Research Paper: Evaluation of the Effectiveness of Dynamic Neuromuscular Stability Exercises on Balance and Walking Function in the Elderly

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ABSTRACT

Objectives: Walking and balance control are determining factors in the independence of the elderly because they are the main components of daily physical activity. This study evaluated the effectiveness of Dynamic Neuromuscular Stability (DNS) training on balance and gait function in the elderly.

Methods: This study had a pre-test/post-test design. It was a quasi-experimental study performed on 30 older men aged 60-70 years in Qom Province, Iran, in 2021. The elderly was randomly divided into experimental (n=15) and control (n=15) groups. The Experimental Group (EG) participated in three 45-min sessions of dynamic neuromuscular stability training every week for 6 weeks, and the Control Group (CG) continued their normal daily routine. Berg balance scale (dynamic balance), modified stork stand (static balance), and temporal and spatial gait parameters were used to collect information before and after applying the training protocol. The obtained data were analyzed using ANCOVA statistical method and the paired t test.

Results: There were significant differences between pre-test and post-test in EG regarding the variables of dynamic balance, static balance (P=0.001), and gait function, but in the CG, no significant difference was observed for these variables (P>0.05). Also, there was a significant difference between the mean scores obtained in the balance and gait tests between the two groups (P<0.05), and EG performed better in the post-test.

Discussion: DNS training due to the great variety of movement in different parts of the body and the effect on improving strength, flexibility, range of motion, and physical fitness can also improve balance and gait function in the elderly. According to the present study results, one of the best ways to reduce the costs and physical, psychological, and social problems caused by aging is to use DNS training for the elderly.

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Highlights

● Dynamic neuromuscular stability training improved balance function (static balance, dynamic balance) in the elderly.

● Dynamic neuromuscular stability training improved gait function (step length, cadence, width of step, and walking speed) in the elderly.

● Perhaps one of the best ways to reduce the costs and physical, psychological, and social problems associated with aging is to use dynamic neuromuscular stability exercises for the elderly.

Plain Language Summary

According to the World Health Organization, over the next 30 years, the elderly will make up about 20% of the world's population, so that by 2050, the elderly population will reach two billion. With increasing age, changes occur in different body systems, and reports indicate that the aging period is associated with defects in balance, muscle weakness, and decreased reaction speed. These factors cause people to lose their independence in performing one or more daily activities and increase the possibility of injury, resulting in high costs. At the same time, preventive measures and exercise can essentially delay the changes caused by aging. Using dynamic neuromuscular stability exercises due to their effect on physical fitness, strength, range of motion, etc., can help improve balance and gait in the elderly.

1. Introduction

According to the definition of the World Health Organization, crossing the age of 60 is known as the aging period [1]. Because of the importance of quality of life and improving life expectancy among people, 1.7% is added to the world's population every year, and this ascending trend for people over 65 and older is 2.5% [2]. Forecasts show that by 2050, the aging population will reach two billion people (25% of the world's population) [3]. In Iran, according to the last census in 2016, out of a population of 79 million people, nearly 7.5 million are elderly [4]. Middle Eastern countries such as Iran and Turkey are among the countries where population growth is increasing rapidly. Given the increase in the prevalence of older people to 8.5% in 2018, forecasts show that aging in these areas is expanding rapidly [5]. With aging, changes occur in different body systems, and reports indicate that about 10% of people lose their independence in performing one or more daily activities by entering old age. This decline in function can be due to psychological factors, environmental conditions, lifestyle, neuromuscular system weakness, changes in functional structures, connective tissue, muscle and muscle strength, neuralgia, changes in senses of vision, atrium, hearing, motor sensation because of increase in age [6].

One of the most severe consequences of old age is the risk of falling, and about one-third of the elderly experience falling one or several times a year [7]. Falling occurs due to some deficiencies in physical fitness factors such as imbalance, muscle weakness, and slow reaction, which ultimately leads to consequences such as poor postural control and changes in gait [8]. Many researchers consider gait and balance control determining factors of the independence of older people's lives because the main components of daily physical activity can be divided into two parts: 1) maintaining balance to maintain body position and spatial orientation and 2) interaction between anatomical components for movement [9]. Balance disorder occurs in more than 75% of people 70 years of age and older [10].

Research has shown that in old age, changes occur in the visual, sensory, atrial, and especially nervous systems as physiological systems involved in the balance of the elderly. These changes expose them to severe damage due to imbalance and gait disorder and increase care and treatment costs [11, 12]. Balance is a complex motor skill that describes the dynamics of the body in preventing falls [13], and dynamic balance is more affected by aging than static balance [14]. However, maintaining balance and mobility is vital for a healthy lifestyle in the elderly, and in addition to making it possible to perform basic daily activities such as getting up from a chair or climbing stairs, it is a basis for adopting an active lifestyle [15]. These age-related functional changes in balance and posture control reduce the ability to perform daily tasks and gait performance in the elderly and reduce their quality of life [16].

Another important consequence of aging is a change in gait pattern and speed, leading to an inability to walk properly [17]. Walking as a fundamental skill is an essential part of daily activities. This skill, which is an indicator for determining the degree of independence in daily affairs, is associated with changes in old age [18]. It has been shown that with aging, a person's walking speed is affected by the length and width of the step [17, 19] so that the walking speed during the 40-80 decade is reduced by 9%-11% and in fast walking speed by 8%-18% [20]. In the elderly, step length, walking height, and speed decrease are closely related to decreased balance. Parvazi et al. also reported less range of motion of lower limb joints, shorter stride length, and greater stride width in the elderly than in the youth [21]. Considering the effects of aging on the reduction of motor and balance function, musculoskeletal structures and the issues mentioned earlier, the prevention of reduced activity levels, overcoming the disabilities of the elderly, and the study of effective factors in changing the quality of their independent life are important. One of these methods is the use of exercise training program, which is a cheap, non-invasive, low-risk, very useful, and purposeful tool for the effectiveness of functional disabilities in the elderly [22], confirmed in previous research. These studies have shown that strengthening and activating any of the factors involved in maintaining balance and gait, such as sensory (vestibular, proprioception) and motor (strength and flexibility) systems, can be a good strategy to prevent gait and balance problems in the elderly [23-25].

Moreover, the muscular and the nervous systems play a significant role in controlling movement, gait, and pattern of movement, especially in the elderly who have limited mobility. One of the exercise rehabilitation techniques is Dynamic Neuromuscular Stabilization (DNS) training, which involves the nervous system and strengthening the muscular system [26]. The rehabilitation should provide a comprehensive program involving all components of physical fitness so that in addition to strengthening the weakening factors in the elderly, it improves balance function and gait performance in the elderly. Evaluation of the effects of DNS exercises has been done to improve balance, performance, and gait parameters on different populations [27, 28], showing the positive effect of these exercises on the above factors. DNS exercises are essential for neuromuscular coordination based on a wide range of strength, range of motion, and proprioception function, including a combination of flexibility, core stability, balance, strength training [29].

More attention should be paid to improving the balance and gait parameters in the elderly. Since the loss of balance and changes in gait pattern are the most common problems of the elderly, which can have physical consequences and impose high costs to families following the fall of the elderly, their motor rehabilitation and increasing their physical activity seem necessary. Considering the novelty of the subject, review of the literature and lack of similar research, and innovation of the mentioned exercises, the researchers decided to evaluate the effects of Dynamic Neuromuscular Stability (DNS) exercises protocol on balance and gait performance in the elderly.

2. Materials and Methods

This applied research had a quasi-experimental design. The study was conducted on two groups with 6 weeks of DNS training intervention in the Experimental Group (EG) and non-training intervention in the Control Group (CG). It also used a pre-test and post-test design. The statistical population included all older men over 60 years of age living in Qom City, Iran. A total of 70 people volunteered for the study, and 30 older adults over 60 years were selected based on the inclusion criteria and then randomly divided into two groups of control (n=15) and experimental (n=15).

A total of 40 people who were not eligible were excluded from the study. The inclusion criteria consisted of the male elderly over the age of 60, independence in daily activities and no use of assistive devices, no history of cardiovascular diseases, respiratory problems, no severe low back pain in the past 6 months, no history of fractures, and severe injury in the lower limb or any visible abnormality problematic for the research implementation, and voluntary participation in the research. The exclusion criteria included the inability to the training, occurrence of pain during the training protocol, lack of cooperation and withdrawal, and absence in two consecutive sessions and three alternating training sessions. All participants entered the study after filling out the consent form. Also, each participant in the study could withdraw at any stage of the research without paying compensation. To collect data, the subjects were asked to be present at the appointed time and place through announcing the subjects and observing the COVID-19 health-related protocols. To prevent coronavirus infection, the subjects were required to wear masks and gloves during exercise. Only three subjects per hour could participate in the study.

Dynamic balance

The Berg Balance Scale (BBS) is a test consisting of 14 functional activities that older subjects are responsible for performing, and the examiner scores the appropriate score according to the instructions for each activity, and the highest overall score on this scale is 56 [30]. The ICC (95%CI) values of 0.93 (0.87-0.96) and 0.95 (0.92-0.97) were reported for inter-rater and intra-rater reliabilities, respectively, which indicated the validity and reliability of the instrument [30].

Static balance

The stork balance test was used to assess static balance, and subjects were asked to stand on their upper leg and place the toes on the knee of the upper leg while placing their hands on their waists. Then, with the start command, lift the heel of the upper foot and stand on your toes and maintain the balance without moving the foot or separating the hands from the waist. Maintaining this position (seconds) was considered an individual record. Acceptable levels of intra- and inter-rater reliability and high validity have been reported for the modified stork stand test [31].

Gait function

Temporal and spatial walking parameters, including step length, step width, and walking pace, were measured by pouring powder to a distance of 10 m on the ground. Test subjects were asked to walk the indicated distance. The step length was measured by measuring the footprint with a ruler that covers the distance between the heel of one limb and the heel of the next limb. To measure the step width, the distance of two points from the center point of each heel was used as a reference, and the step speed was obtained from the number of steps recorded per minute by a stopwatch [32]. To measure the walking speed of the elderly, the subjects were asked to walk a distance of 10 m with a maximum speed. Each subject performed this test twice, and his best record was calculated. By dividing this number by the desired distance, the person's walking speed was obtained in m/s [33].

Exercise protocol

DNS training protocol was implemented in 45-min sessions, three sessions per week for six weeks, for the experimental group. These exercises have several models and different levels of training [29]. The training protocol of the experimental group included warm-up exercises (5 minutes), DNS exercises with respiratory correction (40 minutes), and cooling exercises (5 minutes). According to the DNS approach, the main movements with different levels include diaphragmatic breathing (6 levels), lying on your back 90-90 (21 levels), lying on your stomach (9 levels), wrong action (20 levels), sitting on your side (11 levels), sit for miles (11 levels), tripods (13 levels), kneel (11 levels), squat and get up (9 levels) [29]. The first week of training was devoted to training and practicing basic DNS movements. Each week, compared to the previous week, some movement complexity was added. To increase the effectiveness of the exercises during the training period, the overload principle of increasing the number of repetitions and seconds and the type of training was used. It was essential to pay attention to the following points: A) breathing unconsciously through the diaphragm, B) when performing the movement, be careful that the position of the knees is not in the position of varus and valgus, C) not having flexion or hyperextension in the back. After completing the 6-week protocol with an interval of one week, the post-test was performed, and the final information was recorded. The control group during this period engaged in their daily activities and normal walking.

After collecting information, the data related to the subjects are analyzed in two sections of descriptive and inferential statistics in SPSS version 22. Descriptive statistics, the ANCOVA test, and the paired sample t test were used for data analysis at a 95% significance level (α= 0.05).

3. Results

First, the normality of demographic information and pre-test variables were examined. The Shapiro-Wilk test was used to check the normality of data distribution. This test showed that the data distribution in the two groups was normal (P>0.05). Then, the independent t test was used to evaluate the homogeneity and uniformity of demographic information and pre-test variables in the EG and CG. The results of this section are presented in Table 1, and it was shown that the two groups in terms of demographic information and the variables of static balance, dynamic balance, length of step, cadence, the width of step, and walking speed were not significantly different in the pre-test stage (P>0.05).

Therefore, to investigate the effect of DNS exercises on static balance, dynamic balance, and gait function variables at the intergroup level of the two groups (control and experimental), the analysis of covariance (ANCOVA) test was used, and the paired sample t test was used at the intragroup level. The ANCOVA test results are presented in Table 2. Findings of this test by considering the sphericity presumption showed that in static balance (P=0.001), dynamic balance (P=0.001), length of step (P=0.003), cadence (P=0.003), the width of step (P=0.007) and walking speed (P=0.001), a significant difference between

Table 1. Demographic information of samples (Mean±SD) and data obtained from research variables in the pre-test

Variables	Groups (n=Each group 15)	Mean±SD	t	P
Age (y)	Experimental	64.66±3.84	-0.403	0.690
	Control	65.13±2.29		
Weight (kg)	Experimental	68.40±1.84	1.371	0.181
	Control	67.46±1.88		
Height (cm)	Experimental	165.20±4.47	-0.655	0.518
	Control	166.26±4.44		
Dynamic balance	Experimental	35.93±2.54	0.582	0.565
	Control	35.40±2.47		
Static Balance	Experimental	8.53±0.81	-0.872	0.391
	Control	8.80±0.68		
Length of step	Experimental	0.4±0.05	0.140	0.889
	Control	0.48±0.18		
Cadence	Experimental	84±1.88	0.084	0.933
	Control	83.3±2.40		
Width of step	Experimental	0.2±0.42	0.477	0.637
	Control	0.20±0.41		
Walking speed	Experimental	1.64±0.16	-0.266	0.793
	Control	1.67±0.17		

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the two groups was observed after six weeks of DNS training. It was determined that the EG performed better compared to the CG by assessing the mean scores.

To investigate the differences in pre-test and post-test in the EG and CG groups separately, the paired sample t test was used (Table 3). In the experimental group before and after participating in the DNS training course, the Mean±SD of dynamic balance were 35.9±2.54 and 40.20±1.78, respectively, and the Mean±SD static balance were 8.53±0.81 and 13.23±0.80, respectively. As you can see in Table 3, this increase in static balance and dynamic balance was statistically significant in the EG (P=0.001). Also, a significant difference was observed between the pre-test and post-test stages in the variables of step length, cadence, the width of step, and walking speed in the EG (P<0.05). However, in the CG, no significant change was observed between the means of static balance, dynamic balance, step length, cadence, the width of step, and walking speed variables before and after the DNS training protocol, and it was not statistically significant (P>0.05).

4. Discussion

This study investigated the effect of six weeks of DNS training on balance function factors and gait performance in the elderly. The results showed a significant difference between the control and exercise groups after applying the exercise intervention (DNS) on the balance function factors and gait performance of the elderly. In the experimental group, DNS training improved balance function and gait function in the elderly. Disorders in the proprioception, visual, vestibular systems, flexibility, range of motion, and strength that occur with aging [34-36] can lead to impaired balance and gait. However, the elderly could improve their stability and balance by exercise training [25, 36].

The DNS exercises included different levels of movements in the upper and lower limbs, central body area, breathing, and diaphragm, and so on. Perhaps, at the beginning of the DNS exercises, the increase in strength is due to the neuromuscular coordination created in the muscles [37]. Increased balance function in the elder-

Table 2. The ANCOVA test results for differences between the two groups

Variables		Groups (n=15)	Mean±SD	F	df	P*	Eta Squared
Balance function	Dynamic Balance	EG	40.20±1.78	32.121	1	0.001	0.543
		CG	36.13±2.03				
	Static Balance	EG	13.23±0.80	162.384	1	0.001	0.857
		CG	9.30±0.84				
Gait function	Length of step	EG	0.54±0.05	6.271	1	0.003	0.284
		CG	0.49±0.02				
	Cadence	EG	89.93±5.66	10.806	1	0.003	0.286
		CG	84.66±2.25				
	Width of step	EG	0.17±0.01	8.693	1	0.007	0.244
		CG	0.20±0.04				
	Walking speed	EG	1.84±0.13	23.444	1	0.001	0.465
		CG	1.68±0.15				

EG: Experimental Group; CG: Control Group; * Significance level of ANCOVA test.

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ly after DNS exercises can be due to increased neural mechanisms resulting from exercise, use of more efficient muscle mass, reducing neural inhibitory reactions, and improving and facilitating the transmission of sensory inputs [37, 38]. These factors can cause structural changes in the muscles that may increase strength. This increase in strength can provide more muscle support for joints such as the thighs and knees and ultimately lead to greater joint stability that improves balance [39].

On the other hand, stabilizing and strengthening the core muscles provides a solid basis for the movement of the limbs. Therefore, strengthening the muscles of the central part of the body, under the influence of the stabilization of the body or the integration system of the spine, can coordinate the organs and the whole body. Proper stability of the spine and central part of the body is provided by the correct breathing pattern [40]. During deep breathing, the diaphragm flattens, and the intra-abdominal pressure increases, which abnormally increases the volume of the abdominal wall and chest with isometric contraction [41].

Also, for a proper gait pattern, the coordination of different muscle groups is required. The intensity and range of motion in flexion, extension, adduction, and abduction to walk even one step depends on muscle strength [42]. Adequate muscle strength facilitates walking, and in contrast, a decrease in muscle strength, especially in old age, leads to a decline in normal functional ability. Therefore, we usually should compensate for this decrease in strength with desirable and effective training programs and thus increase the functional capacity of the elderly [43]. In fact, by improving the strength of the lower and middle limb muscles, the risk of falls in the elderly is reduced, and their ability to walk increases. This type of exercise affects the gait of the elderly by creating neural adaptations. As there is strong coordination between the strength of the quadriceps muscles (extensor) and the hamstring (flexors), knees and especially the dorsiflexors, tibialis anterior (and plantar flexor), and gastrocnemius of the ankle and the ability to control balance in the elderly, it is necessary to design an appropriate exercise program to improve and coordinate the muscles to improve balance and gait in these people.

One of the specific goals of the present study is to improve strength, flexibility, range of motion, and coordination of muscles. Maintaining balance requires the cooperation of different muscle groups. Also, flexion, extension, adduction, and abduction during movement and standing can create accurate movement [44]. Enhancing the strength and flexibility of the quadriceps and thigh extensors in the training protocol of the present study (such as squat, knee and thigh extension and flexion, and the use of Traband) can improve the range of motion the knee and thigh joints. Hence, when standing and walking, compensatory movements are not created by the auxiliary muscle and thus improving balance. Various studies have also shown that limitations in the range of motion of the ankle, knee, and thigh reduce balance [45].

Other possible mechanisms and reasons for the effect of exercises include the balance ability of the elderly

Table 3. Difference between the mean variables in the pre-test and post-test of both groups

Variables	Mean±SD					
	Experimental			Control		
	Pre-test	Post-test	P*	Pre-test	Post-test	P
Dynamic balance	35.93±2.54	40.20±1.78	0.001	35.40±2.47	36.13±2.03	0.299
Static balance	8.53±0.81	13.23±0.80	0.001	8.80±0.68	9.30±0.84	0.140
Length of step	0.49±0.05	0.54±0.05	0.011	0.48±0.18	0.49±0.02	0.235
Cadence	84±1.88	89.93±5.66	0.002	83.3±2.40	84.66±2.25	0.358
Width of step	0.21±0.042	0.17±0.016	0.013	0.20±0.41	0.20±0.04	0.789
Walking speed	1.64±0.16	1.84±0.135	0.001	1.67±0.17	1.68±0.15	0.945

* Significance level of the paired t test.

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participants before the exercises. Since the subjects did not regularly participate in physical activities, DNS exercises can increase the physical fitness of these people. So, improving physical fitness in the elderly can be one of the possible causes of improving their balance.

DNS exercises have also been used to improve balance and gait in other populations. Hyun Kim et al. showed that 4 weeks of DNS exercises significantly affect posture control and walking of patients with cerebral palsy [27]. Possible mechanisms of the effect of these exercises are improving the strength of the muscles of the central body and diaphragm in enhancing balance and gait. Zamani et al. (2017) showed that 8 weeks of DNS exercises significantly influenced the balance of patients with multiple sclerosis. The possible mechanisms and reasons for the effect of these exercises include the growth and strengthening of neuromuscular and motor systems [46]. Son et al. (2017) investigated the impact of DNS exercises on balance, function, and gait in people with cerebral palsy and showed that DNS exercises had a significant effect on posture control and walking [28].

Because muscle weakness, inflexibility, and movement control problems are essential factors in poor balance and, consequently, falling, implementing a fitness program is an effective way to prevent falling because exercise and physical activity lead to increased muscle strength, flexibility, and motor control [28]. DNS exercises seem to help improve balance and walk in the elderly due to numerous movements in different parts of the body and the effect on improving strength, flexibility, range of motion, and physical fitness. One of the best ways to reduce the costs and physical, psychological, and social problems is DNS exercises for the elderly.

According to the research findings, it should be noted that improving the balance and gait performance in the elderly, raising the level of physical activity, and motivating participation in training sessions are the strengths of this research. However, the low sample size, the lack of more training groups for comparison, the use of functional tests instead of laboratory tests are some of the weaknesses of this study that should be considered in future research.

One of the limitations of this study is that it did not examine issues related to daily activities, mental status, unavailability of elderly female samples, and comparing them with elderly males. Since the current study was conducted on the elderly, generalizing the results to athletes and people with disabilities should be done with caution. The COVID-19 restrictions also affected the participation of study samples and communication with them. Because of the great importance of balance function factors and walking performance of the elderly and the significant effect of DNS exercises on the elderly, it is recommended to evaluate these exercises on a larger population of older men and women and compare the findings. In this study, functional tests were used to measure gait balance and interaction, and the use of advanced devices such as the Biodex balance system provides more reliable results. Also, the evaluation of range of motion, proprioception, and muscle strength by advanced tools can help in improving the research findings that are recommended to future researchers. The DNS training protocol can also be compared to other training protocols in the elderly.

5. Conclusion

Findings from this study show a significant improvement in the effect of DNS exercises on balance function factors and gait performance in the elderly. According to research findings, because of the effectiveness of exercises (DNS) on research variables and the importance of balance in reducing the risk of injury to the elderly, it seems that doing these exercises is very useful and increases confidence and improves physical fitness. Perhaps one of the best ways to reduce the physical, psychological, and social costs of aging is to use DNS exercises for the elderly.

Ethical Considerations

Compliance with ethical guidelines

The studt was approved by the Ethics Committee of the Faculty of Physical Education and Sports Sciences, University of Tehran (Code: IR.UT.SPORT.REC.1399.042). The subjects were not forced to continue cooperating. At the same time, the principle of confidentiality was observed regarding all information of individuals.

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Authors' contributions

Conceptualization and supervision: Asghar Farhadi and Ibrahim Hassanpour; Methodology: Mohammad hani Mansori; Yousef Moghadas Tabrizi; Investigation, writing – original draft, writing – review & editing: All authors; Data collection: Mohammad Hani Mansori and Kamal Mohammadkhani; Data analysis: Mohammad hani Mansori; Funding acquisition and Resources: All authors.

Conflict of interest

The authors declared no conflict of interest.

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