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Original Article

The Effect of Dynamic Neuromuscular Stabilization Exercises on Balance and Fear of Falling in Female Elderly

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Introduction: The present study was an attempt to investigate the effect of a course of dynamic neuromuscular stabilization (DNS) exercises on balance and fear of falling in female elderly with a history of falling.

Methods: In this quasi-experimental study, 30 female elderly people with a history of falling based on entry and exit criteria were purposefully selected as a sample of study. Then, they were randomly assigned into two control and exercise groups. The variables related to static balance and dynamic balances were assessed by sharpened Romberg Test and Standing Up and Walking Test, respectively. Also, Falls Efficacy Scale International was used to measure the fear of falling. The exercise group performed DNS exercises for 8 weeks, 3 sessions, and 50 minutes per session. Data were analyzed by using paired t-test and analysis of covariance in SPSS24 software at the significant level of $p < 0.05$.

Results: A significant difference between pretest and posttest in static balance with open eyes ($p = 0.0001$, $t = -7.19$), static balance with closed eyes ($p = 0.0001$, $t = -8.02$), dynamic balance ($p = 0.0001$, $t = 6.49$) and fear of falling ($p = 0.0001$, $t = 7.29$) in DNS exercise group. Also, there were significant differences between DNS and control groups in static balance with open eyes ($p = 0.0001$, $F = -14.67$), static balance with closed eyes ($p = 0.0001$, $F = 14.002$), dynamic balance ($p = 0.0001$, $F = 20.12$) and fear of falling ($p = 0.006$, $F = 09.07$).

Conclusion: It is recommended that therapists use dynamic neuromuscular stabilization exercises in female elderly to improve balance and reduce the fear of falling.

Keywords: Dynamic Neuromuscular Stabilization, Exercise Program, Balance, Fear of Falling, Aging

Introduction

Aging is a period of human life associated with reduced physiological capacity and motor function. Falling and reduced balance are among most important health problems that are common in elderly and results in injury in this age group. Falling and reduced balance have physical (pelvic fractures, disability, loss of physical ability and death) and psychological (loss of confidence, self-esteem and reduced life expectancy) consequences that can lead to reduced daily activities and independence of elderly (1, 2). Thus, with the onset of old age, changes occur in the function of musculoskeletal, atrial, sensory-

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physical and visual systems as physiological systems involved in balance, which will expose elderly to these serious injuries caused by imbalance and falling (3).

Falling can also have fatal and non-fatal consequences. About 11% of the elderly die because of falling and about 40-60% of cases cause injuries (4). It was estimated that 524 million people (8%) of the world's population were aged 65 and over in 2010. This figure is expected to increase by three times by 2050 and reach about 1.5 billion people (16% of the world's population) (5). With growth of elderly population, efforts to diagnose and prevent problems and improve the quality of life of the elderly, especially the fear of falling and reduced balance, become important (6). Hence, it is necessary to pay attention to planning of special exercises with the aim of improving balance and controlling posture to prevent the risk of falling to maintain individual performance and maintain independence in daily activities and quality of life in this group. Given the beneficial effects of regular exercise for elderly, different exercise methods, especially those that are cost-effective (financial, time and energy), less problematic and cause minimum environmental risks for this age group, and are based on scientometrics, can be considered as an effective solution for regular physical activity for elderly. In general, various studies have referred to positive effect of different exercises on balance and fear of falling in elderly (7-12).

One type of exercise that helps in recovery of movement is dynamic neuromuscular stabilization or DNS, which is a practical approach to optimizing movement based on the scientific principles of developmental kinesiology. DNS technique involves involuntary activation of the diaphragm with deep abdominal muscles before purposeful movement in humans by initial feedback (13). DNS exercise is an approach in physical medicine performed by manually stimulating the reflex displacement areas to exit the efferent signal from CNS movement control centers to achieve improved muscle system function. If DNS exercises are performed correctly, correct motor neural patterns may replace pathological patterns (14). There is limited evidence on the effect of DNS stabilization exercise on balance and reducing the fear of falling in elderly. Due to limited research in the area of DNS exercises and limited research on elderly and since weakness in neuromuscular control is an effective factor in causing disorders related to balance and falling, and since this exercise program may be effective in improving neuromuscular disorders, the present study aimed to investigate the effect of a course of DNS exercises on balance and fear of falling in female elderly with a history of falling.

Methods

Study design

The present study was a semi-experimental type with a pretest-posttest design, which was conducted on the elderly people of Urmia city, Iran in 2020 - 2021. In the implementation of the current research, ethical considerations were carried out in accordance with the Declaration of Helsinki.

Participants

Among total population of study, 30 elderly people were purposefully selected as sample of study. The number of this studies cases have been determined by using the sample size formula in the group and the data from a former study which is close to the present one and applying the G*POWER software with an effect size of d = 0.54, $\alpha < 0.05$, power (1- β) = 0.80; We determined that at least 30 participants should be included in this study and they were randomly assigned to control (n: 15, mean age: 67.67 ± 3.01 years, mean height: 1.66 ± 0.04 m, mean weight: 67.33 ± 4.93 kg, mean body mass index: 24.38 ± 2.20 kg / m2) and exercise (n: 15, mean age: 69.47 ± 2.72 years, mean height: 1.65 ± 0.05 m, mean weight: 69.07 ± 3.24 kg, mean body mass index: 25.34 ± 1.52 kg / m2) groups. Inclusion criteria included being female, age range of 65 to 75 years and a history of falling. Exclusion criteria included: unwillingness to continue research, pain or injury during the protocol, and observation of severe imbalance disorders that could lead to injury.

Assessments

In the first stage of study, after completing the consent form, anthropometric measurements including weight, height and body mass index of the participants were performed. Then, static balance was assessed using sharpened Romberg test with a reliability of 0.90-91 for open eyes and 0.76-0.77 for closed eyes (15). In the sharpened Romberg test, the subject stood barefoot with one leg (upper leg) ahead of the other leg and the arms crossed on the chest. The duration of maintaining this state with open and closed eyes was considered as the subject score (16). Standing up and walking time test was used to assess dynamic balance. In implementing this test, the subject got up from the chair and without using her arms and after walking 3 m; she returned and sat down on the chair again. The subject was asked to perform this work as soon as possible without running and the total time of the test was recorded (16, 17).

Then, Fall Efficiency Scale International (FES-I) was used to assess the fear of falling in elderly. Yardley et al., developed this 16-item questionnaire in 2005. It is scored on a 4-point Likert scale from "I am not worried at all" to "I am totally worried". A total score of 16 to 64 is obtained for each subject and a higher score indicates higher fear of falling or lower self-efficacy (18). the validity and reliability of this questionnaire in Persian was confirmed by Khajavi et al. (19). Also, to ensure that the subjects did not suffer dementia, Mini-Mental State Examination (MMSE) validated by Seyedian et al., (1996) was used. If subjects obtain a score of 24 or higher on this test, they would enter the next stages of research (20).

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Exercise program

The exercise group followed the dynamic neuromuscular stabilization exercise protocol for 6 weeks (three 50-minute sessions per week) (Table 1). This protocol included 5 minutes of warm-up, 40 minutes of DNS movements along with breathing exercises, and 5 minutes of cooling down. Based on this approach (14), these exercises include diaphragmatic breathing, Baby Rock (supine lying 90-90), prone lying, rotational movements, side lying, oblique movements, three-point movements, kneeling, squat and Czech Get Up (CGU) movements. The complexity of the exercises gradually increased each week (compared to the previous week) by adding a new task to a pre-exercised task. Increasing the complexity of a task helped the researcher to do his task automatically. The dual task model was used to check whether the task is done automatically or not (for example, no new task should interfere with diaphragmatic breathing). In other words, in DNS exercises, the overload principle is applied by making the exercises more complex (21).

Statistical analysis

Shapiro-Wilk test was used to evaluate the normality of the data and in the inferential statistics section, the analysis of covariance and paired t-test were used to evaluate the effect of exercise on variables. All statistical analyzes were performed using SPSS software version 24 at a significance level of 0.05.

Ethical Considerations

In the implementation of the current research, ethical considerations were carried out in accordance with the Declaration of Helsinki. Furthermore, before starting the study, all the participants filled the informed consent form to participate in the study.

Results

Two groups of 15 people including experimental and control groups participated in this study. There was no statistically significant difference between the experimental and control groups in terms of the variables of age, weight, height, body mass index and mental state of the elderly participated in this study ($p < 0.05$). Based on the results of Shapiro-Wilk test, the data related to the research variables are normal, so parametric tests were used to test the hypotheses.

The results showed that 8 weeks of DNS exercise caused a significant difference in static balance with open eyes ($p = 0.0001$, $t = -7.19$) static balance with closed eyes ($p = 0.0001$, $t = -8.02$) and dynamic balance ($p = 0.0001$, $t = 6.49$) and fear of falling ($p = 0.0001$, $t = 7.29$) in female elderly. Static balance with open eyes increased by 3.68 ± 0.99 with 10.77% change and static balance with closed eyes increased by 2.29 ± 0.17 with 17.74% change. Also, dynamic balance increased by 53.5 ± 0.42 with 46.90% change and fear of falling decreased by 3.4 ± 0.04 with 8.29% change following 8 weeks of doing DNS exercises.

The results of intergroup statistical analysis resulting from analysis of covariance (with pre-test covariate) also showed a significant difference between the experimental and control groups in static balance with open eyes ($p = 0.0001$, $F=-14.67$) static balance with closed eyes ($p = 0.0001$, $F = 14.002$) and dynamic balance ($p = 0.0001$, $F = 20.12$) and fear of falling ($p = 0.006$, $F = 9.7$). However, in the control group that did not receive the exercise program, there was no significant difference between intragroup and intergroup changes in both variables ($p < 0.05$). Table 2

Discussion

The aim of present study was to investigate the effect of 8 weeks of DNS exercise on static and dynamic balance and fear of falling in female elderly. Results of the study revealed that DNS exercise program significantly increased the test time of static balance with open eyes. Since one should maintain balance with the help of visual, atrial and sensory systems in this system, it can be concluded that performing DNS exercises in these individuals may improve and probably facilitate the transmission of inputs to each of these senses, two or all three senses simultaneously to maintain balance. In addition, the effect of DNS program on static balance with closed eyes showed that the test time of static balance with closed eyes also increased significantly. In this test, with the eyes closed, the visual sensory inputs are disconnected and the person relies on the atrial and sensory-system inputs to maintain balance (22). Due to an increase in time, it can be concluded that functional exercises may facilitate the transmission of messages from one or both senses to higher nerve centers to maintain balance. Also, the effect of DNS exercise program on dynamic balance performance test showed that dynamic balance test time decreased significantly and dynamic balance improved in these individuals. Thus, based on the results, in explaining the causes and mechanisms justifying the improvement of balance, it is necessary to refer to various components of the sensory-motor and nervous system responsible for maintaining balance (23). The central nervous system must evaluate information from sensory receptors throughout the body to be aware of the body's position in space. The information collected by the visual, atrial, and sensory systems is processed at three distinct levels of motor control, including the spinal cord, brainstem, and higher levels such as the cerebellum, basal ganglia, and cortex (22).

Table 1. DNS exercise program

Session	6 to 15 minutes	16 to 25 minutes	26 to 35 minutes	36 to 45 minutes
1	A1-B1-B2	C1-C2-G1	E1-E2-F1-F2	H1-H2-K1-K2
2	A1-B2-B3	C1-C2-C3-G1	E1-E3-F3	H1-H2-K1-K2
3	A1-B3-B4	C2-C3-G1-G2	E2-E3-F2-F3	H2-H3-K2-K3
4	A1-B4-B5	C1-C4-G1-G2-G3	E4-F4	H2-H3-H4-K3-K4
5	A1-B6-D1	C5-G4	E2-E4-E5-F2-F4-F5	H1-H5-K4-K5
6	A1-B6-B7-D1-D2	C5-C6-G5	E4-E6-F4-F6	H5-H6-K5-K6
7	A1-B7-B8-D1-D2	C6-C7-G5-G6	E4-E5-E6-F4-F5-F6	H5-H6-K5-K6
8	A1-B9-D1-D3	C8-G5-G6-G7	E6-E7-F6-F7	H5-H6-K6
9	A1-B10-D3-D4	C4-C8-G7-G8	E7-E8-F7-F8	H7-K6-K7
10	A1-B10-B11-D5-D6-D7	C6-C7-G8-G9	E6-E7-E8-F6-F7-F8	H7-H8-K7
11	A1-B11-B12-D8-D9	C6-C7-G9-G10	E8-E9-F8-F9	H7-H8-K7-K8
12	A1-B12-B13-D10-D11	C7-G8-G9-G10	E7-E8-E9-F7-F8-F9	H7-H8-H9-K8
13	A1-B14-D10-D11-D12	C8-G9-G10-G11	E7-E10-F10-H1	H9-K8-K9
14	A1-B15-D13-D14	C7-C8-G10-G11	E7-E11-F11-H1	H9-H10-K9
15	A1-B16-B17-D15-D16	C6-C7-G11-G12	E11-F11-H3	E10-F10-H10
16	A1-B18-B19-D17-D18	C6-C7-G13	E11-F11-H7	E10-F10-H10
17	B20-D19	C9-G11-G12-G13	E11-F11-H8	CGU
18	B21-D20	C9-G11-G12-G13	E11-F11-H9	CGU

A1-A6: Different levels of breathing exercise B1-B21: Different levels of Baby Rock C1-C9: Different levels of Prone
D1-D20: Different levels of rolling E1-E11: Different levels of side lying F1-F11: Different Levels of Oblique Sit
G1-G13: Different Levels of Tripod H1–H11: Different levels of kneeling K1-K9: Different Levels of Squat

Hence, the researchers stated that the effectiveness of exercise on balance requires response at three levels of movement. At the spinal cord level, its main role is to regulate muscle reflexes. The sensory information obtained from the mechanical receptors of the joint following the occurrence of balance reflexes reflexively causes a supportive contraction around the joint and prevents excessive pressure on the passive factors restricting the joint movement (24). At the brainstem level, the occurrence of balance reflexes helps to control the balance of body, and at the higher nerve centers (cortex and cerebellum) level, a person with concentration and attention and consciously tries to control the joint position and balance of body. Control at each of these levels requires sensory information derived from the visual, atrial, and sensory-physical systems. As a result, as the exercise conditions become more difficult, the overload on the mentioned senses increases (24). Depending on the physiological adaptations in skill learning, exercise can reduce variability in the use of motor units (25), increase motor cortex ductility, or help in the learning (or re-learning) of elderly to use their muscles to perform motor tasks optimally. Interestingly, recent evidence suggests that motor skills exercise is closely associated with increased spinal cortical excitability, which is not achieved with strength exercises. It seems that neural adaptations obtained by these exercises remain for the long time (26), indicating the high importance of the DNS exercises. The results obtained from this study were consistent with those of research conducted by Khanmohamadi et al., Dashti et al., Orssatto et al., and Penzer et al., in terms of the effect of exercise on the balance of elderly (27-30). However, they were inconsistent with results of the study conducted by Kelly et al. This inconsistency might be related to differences in the exercises used in different studies. In the mentioned study, functional training was performed in water, while in the present study, a DNS exercise protocol that is in accordance with basic functional activities, was used. A very important issue in designing DNS exercises is paying special attention to the principle of specificity of exercise, which is probably one of the reasons for the success of this type of exercise in improving the balance of elderly.

The exercise program used in the present study emphasized more on basic functional movements and included basic activities related to motor learning and so-called basic functional principles that require maintaining proper alignment and learning and recovery of movement patterns. In general, any voluntary movement performed by people will disturb their balance due to multi-loop structure of the human body (26). To compensate for this inner turmoil, voluntary movements were performed with anticipatory postural adjustments. These involuntary automatic movements are a source to ensure accurate and coordinated movement (22). In fact, the muscles controlling these postural adjustments are activated before the activation of voluntary muscle activity (22). As specificity principle of the used exercises was determined, this type of exercise probably has an effect on the activation of the muscles responsible for anticipatory postural adjustments and voluntary movements to control balance. Moreover, improving balance can be due to a better division of attention between motor tasks. In fact, exercise based on specific tasks can cause the person to focus more on that physical task. One of the factors that may affect the ability to increase balance and strength through exercise is the initial level of physical activity of elderly (31).

Table 2. Results of analysis of covariance and paired t test to examine the research variables in experimental and control groups

Variable	Mean ± SD	Intergroup T		ANCOVA			
				Independent variable		Covariate (pre-test)	
		t	P	F	p	F	p
Static balance (open eyes)				14.67	0.001**	0.19	0.66
Experimental		-7.19	0.001*				
Pre-test	30.50 ± 3.06						
Post-test	34.18 ± 4.05						
Control		-0.57	0.57				
Pre-test	30.64 ± 3.44						
Post-test	31.03 ± 3.19						
Static balance (close eyes)				14.002	0.001**	0.90	0.01
Experimental		-8.02	0.001*				
Pre-test	10.62 ± 1.27						
Post-test	12.91 ± 1.44						
Control		-0.22	0.82				
Pre-test	11.07 ± 2.13						
Post-test	11.18 ± 1.81						
Dynamic balance				20.12	0.001**	0.81	0.05
Experimental		6.49	0.001*				
Pre-test	17.32 ± 3.34						
Post-test	11.79 ± 2.92						
Control		1.15	0.26				
Pre-test	17.14 ± 3.64						
Post-test	16.35 ± 4.30						
Fear of falling				9.07	0.006**	0.16	2.00
Experimental		7.29	0.001*				
Pre-test	44.46 ± 4.32						
Post-test	41.06 ± 4.28						
Control		1.96	0.07				
Pre-test	45.93 ± 3.49						
Post-test	44.73 ± 3.86						

*Sign of statistical significance within the group
** Sign of statistical significance between the groups

The subjects of present study did not have pathological diseases, and were functionally independent and were able to walk without using any aids (such as canes or walkers). Before participating in these exercises, none of them participated in regular sports activities, so an improvement in their balance can be attributed their low level of initial physical fitness. Moreover, the improvement of balance due to exercise can be attributed to the effect of these exercises on improving muscle strength, range of motion of joints, neurological control of movements and psychological factors of the subjects. DNS exercises also rewrite the exercise program on the brain, just like in infancy when a child learns to walk and starts from the distal joints of body to overcome gravity, which is one of the possible reasons for effectiveness of this exercise program Penzer et al., Since DNS exercises were specifically designed similar to basic movement pattern tasks, they are likely to improve neuro-motor control and functional adjustments (28). Based on the obtained results, DNS exercises require motor control responses at brainstem level. By using functional exercises, it is possible to improve motor control at all its levels, which is one of the important principles of rehabilitation of balance and proprioception. Proper motor control requires reflex responses at the spinal cord level, postural reactions, and automatic balance at the brainstem level and conscious responses at the cortex level (32).

Results of the present also revealed the effect of using this exercise program on reducing the fear of falling in the elderly. These results are in line with results of a study conducted by Ebrahimi Atri et al., which showed the effect of Pilates exercise on reducing the fear of falling in people with MS (33). They are also in line with results of study conducted by Sosnoff et al., which showed the effect of mental exercises on reducing the fear of falling in elderly. The rate of falling is high in elderly due to sensory, motor, cognitive or a combination of these defects with increasing age (34). The results of a study conducted by Ebrahimi Atri et al., showed that resistance and endurance exercises made balance-related systems involved and reduced the fall by increasing the balance. The results of the present study in the area of balance also showed the improvement of static and dynamic balance that can also be effective in achieving results in the area of fear of falling (33). The results of a study conducted by Babayiğit İrez et al., showed that central area exercises such as Pilates improved balance and reduced the frequency of falls (35). Bird et al., revealed that reducing the fear of falling is associated with eliminating or improving risk factors (36). Gillespie et al., also showed that exercise intervention such as resistance and balance exercises are effective in reducing the rate of falling and reducing the need for psychotropic drugs or other pharmaceutical methods and managing vision problems, postural stress and other problems (37). Also, application of exercise program can be effective factors in reducing the fear of falling in the elderly by improving balance control and activation of sensory receptors (38).

Conclusion

In general, the results of present study revealed the effect of DNS exercise program on improving balance and reducing the fear of falling in female elderly with a history of falling. Due to the effect of dynamic neuromuscular stabilization training program on balance and proprioception, the use of this training program to improve static and dynamic balance and proprioception and prevention of falling in older women with a history of falling is recommended.

Study limitations

The limitations of the present study are the lack of control over the level of motivation of the subjects during assessments and exercises, as well as the lack of control over issues related to daily life such as lifestyle and sleep, the amount of rest and their mental and psychological conditions.

Conflict of interest

None.

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Authors' contributions

All authors conceived and designed the experiments. Gazizeh Mohseni performed the experiments, and analyzed the data. Ebrahim Mohammad Ali Nasab Firouzjah performed the statistical analysis and drafted the initial manuscript. All authors have read, contributed to, and approved the final version of the manuscript.

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