Effect of an Eight-Week PNF Training of the Lower Extremities on the Static, Dynamic, and Functional Balance in Elderly Women Aged 60-70 Years

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Abstract

Loss of muscle strength and joints range of motion associated with aging are the main causes of balance deficit and falling in the elderly, and training using proprioceptive neuromuscular facilitation (PNF) may be effective in improving these factors. This study aimed to determine the effectiveness of an eight-week PNF training of the lower extremities in improving the static, dynamic, and functional balance among elderly women aged 60-70 years. To this end, a pre-test and post-test quasi-experimental design was adopted for the study. Participants (30 elderly women, age 69.26±3.72 years, weight 67.26±5.91 kg, height 155.78±4.64 cm) were randomly assigned into two groups of the experiment (training group, $n = 15$) and control (daily life activities, $n = 15$). The training intervention consisted of eight weeks (24 sessions of 50 minutes, three sessions per week) of PNF training of the lower extremities. The static, dynamic and functional balance were measured in the pre-test and the post-test using the Sharpened Romberg Test, the Timed Up and Go Test, and the Fullerton Advanced Balance Scale, respectively. The Results revealed significant improvements in the experiment group in terms of static balance with eyes open (20.48%), static balance with eyes closed (54.70%), dynamic balance (26.60%), and functional balance (12.37%, all $p \leq 0.001$). Comparison of the groups in the post-test showed that the experiment group significantly was better than the control group in static balance with eyes open ($p < 0.001$), static balance with eyes closed ($p < 0.001$), dynamic balance ($p = 0.019$) and functional balance ($p = 0.006$). Based on the findings, an eight-week PNF training of the lower extremities is effective in improving static, dynamic and functional balance in elderly women; where the ability of static balance with eyes closed receives the most influence from the training.

Keywords: Aging, Falling, Balance, Proprioceptive Neuromuscular Facilitation.

1. INTRODUCTION

The elderly population in the world is incrementally growing. The World Health Organization (WHO) reported that the number of people aged 60 years and over in 2019 was one billion, and this number will increase by 110% in the next 30 years.[1] Aging is a biological change over time that occurs in the way an organism lives. This change is accompanied by a decrease in the individual's capacity to adapt to sudden conditions and inability to rebalance, and gradually causes changes in the structure and function of different organs of the body. Aging is associated with significant physical-motor changes, of which a decrease in muscle strength and joint range of motion and flexibility are the most fundamental changes.[2] Muscle strength is an important component in maintaining physical function, mobility, and vitality in old age; Muscle weakness, on the other hand, is independently considered as a risk factor for high mortality and morbidity rates in the elderly.[3] Sarcopenia, the loss of age-related skeletal muscle mass, is a major cause of decreased muscle strength in the aging process and is associated with dysfunction, disability, falling, and loss of independence in the elderly.[4] Experimental studies show that the decrease in muscle strength and joint range of motion in the aging process is the main cause of balance deficit[5,6], and subsequently balance deficit is the main determinant of falling in the elderly.[7] Falling is a common problem among the elderly

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population and one of the main causes of mortality and morbidity is injuries caused by falls. Although most falls in the elderly do not lead to severe injury or death, their negative psychological effects can lead to fear of subsequent falling, lack of self-confidence, reduced desire to engage in physical and social activities, increased dependence on others, and a decline in the quality of life. About 70% of falls in the elderly occur due to impaired dynamic balance during gait and ineffective biomechanical gait pattern.[8]

It has been suggested that exercise training designed based on the Proprioceptive Neuromuscular Facilitation (PNF) principles may be effective in improving postural control and balance. In the field of rehabilitation, PNF is considered as a method to enhance or accelerate the response mechanism of neuromuscular stimulation of proprioceptive sense, which includes a set of techniques that stimulation of proprioceptive sense enhances the response of the nervous and muscular system. In the field of exercise and sport, PNF is known as a stretching technique that is used to improve the joint's range of motion and muscle elasticity.[9] Various techniques for PNF have been introduced in the literature, including the Contract-Relax (CR) and the Contract-Relax-Antagonist-Contract (CRAC) methods. The CR method involves stretching the target muscle and holding it in the same position, while the person contracts the target muscle with maximum isometric strength for a certain period. This step is followed by a shorter relaxation of the target muscle, which usually involves passive stretching.[9] The CRAC method has the same procedure as the CR method, but instead of inactive stretching of the target muscle, the individual is asked to contract the antagonist/opposite muscle of the target muscle for another certain period.[9] The advantage of using PNF compared to traditional static and dynamic stretching methods in improving active and passive range of motion and output power has been investigated and confirmed. To benefit from the long-term effects of PNF training, it has been recommended that the training must be performed at least twice a week. Factors such as age, gender, duration of contraction, adopted technique (CR or CRAC), and percentage of maximum voluntary isometric contraction (MVIC) mediate the effectiveness of PNF-based interventions. Four theoretical mechanisms consisting of autogenic inhibition, reciprocal inhibition, stress relaxation, and gate control theory are suggested in the literature, all of which provide potential explanations for increasing the range of motion through the PNF stretching technique.[9]

A large part of the literature has been dedicated to studying the effectiveness of rehabilitation interventions using PNF techniques in people with stroke. Experimental studies show that rehabilitation based on PNF principles has been successfully used to improve muscle strength[10,11], balance[10,12-15], mobility[10], and gait ability and parameters[14] in patients with stroke. Although research on the efficacy of PNF in healthy elderly is limited (approximately 20 to 30 studies have been performed on elderly subjects), studies have shown that the use of PNF in healthy elderly over 60 years, leads to significant improvement in flexibility[16], muscle strength[17], knee torque[18], static, dynamic and functional balance[17-27], ability to walk[21], and fear of falling[19]. PNF-based training has also been reported to be effective in improving balance in the elderly with low back pain.[28,29] Not only in the elderly, but also the improvement of postural control and balance as well as the strengthening of the muscular structure involved in postural posture control of healthy young people have been reported following PNF training programs.[30-32] Despite this evidence, Areeudomwong and Buttagat (2019) partly confirmed the effectiveness of a three-week PNF training in reducing pain and disability and improving static balance in people with chronic low back pain and mentioned that the effect size of PNF training is not enough large to be considered at the level of clinical significance.[33] In general, research on the elderly shows that PNF-based interventions are effective methods in improving balance abilities and physical factors involved; However, further studies are needed to identify the most effective training protocol due to the limited studies and the multiplicity of mediating factors on the effectiveness of PNF-based interventions such as duration of contraction, type of the adopted PNF techniques, the percentage of maximum voluntary isometric contraction and the duration and frequency of training sessions.[9]

Sensory information of the lower extremities, which are provided by specialized mechanical receptors, plays an important role in balance and displacement. Awareness of the foot position (proprioceptive sense) and postural responses decreases in the aging process.[34] Also, the threshold of vibration sensation, tactile sensation, and density of sensory receptors decrease with aging.[35] These sensory impairments in the lower extremities are associated with a risk of falling in the elderly.[36] In the present study, therefore, we focused on PNF training for the lower extremities. More specifically, the study was designed to determine the effectiveness of an eight-week PNF training of the lower extremities in improving the static, dynamic, and functional balance among elderly women.

2. MATERIALS AND METHODS

2.1. Design and Participants

This study adopted a pre-test and post-test quasi-experimental design. The total sample size was calculated to be 30 cases using the G*Power program (two-tailed, effect size = 1.10, $\alpha = 0.05$, power = 80%, allocation ratio = 1).[37] Volunteers were identified based on a research call in the care center for the elderly. After the preliminary evaluations, 37 people met the inclusion criteria, and 30 of them participated in the study (Figure 1). Inclusion criteria were: 1) age 60 to 70 years, 2) no records of fractures in the lower limbs in the last ten years, 3) no movement restrictions in the pelvic, thigh, and knee joints, 4) no use of drugs affecting the nervous and psychiatric systems, 5) not using walking aids, 6) getting a score above 12 on the Composite Physical Function (CPF) Scale, 7) getting a score above 24 on the Mini-Mental State Examination (MMSE). Exclusion criteria also included the absence of more than two sessions of training, injury, or illness during the study, and withdrawal from study participation. After baseline assessments, eligible participants were randomly assigned into two groups of the experimental (training group, $n = 15$) and the control (daily life activities, $n = 15$).

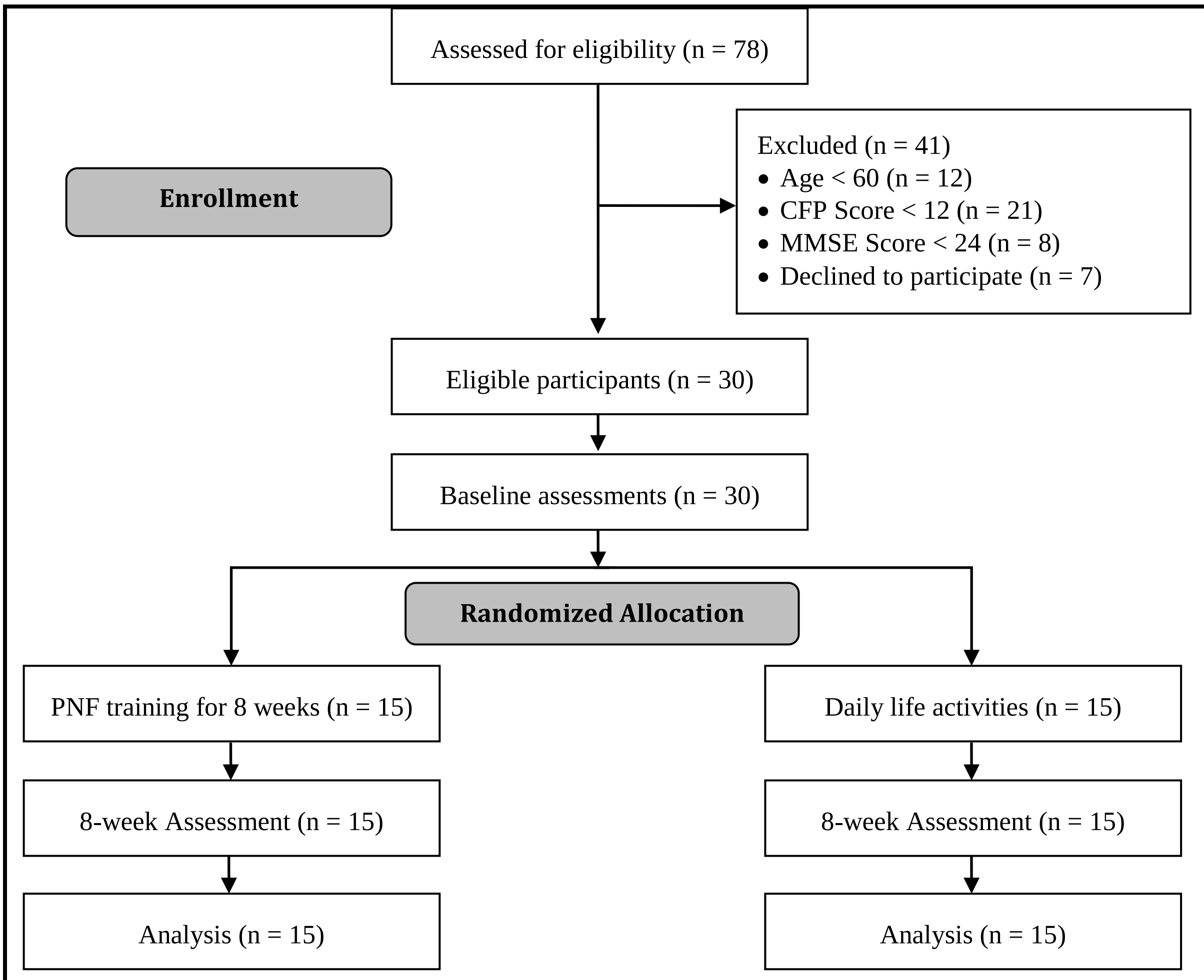

Figure 1: CONSORT Flow Diagram

2.2. Training Procedure

The intervention consisted of eight weeks of PNF training of the lower extremities (24 sessions of 50 minutes, three sessions per week). In all sessions, a four-step procedure was used to execute the training. These steps included (1) introducing the training program, (2) general warm-up to reduce the risk of injury, (3) performing the training program, and (4) recovery. The exercises are aimed at stabilizing the ankle joint, retraining the proprioceptive sense of the ankle joint, balance in the ankle joint, and subsequently balance for the whole body. The PNF techniques including hold and relaxation (HR), contract and relaxation (CR), slow reversal (SR), and rhythmic stabilization (RS) were applied to the movements of the ankle joint (i.e., plantarflexion, dorsiflexion, inversion, and eversion). The intensity of the training was adjusted by the trainer and a one-minute rest was given between the exercises of each technique. The training performed in each session is described in Table 1. The participants in the control group did not receive any intervention and were engaged in daily life activities. It should be noted that the participants in the control group were individuals who did not participate in any organized physical activity program during the study.

Table 1: PNF training in each session

Target Muscles	PNF Techniques	Duration (sec.)	Repetition for each leg
1. Ankle Plantar Flexors	HR	30	3
	CR	35	3
	SR	35	3
2. Ankle Dorsiflexors	HR	30	3
	CR	35	3
	SR	35	3
3. Ankle Plantar Flexors	RS	90	3
4. Ankle Dorsiflexors	RS	90	3
5. Ankle Invertors	HR	30	3
	CR	35	3
	SR	35	3
6. Ankle Evertors	HR	30	3
	CR	35	3
	SR	35	3
7. Ankle Invertors	RS	90	3
8. Ankle Evertors	RS	90	3

Note: The intensity of the exercise was adjusted by the trainer's hand; A one-minute rest was given between the exercises of each technique. HR = Hold and Relaxation; CR = Contract and Relaxation; SR = Slow Reversal; RS = Rhythmic Stabilization.

2.3. Measurements and Instruments

The static, dynamic and functional balance were measured in the pre-test and the post-test (one day before and after the intervention) using the Sharpened Romberg Test, the Timed Up and Go Test, and the Fullerton Advanced Balance Scale, respectively.

2.3.1. The Sharpened Romberg Test

The participants were asked to place their dominant foot on the ground, lift the other foot off, and place it in front of the dominant foot, while the arms were crossed on the chest. Performance on this test is measured by the time taken to maintain described position with eyes open or closed. The reliability of the Sharpened Romberg test for the elderly population was reported to be 0.90 and 0.77 in eyes open and closed conditions, respectively.[38] In the present study, each participant performed the test three times in each condition (i.e., eyes open and closed), and the average time obtained was recorded as performance in the test.

2.3.2. The Timed Up and Go (TUG) Test

This test was introduced by Podsialdo and Richardson (1991) to measure the basic functional mobility of frail elderly persons.[39] In this test, the participant is observed and timed while she rises from an armchair, walks three meters, turns, walks back, and sits down again. The average time obtained by three trials is used as performance in the test. The performance of fewer than 10 seconds means high motor ability, 10-19 seconds means normal movement and independence in walking, 20-29 seconds means slower movement, imbalance, and need for support in walking, and performance of more than 30 seconds means the reduced motor ability and prone to falling.[39]

2.3.3. Fullerton Advanced Balance (FAB) Scale

This test has been developed by Rose, Lucchese, and Wiersma (2006) to assess functional balance in functionally independent older adults.[40] The FAB is a multidimensional balance consisting of 10 items (e.g., turn in full circle; step up and over; tandem walk), and the performance in each item is scored on a continuum of 0-4. Each participant who receives a score less than 25 is at high risk of falling.[40]

2.4. Data Analysis

Descriptive statistics including mean (M) and standard deviation (SD) were used to present the data. Before the analysis, normality and homogeneity of variance assumptions for all data were checked by Shapiro-Wilk and Levene's tests, respectively. The paired-samples *t*-test was used to examine within-group changes and the independent-samples *t*-test was used for all between-group comparisons in the pre-test and the post-test. Effect sizes (Cohen's *d*) were calculated to determine the practical significance of the results. The *d*-values between 0.3 and 0.49 were taken to indicate a small effect, values between 0.5 and 0.79 were taken to indicate a moderate effect, and values greater than 0.8 were taken to indicate large practical significance.[41] The significance level was set at 0.05 for all analyses. Statistical analyses were performed using IBM SPSS (version 24).[42]

3. RESULTS

Table 1 shows the descriptive statistics of the individual characteristics of the participants in the experiment and control groups. To ensure the homogeneity of the groups, independent-samples *t*-test was used to compare individual characteristics and measured variables in the pre-test, indicating no significant difference between the experiment and control groups in terms of age ($t(28) = -0.038$, $p = 0.970$), weight ($t(28) = -0.867$, $p = 0.394$), height ($t(28) = 0.317$, $p = 0.754$) t), body mass index ($t(28) = -1.120$, $p = 0.273$), static balance with eyes open ($t(28) = -0.150$, $p = 0.882$), static balance with eyes closed ($t(28) = -0.757$, $p = 0.456$), dynamic balance ($t(28) = 0.248$, $p = 0.806$), and functional balance ($t(28) = -0.193$, $p = 0.849$).

Table 1: Descriptive statistics of participants' characteristics

Characteristic	**Groups**	
	Experiment (*n* = 15)	Control (*n* = 15)
Age (yrs)	69.23±3.78	69.29±3.81
Weight (kg)	66.23±6.34	68.21±5.54
Height (cm)	156.08±3.66	155.50±5.53
BMI ($kg.m^{-2}$)	27.15±2.01	28.33±3.26
CPF Score	18.15±1.21	18.07±1.54
MMSE Score	27.62±1.71	27.64±1.55

Note: Data were presented as M±SD; CPF = Composite Physical Function; MMSE = Mini-Mental State Examination.

Table 2 shows the descriptive statistics of the variables, the percentage of within-group changes, and the results of the paired-samples *t*-test to examine within-group changes. It should be noted that in all cases, the *t*-test for independent samples was performed with the assumption of equal variances (*p*s > 0.05 for Levene's test). The results showed that static balance with eyes open in the experiment group increased significantly by 20.48% from the pre-test to the post-test ($t(14) = 17.34$, $p < 0.001$), while there was no significant within-group change in the control group (change percentage = 1.08%, $t(14) = -1.54$, $p = 0.147$). Static balance with eyes closed in the experiment group also increased significantly by 54.70% from the pre-test to the post-test ($t(14) = -18.27$, $p < 0.001$), while there was no significant within-group change in the control group (change percentage = 2.65%, $t(14) = -1.75$, $p = 0.103$). Time to complete dynamic balance task (i.e., TUG test) in the experiment group decreased significantly by 26.60% from the pre-test to the post-test ($t(14) = 11.49$, $p < 0.001$), while the within-group change in the control group was not statistically significant (change percentage = 6.11%, $t(14) = 1.04$, $p = 0.315$). It should be noted that lower scores in dynamic balance indicate better performance in the TUG test. The score of functional balance in the experiment group increased significantly by 12.37% from the pre-test to the post-test ($t(14) = -5.73$, $p < 0.001$), while there was no significant within-group change in the control group (change percentage = 1.19%, $t(14) = -1.00$, $p = 0.336$).

Table 2 also shows the results of the independent-samples *t*-test to compare the variables between the groups in the post-test to examine the effectiveness of the intervention. According to the results, there was a significant difference between the experiment and control groups in the post-test in terms of static balance with the eyes open ($\Delta M = 5.35$, $t(28) = 4.79$, $p < 0.001$, Cohen's $d = 1.85$), static balance with eyes closed ($\Delta M = 3.84$, $t(28) = 6.79$, $p < 0.001$, Cohen's $d = 2.62$), dynamic balance ($\Delta M = -2.19$, $t(28) = -2.51$, $p = 0.019$, Cohen's $d = 0.97$), and functional balance ($\Delta M = 3.11$, $t(28) = 3.004$, $p = 0.006$, Cohen's $d = 1.16$). As shown in Figure 2, the balance profile of the experiment group in the post-test is better than the control group.

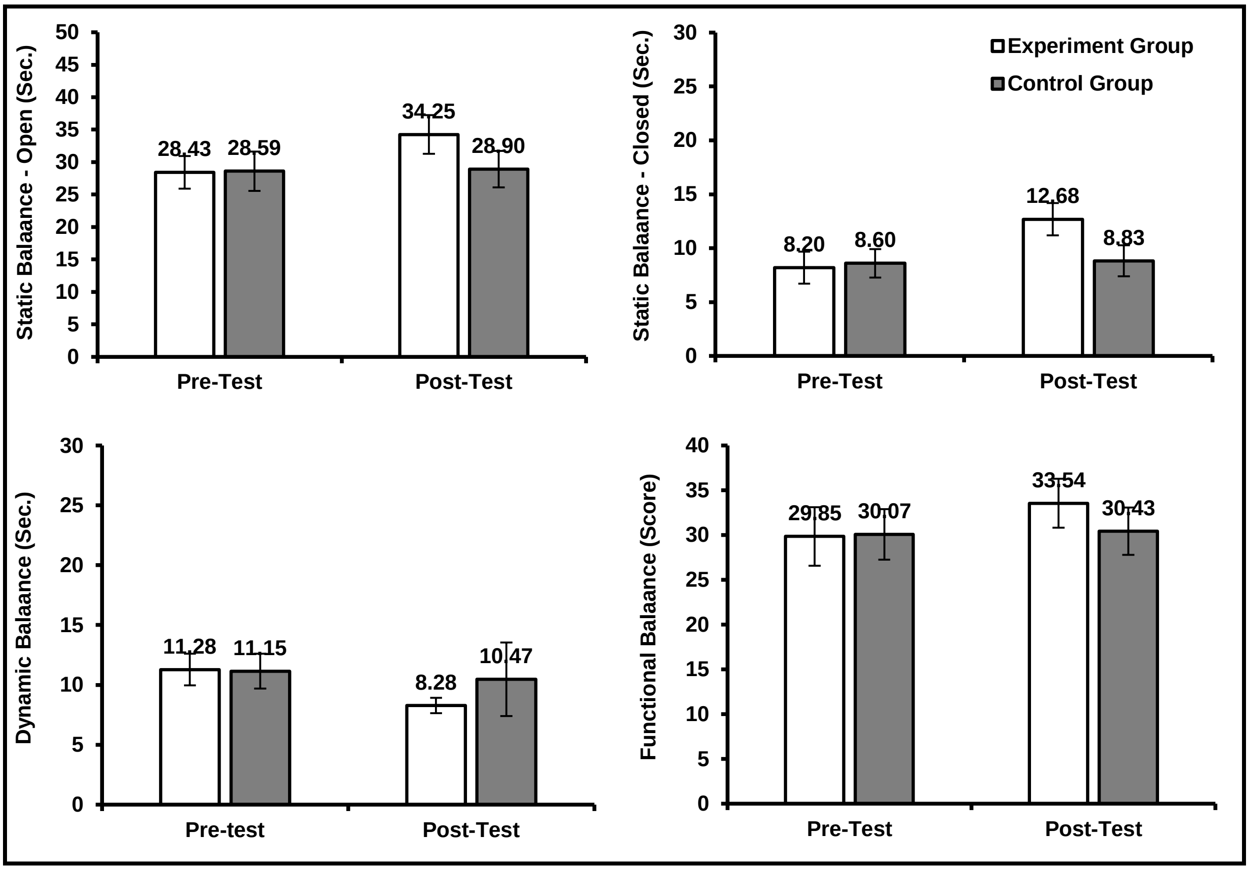

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Figure 2: Mean and standard deviation of static (eyes open and closed), dynamic and functional balance by group and measurement.

Table 2: Descriptive statistics of variables by group and measurement and the results of within-group and between-group comparisons.

Variables	Groups	Measurements			Between-Group Comparisons in Post-test			
		Pre-test	**Post-test**	**%Change**	**Δ*M***	***t***	***p***	**Cohen's *d***
Static Balance – Eyes Open (sec.)	Experimental	28.43±2.52	34.25±2.99	20.48 ↑[a]	5.35	4.79	<0.001***	1.85
	Control	28.59±3.02	28.90±2.81	1.08 ↑				
Static Balance – Eyes Closed (sec.)	Experimental	8.20±1.47	12.60±1.50	54.70 ↑[a]	384	6.79	<0.001***	2.62
	Control	8.60±1.32	8.83±1.45	2.65 ↑				
Dynamic Balance (sec.)	Experimental	11.28±1.33	8.28±0.64	-26.60 ↓[a]	-2.19	-2.51	0.019*	0.97
	Control	11.15±1.45	10.47±3.08	-6.11 ↓				
Functional Balance (sec.)	Experimental	29.85±3.26	33.54±2.73	12.37 ↑[a]	3.11	3.004	0.006**	1.16
	Control	30.07±2.81	3043±2.65	1.19 ↑				

Note: *$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$, ↑ Increase from the pre-test to the post-test; ↓ Reduction from the pre-test to the post-test. [a] Significant difference between the pre-test and the post-test at the 0.001 significance level based on the paired-samples *t*-test.

4. DISCUSSION

This study aimed to examine the effectiveness of an eight-week PNF training of the lower extremities in improving the static, dynamic, and functional balance among elderly women aged 60-70 years. The results supported the effectiveness of the PNF-based intervention, indicating significant within-group improvements in the static balance with eyes open (20.48%), static balance with eyes closed (54.70%), dynamic balance (26.60%), and functional balance (12.37%), while changes in the control group were not statistically significant. Between-group comparisons in the post-test provide more support, revealing significant differences with large effect sizes between the experiment and control groups in terms of static balance with eyes open (d = 1.85), balance Static with eyes closed (d = 2.62), dynamic balance (d = 0.97) and functional balance (d = 1.16). In the post-test, the balance profile of the experiment group was better than the control group, confirming that an eight-week PNF training of the lower extremities is effective in improving the static, dynamic, and functional balance in elderly women.

The smallest and largest effect size was related to the dynamic balance (d = 0.97) and static balance with eyes closed (d = 2.62), respectively. These results suggested that the ability of static balance with eyes closed receives the most influence from PNF training of the lower extremities, where the dynamic balance benefits less from the training. These observations were not unexpected as there was no emphasis on the control and transfer of body weight in the training. It seems that the observed improvement in the dynamic and functional balance most likely arises from the increased static balance, as the static balance is fundamental for the dynamic and functional balance.[26] The findings of the present study support the evidence reported in the literature. The studies showed that the PNF training programs improve static, dynamic, functional balance in healthy elderly[17-27], which are consistent with the findings of the present study. However, Areeudomwong and Buttagat (2019) reported that the effect size of a three-week PNF training on the static balance is not enough large to be considered at the level of clinical significance.[33] Although the characteristics of the participants in the study conducted by Ariodamwang and Batagat[33] were different from the participants in the present study, the large effect sizes obtained for the static balance in the present study addresses the need to replicate research findings in matched samples to be able to conclude.

5. LIMITATIONS AND FUTURE RECOMMENDATIONS

The findings of this study were specific to elderly women aged 60 to 70 years who were cognitively and physically healthy, which limits the interpretation and generalization of the findings to other populations. We also examined the effect of an 8-week intervention (weekly 3 sessions, 50 min per session) and implementation of interventions with shorter or longer periods may lead to different effects and results. Due to the limited number of eligible participant, it was not possible to apply a randomized selection, which may affect the validity and generalizability of the findings in this study. Therefore, it is strongly recommended to adopt a full randomized controlled design in the future studies. To identify the most effective PNF training program for the elderly, researchers may design and examine different intervention programs on balance abilities by manipulating the PNF techniques, duration of contraction, level of maximum voluntary isometric contraction, and duration and frequency of training sessions. Also, combination of PNF training with balance exercises may be an effective strategy to improve balance in the elderly, which can be examined in the future studies.

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6. CONCLUSION

Based on the findings of the present study, it can be concluded that an eight-week PNF training of the lower extremities is an effective method in improving balance abilities including static (eyes open and closed), dynamic and functional balance in healthy elderly women aged 60 to 70 years. Static balance with eyes closed receives the most impact from the PNF training. A minimum of 24 sessions of 50 minutes over eight weeks is recommended for healthy elderly people to be able to benefit from the PNF training of the lower extremities.

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