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Original Article

Comparison of the Effect of Eight Weeks of Strength Training, Aquatic Exercise, and Omega-3 Supplement Consumption on Motor Function of Diabetic Men With Peripheral Neuropathy

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Abstract

Background: Diabetes leads to some motor function dysfunction. The aim of this research was to compare the effect of eight weeks of strength training, water exercise, and omega-3 consumption on the motor function of diabetic men with peripheral neuropathy.

Materials and Methods: Among the diabetic patients with peripheral neuropathy (30-60 years old), 80 people were purposefully selected and then randomly divided into four groups, including 8 weeks of taking omega-3 supplements, 8 weeks of strength training, 8 weeks of water training, and control (20 people in each group). Eventually, a one-way analysis of variance was used for the group comparison of variables.

Results: In terms of simple reaction time, strength training ($P=0.03$) and water training ($P=0.01$) were lower than the control group. In addition, the water exercises ($P=0.04$) and strength training ($P=0.04$) were lower than the consumption of omega-3. However, in terms of the balance score, strength training ($P=0.001$), water training ($P=0.001$), and omega-3 consumption ($P=0.01$) were higher than the control group. Similarly, water exercises ($P=0.02$) and strength training ($P=0.03$) were higher than the average consumption of omega-3. Regarding the leg muscle strength score, the strength training ($P=0.001$), water training ($P=0.001$), and omega-3 consumption ($P=0.003$) were higher than the control group. Finally, the strength training ($P=0.012$) was higher than the mean consumption of omega-3 ($P=0.012$).

Conclusion: In general, strength training, water exercise, and omega-3 consumption improved motor performance in diabetic neuropathy men.

Keywords: Motor function, Strength training, Aquatic training, Diabetes

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Introduction

Peripheral neuropathy caused by diabetes causes a significant disturbance in balance and the ability of these patients to maintain balance during daily activities (1). Diabetic neuropathy is characterized by the progressive destruction of nerve fibers, which disrupts the function of the nerve from the periphery to higher areas. It is heterogeneous and affects different parts of the nervous system, which results in different clinical manifestations depending on the location and type of the involved nerve fibers (2). Nerve function damage leads to several defects in motor systems (weakness and muscle atrophy) and the disruption of afferent and afferent pathways in the individual's body (3). Pathological changes caused by diabetic neuropathy, including axonal degeneration in foot and ankle nerves, lead to a decrease in the speed of nerve conduction and ultimately delay the sending of sensory-physical information needed from the ankle complex to control balance (4). Not sending this information accurately from the lower limb makes it more difficult to control the balance and makes it easier to fall (1). In people with diabetic peripheral neuropathy, the lack or destruction of lower limb afferents causes loss of accurate proprioceptive feedback from the lower limbs, leading to the postural instability of these people so that the probability of these people falling is 15 times higher than healthy people and diabetic patients without neuropathy. The decrease in the strength of the dorsiflexion muscles of the ankle and the reduction in the sense of touch, joint position, and proprioceptiveness increase the amount of body fluctuations, and these factors are among the main reasons for reducing the balance of the elderly, especially diabetic men who had a busy and hardworking youth. In addition, decreasing the speed of nerve message transmission and increasing the reaction time, by reducing the neuromuscular control in these people, affects their balance (4).

Physical activities and sports have been proposed as one of the main pillars of diabetes care and management over several decades, and the low cost and non-drug nature of physical activity increase its therapeutic importance (5). Strength exercises are performed by applying pressure on a specific muscle group in several repetitions and in the long run, they will strengthen the muscles of the body and increase muscle mass. These exercises help diabetic patients to do everyday tasks easily and make their bones healthy (6). By increasing physical activity and as a result, reducing blood glucose, damage to nerves is reduced and can lead to a reduction in the complications caused by sensorimotor neuropathy that occurs due to the destruction of nerve cells (7). In fact, by causing a disturbance in the neuromuscular system, exercise causes changes in muscle strength and posture control, and balance of people (8). Exercising in water is also considered a new type of treatment for diabetics so that changes in body weight in water have been proven. Many people with diabetes are overweight and face problems in terms of joint and muscle pains, and doing many aerobic exercises is tiring for them. Therefore, exercise training in water can be useful for diabetic patients due to the nature of water and the diversity of exercise (9).

On the other hand, omega-3 fatty acids are also useful for improving diabetic patients. Omega-3 fatty acids are known as essential fatty acids and must be supplied through diet. According to previous studies, a deficiency of essential fatty acids has been observed in diabetic patients. The supplement of omega-3 fatty acids is effective in reducing some of the complications of diabetes, and it has been considered in the glycemic control of diabetes (10). Hence, according to the effect of resistance and water exercises on the improvement of various indicators and the neuromuscular parameters of sensory and motor neuropathy, doing sports exercises has a low cost, and sports training is a non-pharmacological treatment. On the other hand, considering the increasing number of people with diabetes, the costs of its treatment, and the high mortality rate of people with diabetic neuropathy, no study has so far simultaneously examined the effect of strength training and exercise in water, along with supplements on the conduction to show nerve and neuropathy. Thus, the purpose of this research was to investigate the effect of 8 weeks of strength training, water sports, and omega-3 supplement consumption on static balance, simple and selective reaction times, and leg muscle strength in diabetic men with peripheral neuropathy.

Materials and Methods

This study was conducted in 2022 using a pre- and post-test research method with a control group. In this research, changes resulting from performing strength training, water sports, and omega-3 supplement consumption in four groups were evaluated on static balance, simple and selective reaction times, and leg muscle strength. The statistical population of the research included all diabetic men with peripheral neuropathy who were referred to Sabzevar Diabetes Center. The sample size included 80 patients with peripheral neuropathy who were purposefully selected and randomly (block randomization) divided into four groups of omega-3 supplement (n = 20), strength training (n = 20), water training (n = 20), and control (n = 20). The characteristics of these 80 people (after completing the informed consent form) included men suffering from type 2 diabetes with an age range of 30-40 years, type 2 diabetes having peripheral neuropathy (scores 7-30 obtained from the Michigan questionnaire by a specialist doctor), having fasting blood glucose higher than 126 mg/dL, and, having hemoglobin A1c higher than 6.5%. The other people were those having a body mass index of 25-30 kg/m^2, not having chronic diseases, cancer, and other complications that prevent the research process at the time of the research, having no history of regular sports activity, not smoking, and not using a special diet or treatment method. The available sampling method was employed for selecting the samples who were diabetic neuropathy cases, interested in participating in the research, and homogeneously placed in four exercise groups based on the amount of hemoglobin A1c. Then, they were randomly assigned to one of the groups.

Moreover, in the training groups, strength training and water training were performed 3 times a week for 8 weeks and 3 times a week for 8 weeks, respectively. Strength exercises for 10-15 minutes were performed as resistance exercises in the muscles and joints of the lower limbs and included hip abductor exercises, ankle muscle strengthening, and knee extensor muscle strengthening. Exercises in the water included leg exercises in the pool for about 10-15 minutes, and each exercise was performed three times. The supplement-consuming group also consumed omega-3 (daily 2000 mg of omega-3 fatty acids supplement, Karen Company, Iran) in the form of two capsules containing eicosapentaenoic acid and docosahexaenoic acid. The control group continued their normal life. All people were advised not to consume foods containing omega-3 fish or fish, as well as supplements containing antioxidants, during the research.

In this research, the height of the patients was measured in centimeters with a tape measure, and the weight in kilograms was measured with a digital scale (Seka weighing and measuring device), and then the body mass index (the ratio of weight to the square of height) was calculated as well. Patients' blood tests were used to check blood hemoglobin. In addition, a glucometer (in mg/dL) and a sphygmomanometer (Omron, in mm Hg) were employed to check and measure blood sugar and check blood pressure, respectively. In this study, the valid Michigan Neuropathy Assessment Questionnaire was also utilized to determine and diagnose the presence of peripheral neuropathy in diabetic patients.

Muscle Strength Testing Tool

The muscle strength in a number of target muscles is assessed only to determine the size of the weights according to the type of exercise. Muscle strength for all people will be measured by a hand-held dynamometer in an isometric way. This method is safer than the other methods, and its reliability and repeatability have been proven in previous studies (5). This device can measure up to 136.1 kg in the upper range and 22.6 kg in the lower range and can record changes up to 0.1 kg. In this study, the dynamometer was firmly held by the examiner, while the subject was exerting his maximum force against it, and the muscle strength values were recorded in kilograms.

In all subjects, the order of measuring the muscle strength was the same (first, the strength of the plantar flexor muscles of the right and left ankles in the lying position, then that of the hip abductor muscles of the right and left legs in the lying position, and finally the strength of the extensor muscles) The right and left knees were measured and recorded while sitting on the bed. To familiarize and prepare the person for the maximum voluntary isometric contraction, one or two contractions were performed experimentally. The duration of the main contraction was 5 seconds, while the contraction was accompanied by verbal guidance, and the person was asked to create a uniform contraction.

To test the strength of the ankle plantar flexor muscles, the person in question was asked to sleep so that the heel was out of the bed and the ankle was in a neutral or slightly dorsiflexed position. The distal end of the lower leg was completely fixed by the strap and the person was asked to move his ankle up without lifting the lower leg from the bed.

To measure the strength of the hip abductor muscles, the person was asked to sleep on the left side so that the legs were completely along the trunk and the lower leg was slightly bent from the hip and knee area. Then, the person was asked to place his lower hand under his head and hold the edge of the bed with his upper hand. Next, the person moved his upper (right) leg up with all his strength without ending the knee, and manual resistance was applied by a dynamometer at a distance of 10 cm above the upper edge of the patella on the outer side of the leg.

To calculate the strength of knee extensor muscles, the person was asked to sit on the edge of the bed and hold the sides of the bed with his hands. Then, he was asked to move his leg forward. As he was moving, manual resistance was applied by a dynamometer at the distal end of the leg and above the wrist.

Static Balance Testing Tool for Patients

To perform this evaluation, the force plane will be used to evaluate the fluctuation of the center of pressure. The force plate receives and records the center of the pressure signal. In this research, standing on two legs was employed to evaluate people on the force screen, including one time with eyes open and one time with eyes closed. For this purpose, people were asked to stand in a stationary position with their hands next to the body so that the heels were placed together and an angle of 30 degrees was created between the inner edges of the feet. When performing the test with open eyes, the person had to look at the target set at 1.5 meters, and when performing the test with closed eyes, as soon as he heard the therapist's command, he had to close his eyes in order to eliminate visual inputs and record the data.

The information obtained from the force plate with a frequency of 100 Hz and after entering the analog to digital conversion system was recorded in the computer memory and analyzed by the software.

Simple and Selective Reaction Time Measurement

To evaluate the simple reaction time, the participant was asked to stand on the switch mat and jump quickly in response to the light stimulus. The elapsed time from the flashing of the light to the disappearance of foot pressure on the mat switch was recorded as the reaction time (11). To measure the selective reaction time, the participants were placed on a black platform (0.8×0.8) that had four rectangular panels (13×23 cm), one in front of each foot and another on the sides of each foot. A panel was randomly lit in each trial, and participants had to step on the lit panel as quickly as possible. To determine the foot contact time, each panel had a pressure switch. After 4-8 practice trials, 20 trials were performed with 5 trials per panel. The selective reaction time was measured as the time period between the light of the panel and the contact of the foot with it. The test time of 20 cases was used in the analysis (12).

Statistical Method

The Shapiro-Wilk, analysis of variance (ANOVA), and Tukey's post hoc tests were employed to check the normality of data distribution, determine differences between groups, and determine differences between groups, respectively. The research hypotheses were tested at a significance level of 0.05. It should be mentioned that SPSS software was utilized for calculations and data processing.

Results

According to the Shapiro-Wilk test, the data had a normal distribution. Further, some physical indicators and body composition of the subjects were measured in two stages (pre-test), the results of which are provided in Table 1.

Table 2 presents the value of dependent variables in different groups in the pre- and post-test stages.

The *t* test results (Table 2) demonstrated that the selective reaction time significantly decreased in strength training ($P=0.001$), water training ($P=0.003$), and omega-3 consumption groups ($P=0.002$). Furthermore, in terms of the simple reaction time, a significant decrease was observed in strength training ($P=0.001$), water training ($P=0.004$), and omega-3 consumption ($P=0.04$) groups (Table 2).

Table 1. Physical Indicators and Body Composition of the Research Groups in Balsas State

Markers	Control	Training	Water Training	Supplement	*P* Value[a]
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Body weight (kg)	33.90 ± 4.79	32.80 ± 5.44	33.20 ± 4.68	35.45 ± 4.55	0.99
Height (cm)	174.60 ± 1.26	175.60 ± 1.05	174.14 ± 0.96	178.16 ± 0.752	0.76
Body mass index (kg/m^2)	76.97 ± 1.29	76.60 ± 1.20	76.77 ± 1.33	75.42 ± 1.45	0.99
Age (years)	25.2 ± 1.16	24.8 ± 0.6	25.3 ± 0.52	23.8 ± 1.43	0.89

SD: Standard deviation;
[a] ANOVA test.

Table 2. The Value of the Research Variables in the Pre-test and Post-test

Makers	Group	Time	Mean ± SD	*P*-value
Static balance	Control	Pre-test	13.240 ± .766	0.99
		Post-test	14.2 ± 1.03	
	Omega-3 supplement	Pre-test	13.13 ± 1.12	0.03
		Post-test	16.52 ± 1.42	
	Strength training	Pre-test	12.986 ± 1.14	0.001
		Post-test	19.12 ± 1.1	
	Water training	Pre-test	13.49 ± .72	0.003
		Post-test	19.19 ± 1.14	
Leg muscle strength	Control	Pre-test	11.7 ± 1.76	0.99
		Post-test	12.37 ± 1.22	
	Water training	Pre-test	11.9 ± 1.37	0.001
		Post-test	15.1 ± .99	
	Strength training	Pre-test	12.5 ± 1.58	0.001
		Post-test	15.7 ± .94	
	Omega-3 supplement	Pre-test	12.45 ± 1.62	0.02
		Post-test	14.52 ± 1.23	
Simple reaction time	Control	Pre-test	2.6 ± .6	0.99
		Post-test	2.6 ± .76	
	Water training	Pre-test	2.52 ± .6	0.004
		Post-test	2.1 ± .23	
	Strength training	Pre-test	2.54 ± .56	0.001
		Post-test	2.2 ± .43	
	Omega-3 supplement	Pre-test	2.61 ± .44	0.04
		Post-test	2.5 ± .33	
Selective reaction time	Control	Pre-test	124.43 ± 40.11	0.99
		Control	125.43 ± 39.12	
	Water training	Pre-test	122.4 ± 41.4	0.003
		Post-test	100.21 ± 23.4	
	Strength training	Pre-test	123.16 ± 39.15	0.001
		Post-test	95.3 ± 22.21	
	Omega-3 supplement	Pre-test	124.43 ± 39.12	0.002
		Post-test	113.2 ± 28.1	

Note. SD: Standard deviation.

As regards the selective reaction time, there was a significant difference between the average score of the control group and strength training, water exercise, and omega-3 consumption groups ($P=0.001$) so that the average score of strength training ($P=0.001$) and water exercises ($P=0.001$) was lower than that of the control group. The average of water exercises ($P=0.01$) and strength training ($P=0.03$) had significant differences with the average consumption of the omega-3 group. Moreover, with regard to the simple reaction time, a significant difference was found between the average score of the control group and the strength training, water training, and omega-3 consumption groups ($P=0.001$) so that the average strength training ($P=0.03$) and water training ($P=0.01$) was lower than that of the control group. Additionally, the average of water exercises ($P=0.04$) and strength training ($P=0.04$) had significant differences with the average consumption of the omega-3 group (Tables 3 and 4).

The *t* test results revealed that static balance significantly increased in strength training ($P=0.001$), water training ($P=0.003$), and omega-3 consumption ($P=0.03$) groups. In terms of leg muscle strength, there was a significant increase in strength training ($P=0.001$), water training ($P=0.001$), and omega-3 consumption ($P=0.02$) groups (Table 2).

In terms of the balance score, there was a significant difference between the average score of the control group

Table 3. Between Test Effect

	Sum of Squares	df	Mean Squares	F	*P* Value	Partial Eta Squared
Static balance	176.4	3	58.43	17.5	0.001[a]	0.675
Leg muscle strength	68.1	3	22.02	13.6	0.001[a]	0.965
Simple reaction time	6.16	3	2.7	51.2	0.001[a]	0.786
Selective reaction time	665.21	3	125.32	72.1	0.001[a]	0.678

[a] Significant by ANOVA test.

Table 4. Pairwise Comparison

Markers	Groups		Mean Difference	SD	*P* Value
	Group (I)	Group (J)			
Static balance	Control	Strength training	-4.2	0.82	0.001*
		Water training	-4.99	0.82	0.001*
		Omega-3 supplement	-2.3	0.82	0.01*
	Strength training	Water training	0.83	0.92	0.82
		Omega-3 supplement	0.83	0.003	0.82
	Water training	Omega-3 supplement	0.84	0.002	0.82
Leg muscle strength	Control	Strength training	-3.33	0.56	0.001*
		Water training	-2.71	0.56	0.001*
		Omega-3 supplement	-1.83	0.56	0.001*
	Strength training	Water training	0.61	0.56	0.29
		Omega-3 supplement	1.52	0.56	0.01*
	Water training	Omega-3 supplement	0.93	0.56	0.12
Simple reaction time	Control	Strength training	0.42	0.3	0.03*
		Water training	0.51	0.5	0.01*
		Omega-3 supplement	0.11	0.42	0.21
	Strength training	Water training	0.11	0.21	0.99
		Omega-3 supplement	0.32	0.12	0.04*
	Water training	Omega-3 supplement	0.41	0.11	0.04*
Selective reaction time	Control	Strength training	30.21	18.2	0.001*
		Water training	25.32	17.2	0.001*
		Omega-3 supplement	12.22	10.2	0.03[a]
	Strength training	Water training	5.21	0.2	0.99
		Omega-3 supplement	18.32	8.4	0.01 [a]
	Water training	Omega-3 supplement	13.22	5.3	0.03 [a]

Note. SD: Standard deviation;
[a] Significant by Tukey's post hoc test.

and the strength training, water exercises, and omega-3 consumption groups ($P=0.001$) so that the average score of strength training ($P=0.001$), water exercises (011 ($P=0.01$), and omega-3 consumption ($P=0.01$) groups was lower than that of the control group. The mean of exercises in water ($P=0.02$) and strength training ($P=0.03$) exerted a significant difference with the mean consumption of the omega-3 group. As regards the leg muscle strength score, a significant difference was observed between the mean score of the control and strength training, exercises in water, and omega-3 consumption groups ($P=0.001$). More precisely, the average score of the strength training ($P=0.001$), water training ($P=0.001$), and omega-3 consumption ($P=0.003$) groups was lower than that of the control group. The average strength training ($P=0.012$) was significantly different from the average consumption of the omega-3 group (Tables 3 and 4).

Discussion

The results of the present study showed that for the control groups, strength training, water training, and omega-3 consumption had a significant effect on leg muscle strength and balance. In this regard, Farhan et al found that doing combined exercise improves balance and reduces the possibility of falling in elderly women with diabetic peripheral neuropathy (13). Likewise, Hedayati et al reported that eight weeks of the resistance exercise program in diabetic women with peripheral neuropathy increases balance (14). The results of Kargarfard et al revealed that exercise therapy in water can be used as a useful and effective treatment method to improve balance and then the daily performance of patients (11). In a study, Irandoust et al investigated and reported the effect of water exercise on the postural mobility of healthy elderly people with endomorphic somatotype. Their results showed that the design of exercise programs in water, especially for elderly endomorphs, is better than exercises on land. Probably, exercising in water has a positive effect on motor control and balance, and walking in water is suitable for them (15).

In the explanation of the findings of this research and in line with the mentioned research, the possible reasons may include observing an increase in the balance due to strengthening exercises, facilitating and synchronizing fast twitch and large motor units, stimulating muscle spindles, reducing the self-restraint effect of Golgi tendon organs, and increasing coordination of muscles involved in contraction activities. By stimulating the muscle spindles, muscle contraction increases the activity of the gamma-efferent nerves in the spindles, and increasing this sensitivity in the spindles improves the sense of joint condition. Further, the improvement in strength is probably due to the neural changes that contribute to the effective functioning of the muscle. An increase in nerve activation, an increase in the synchrony of contraction of motor neurons, and a decrease in the inhibitory action of the Golgi tendon organ have been reported in this regard (16). Furthermore, the environmental conditions of the water can be mentioned among the reasons for the increase in the balance due to water exercises. The environmental conditions of the water allow people to perform a wide range of movements without increasing the risk of falling or injury. In addition, the protective environment of water allows elderly people to maintain a straight and smooth posture independently (17). The disturbing forces of stability and balance in water also provide a suitable environment for balancing activities and challenging the systems involved in balance. Moreover, due to the increase in the reaction time, these types of exercises are suitable for people with a lack of balance because movements are slower due to the viscosity of water, and as a result, people have more time to respond and react (18). The repetition and speed of movements may increase strength and endurance and improve flexibility and reaction time (18).

On the other hand, the findings demonstrated that the strengthening exercises and hydrotherapy have significantly improved the simple and selective reaction time in the experimental groups with respect to the average simple and selective reaction time of the experimental groups compared to the control group. In a study, Morrison et al investigated the effect of 12 weeks of aerobic training on walking, balance, reaction time, and fall risk indicators in elderly people with diabetes with/without peripheral neuropathy. The results of the research represented that before exercise, the diabetic neuropathy group had a higher risk of falling, slower reaction time, and slower walking speed compared to diabetic individuals. After training, the hand/foot reaction time improved and walking speed was faster for both groups. Although the risk of falls was not significantly reduced, the observed changes in the gait, reaction time, and balance measures suggested that aerobic exercise of various intensities was beneficial for improving dynamic status in the elderly with and without neuropathy (19).

Some reasons can be mentioned for improving the simple and selective reaction time after strengthening exercises and hydrotherapy (and increasing the selective reaction time in the omega-3 consumption group). An increase in the peripheral plasma concentrations of catecholamines, adrenaline, and noradrenaline during physical activity causes changes in the central nervous system (CNS); it seems that this increase in the CNS is to raise the level of arousal (20). Physical activity causes an increase in blood temperature, leading to an increase in the speed of nerve transmission (21). Physical activity leads to an increase in the amount of calcium transported from the plasma to the brain (22). This process, in turn, increases the composition and synthesis of dopamine in the brain through a calmodulin-dependent system, and the increased levels of dopamine coordinate and integrate different brain functions (23). This article can also be a good justification for increasing the speed of information processing that occurs in the CNS. It is also possible that the positive effect of moderate physical activity on reaction time is related to the speed of cognitive processing (24). The beneficial effects of exercises and sports activities, including water activities and strengthening exercises, on improving the simple and selective reaction time can be attributed to the improvement in neurological and physiological adaptation. In addition, daily consumption of omega-3 can prevent muscle inflammation and is useful for increasing the synthesis of muscle proteins (25). Research has confirmed the daily consumption of 4 grams of omega-3 increases the activity of intracellular mechanisms related to the synthesis of muscle proteins. In some studies, the length of the consumption period has been suggested to be at least two weeks; however, acute and single-session consumption of omega-3 can also have beneficial effects.

Conclusion

The findings of the present study revealed the importance and necessity of providing solutions to improve balance, simple and selective reaction times, and strength for diabetic neuropathy patients. Considering that balance and reaction time are disturbed in these patients, it is possible to improve the balance in these patients with strengthening exercises, water exercises, and consumption of omega-3.

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Authors' Contribution

Conceptualization: Alireza Saadatifar.
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Competing Interests

The authors have no conflict of interests.

Ethical Approval

This article has been approved by the Ethics Committee of the Islamic Azad University Shahroud Branch with the code IR.IAU.SHAHROOD.RES.1400.058.

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