on patients with pre-frailty needs further validation.

There are certain limitations in this study. First, in the two groups of Participants, there were twice as many women as men, which may have biased the exercise results. Second, commonly used lower limb muscle strength monitoring indicators were not measured.

In summary, the degree of frailty, balance, and gait speed were improved by the OEP in older hypertensive patients with pre-frailty. Diastolic blood pressure was reduced after 12 weeks of the OEP. We conclude that assessing patients with mild frailty and applying appropriate interventions, such as the OEP, may prevent progression to a severely frail state.

Conflict of interest

There're no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.

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