Research Paper

Effects of Dynamic Neuromuscular Stabilization and Aquatic Exercises on the Pain, Disability, Lumbopelvic Control, and Spinal Posture of Patients With Non-specific Low Back Pain

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ABSTRACT

Objectives: Using an exercise intervention to improve lumbopelvic control (LPC) can enhance the pain severity and disability of participants with non-specific low back pain (NSLBP). The present study aimed to compare dynamic neuromuscular stabilization (DNS) exercises and common aquatic exercises (AEs) in terms of improving the pain, disability, LPC, and spinal posture of patients with non-specific low back pain (NSLBP).

Methods: This single-blind controlled clinical trial was conducted on 45 subjects who were randomly divided into three groups, such as DNS (n=15), AEs (n=15), and control (n=15). LPC, spinal posture, pain severity, and disability were assessed in pretest and six weeks after the intervention by pressure biofeedback, a spinal mouse device, the visual analog scale (VAS), and the Oswestry disability questionnaire, respectively. No intervention was implemented for the control group.

Results: No significant differences were observed between the study groups regarding the impact of the interventions on improving pain and disability (P>0.05). In addition, no significant difference was observed between the AEs and DNS groups regarding the improvement of LPC disorders (P>0.05). The spinal inclination angle (P=0.03) and inclination of range of motion (P=0.05) were significantly improved only by the AEs.

Discussion: According to the results, the DNS exercises and AEs had no significant differences in terms of impact on the improvement of pain, disability, and LPC. Therefore, proper alternatives can be used to enhance such dysfunctions in case of a lack of access to pools and hydrotherapy pools.

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Highlights

• No significant differences were observed between dynamic neuromuscular stabilization (DNS) and aquatic exercises (AEs) intervention groups regarding the impact of the interventions on the improvement of pain and disability.

• No significant difference was observed between the AEs and DNS groups regarding the improvement of Lumbopelvic Control lumbopelvic control (LPC) impairments.

• The spinal inclination angle and range of motion were significantly improved only by the AEs intervention.

Plain Language Summary

According to the results, the effect of dynamic neuromuscular stabilization and aqua exercise interventions on improving pain and disability was the same. In addition, the aqua training and dynamic neuromuscular stabilization exercises had the same effect on improving lumbopelvic uncontrolled movements. However, the spinal posture and range of motion improved only by the aqua training.

1. Introduction

Low back pain (LBP) is among the most common musculoskeletal disorders, affecting 4%-33% of the population at different ages. LBP has a high effect on the quality of life and may cause disability [1]. Non-specific LBP (NSLBP) is the low back pain of unknown causes [2]. Studies show that 84% of people experience LBP at least once in their lifetime, of which 23% are chronic and 12% have been shown to cause limitations in daily activities. On the other hand, the treatment costs of LBP impose a financial burden on the health system and community [3]. Several of these patients constantly seek treatment for their pain and disability without any pathology in their radiographs, mostly experiencing symptoms such as pain, reduced power and strength in the upper body, biomechanical changes, spinal deformity, and impaired movement control [4]. Various systematic reviews over the past decade have raised significant concerns about the effect of exercise on LBP management due to the lack of evidence supporting specific exercises [5-7].

For decades, aquatic exercises (AEs) have been suggested by physicians to patients with chronic LBP because they can effectively control pain. According to a review study by Psycharakis et al., aqua therapy can significantly decrease pain and improve the physical function of people with LBP [1]. They also, evaluated the effects of aquatic and usual exercises on the muscle activity of subjects with and without LBP, reporting no significant difference between the exercise environments in terms of muscle activation [1]. These findings can be attributed to specific features of water and their effects on the inhibition of pain receptors. According to the literature, patients with NSLBP have altered motor strategies compared to healthy individuals [8].

In recent decades, a proper understanding of the correlations between the stability of the muscularsystem and the optimal functioning of the motion system has been established. Evidence suggests that the dysfunction of spinal stabilization muscles might impair movement control, which is associated with reduced control over the neutral joint condition and the subsequent segmental instability in the lower back area, eventually leading to pain [9].

Dynamic neuromuscular stabilization (DNS) is an exercise protocol that has lately attracted the attention of investigators in the field of chronic pain inhibition. This approach mainly aims to restore physiological movement patterns, defined by growth kinesiology. In these exercises, optimal torso stability is crucial to activate the core muscles and allow these muscles to produce maximum strength during functional activities. The quality of this coordination is essential to joint performance and affects local and global biomechanical and anatomical parameters in the kinematic chain [10]. The DNS approach focuses on regulating intra-abdominal pressure and integrated spinal stabilizing system to optimize movements and prevent excessive loads on the joints. Muscle balance is observed between the deep flexors and spinal extensors and between the diaphragm and pelvic floor muscles, providing stability to the lumbar spine through the spinal stabilization system and resulting in spinal stability [11]. According to a study by

Clare Frank et al., the DNS protocol prepares functional instruments to identify and activate the inner spinal stabilizers to optimize the movement for the rehabilitation of sports injuries and performance [11].

Research regarding LBP indicates a disorder in the pattern of lumbopelvic movements during activities, such as sitting, standing, and lower limb movements in patients with LBP. These disorders involve uncontrolled movements. Impaired motor control is the poor control and coordination of the vertebral movements in the lumbopelvic region [12]. Therefore, pain and disability improvement can be examined by applying an intervention aimed at improving lumbopelvic control (LPC). Since the effect of DNS training on the improvement of chronic LBP has not been studied so far, the hypotheses of the present study are as follows:

1. A significant difference is observed between aqua therapy and DNS interventions in terms of their impact on pain and disability.

2. A significant difference is observed between aqua therapy and DNS interventions regarding their effect on LPC.

3. A significant difference is observed between aqua therapy and DNS interventions in terms of their impact on posture and spinal range of motion.

2. Materials and Methods

Participants

This single-blind randomized controlled clinical trial was conducted with a pretest, posttest design and a control group at the laboratory of sports injuries and corrective exercises of Razi University from 26 September 2020-10 March 2021. In total, 45 subjects were enrolled in the study based on research by Liu et al. [13] and after the confirmation of a specialist. All of the subjects were evaluated by a specialist physician and if they met the inclusion criteria, they were referred for further evaluation and interventions.

The inclusion criteria included age of 30-50 years, having NSLBP for a minimum of three months, oswestry disability index (ODI) of 20-61 and a mean visual analog scale (VAS) score of above zero and participating in no therapeutic interventions within the past three months and during the study period. The exclusion criteria included bone fractures, spinal stenosis, vertebral fractures, history of lumbar surgery, inflammatory joint diseases, pregnancy, and shorter postpartum than six months [2, 5]. The medicine for these patients was only calcium and vitamin D (because its consumption is low in Iran) and when they had a lot of pain, they took meloxicam 7.5 mg up to twice a day. Meloxicam was not taken regularly and was not taken before exercise or on the day of the test.

The proposal of the present study was approved by the Ethics Committee of Razi University (Code: IR.RAZI.REC.1399,005) and the Iranian Registry of Clinical Trials (Code: IRCT20200704048002N1). All the participants signed a written consent form and the research process was consistent with Helsinki Declaration.

Using a random number generator software service, the subjects were randomly allocated into three groups, such as DNS exercises (n=15), aquatic exercises (AEs) (n=15), and control (n=15) (Figure 1). Subject allocation concealment was also carried out using the SNOSE method; to this end, the allocation sheet was provided to the person not included in the study, random numbers were placed in opaque envelopes, and each envelope was numbered sequentially.

Following the pretest assessments, each patient and the assessor became aware of the patient's group after selecting an envelope. LPC, spinal posture, pain intensity, and disability were measured at the pretest and posttest by pressure biofeedback, a spinal mouse device, VAS, and ODI, respectively. The subjects performed the interventional exercises for six weeks. The AEs were carried out by a specialist with a relevant license, and the DNS exercises were performed by a corrective exercise specialist. Notably, the subjects in the control group received no intervention.

Outcome measures

In this study, pain and disability were evaluated as primary outcomes with visual VAS and ODI, respectively, and limbopulvic control and spinal posture were evaluated as secondary outcomes with pressure biofeedback unit and spinal mouse.

Pain and disability evaluation

To evaluate the pain intensity of the subjects, the VAS was used. The VAS is a 10-centimeter ruler with zero at one end indicating no pain, and 10 at the other end indicating most intense pain; the participants were asked to report their pain degree on the ruler (ICC=0.95) [14]. The ODI includes 10 items, and each one has six options.

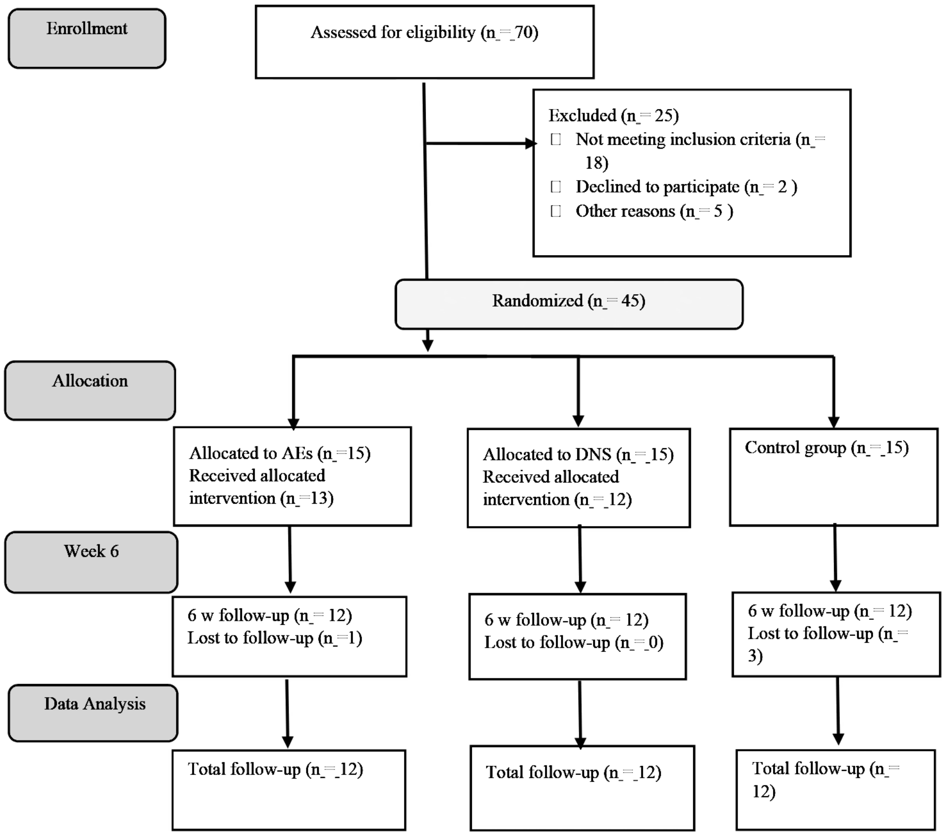

Figure 1. Flowchart of study

These items examine the daily activities performed by the respondent, and each item measures disability on a scale of zero (optimal performance) to five (disability in performance). The score range is 0-100. Zero indicates that the subject is healthy, while 0-20, 21-40, 41-60, 61-80, and>80 represent low, moderate, high, severe, and acute disabilities, respectively [15].

LumboPelvic Control (LPC) tests

Four LPC tests were executed, including the knee lift abdominal test (KLAT), bent knee fall-out (BKFO) test, Active Straight Leg Raising (ASLR) test, and prone tests were performed using a pressure biofeedback unit:

KLAT test: Participants were supine and a bag of biofeedback pressure was placed under their spine so that the lower margin was at the level of the superior posterior iliac spine. The biofeedback bag pressure was then increased to 40 mm Hg (baseline pressure). The patient raised one leg off the examination table until the hip and knee joints were 90° (hold for 4-6 s). Then, the maximal pressure changes were written by the assessor (Figure 2a). BKFO test: the subjects were positioned supine, and the calf of the biofeedback pressure device was vertically placed under the lumbar with the lower edge 2 cm caudal of the posterior superior iliac spine on the opposite side of the flexed knee. A rolled towel was then placed under the spine near the biofeedback bag so that the two sides of the spine were at the same level; then the pressure of the biofeedback unit was raised to 40 mmHg (baseline pressure). Afterward, the hip of one leg was flexed, and the knee was also flexed to 120° while the foot remained on the examination table. The patients were asked to gently flex their hip to 45° of the abduction/lateral rotation while keeping their foot flat on the table beside their straight knee and return to the first position. The maximal pressure changes were written (Figure 2b). ASLR test was also done in the supine position, and the bag of biofeedback pressure was put horizontally below the lumbar; then the pressure of biofeedback was raised to 40 mmHg (baseline pressure). The subjects raised one straight leg 20cm from the examination table and held it for 20s. The highest pressure changes were registered (Figure 2c). Finally, in the prone tests, the patients were in the prone position on the test table. The bag of biofeedback pressure was put between the ASIS and navel then its pressure was increased to 70 mmHg. The subjects carried out 3 contractions with the verbal order: “Pull in your abdomen without any motion on your lum-

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Figure 2. Leg and knee tests

A: Knee Lift Abdominal Test; B: Bent-knee Fall-out Test; C: Active Straight Leg Raising test; D: Prone Test

bar or pelvic region and hold this situation until you are told otherwise." The assessor distinguished whether the participants were displaced their spine/pelvic by palpation over ten seconds (Figure 2d).

To measure the LPC of the patients, the pressure changes from the baseline pressure of each test were written by the assessor. If the mean pressure changes of the 4 tests were $> |\pm 8|$ mmHg, the subjects were classified as weak LPC. If the mean pressure changes of the 4 tests were $\leq |\pm 8|$ mmHg, the subjects were classified as proper LPC [16-18].

Spine posture evaluation

To measure the lumbar lordosis and spinal curvature angles on the sagittal plane, a spinal mouse device (model 3.32, made in Switzerland) was used. A spinal mouse is used to assess spinal shape and mobility by surface-based measurements. The participants stood in front of the assessor without shoes, and then the C7 and S2 were pointed. Following that, thoracic kyphosis and lumbar lordosis angles in the standing position were assessed by putting the spinal mouse device on the C7 and pulling it down to the S2. The total flexion and extension Range of Motion (ROM) of the spine was also evaluated in the upright situation. Thoracic kyphosis, lumbar lordosis, and sacral inclination were evaluated at the next stage. The thoracic kyphosis angle is the curvature of the total spine from the T1 to the T12 vertebra and the sum of the eleven angles from T1 to T12. The sum of the angles from T12 to L5 in the curvature throughout the lumbar vertebra is the angle of lumbar lordosis. The sacral inclination angle is the angle between the back surfaces, which is

Table 1. Aquatic Exercises (AEs)

Exercise Stages	Duration (Minute)	Exercises	Sets×Reps
Warm-up	10	Walking forward and backward, stretching all major muscle groups (gluteus, lumbar back, and hamstrings)	3×8-12
Main Training Program	35	Jogging forward and backward, standing on one leg (balance for 20 seconds on each leg), stepping sideways, squats, hip flexion, extension, abduction, and adduction, leaps, kicks, leg crossovers, hopping movements focused on moving in multiple directions, bounding off the bottom of the pool, arm rotations, plank, deep water cycling with woggles	3×8-12
Cool-down	5	Stretching, deep breathing technique, relaxation, and self-care free water-activity.	2×8-12

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drawn through the sacrum with the vertical line through the spine. In this study, the positive values obtained from the measurements were attributed to kyphosis, and the negative values indicated lordosis [19].

Interventions

The AEs were carried out 50 minutes for each session, three times per week for six weeks. The AEs included a 10-minute warm-up, a 35-minute main training program, and a five-minute cool-down. These exercises were performed in a 25-meter indoor pool (depth: 1.25-1.50 m, mean water temperature: 28°C) under the supervision of an AE therapist. The warm-up involved all-direction walking and calf and upper and lower back muscle stretching, and the main exercises included 10-25 m of the front, back, and sideway walking, 10-25 m of front jogging, 15-20 m of walking at a self-selected pace, forward and side lunges, leg pedaling and cycling in the supine position, upper body mobilization, shoulder transvere exercises, and deep water cycling. Each exercise was repeated in three sets in each session (Table 1) [20].

The DNS exercise protocol was executed based on the study by Mahdieha et al. (2020) for six weeks (three 50-minute sessions per week). The protocol included a five-minute warm-up, 40-minute DNS exercises with breathing, and a five-minute cool-down. In accordance with the DNS approach, the exercises involved diaphragmatic breathing, baby rocks (supine 90-90), prone, rolling, side lying, oblique sits, tripod, kneeling, squatting, and standing. The first week of the DNS protocol was specifically focused on training and practicing basic exercises. The training complexity was slowly increased by adding a new exercise to the last practiced exercises every week as opposed to the preceding week; increasing the complexity of a task helped the subjects automate their performance. Notably, we used the dual-task paradigm to determine whether a task was automated (e.g., no new task could disturb diaphragmatic breathing) [21].

The overload principle in DNS exercises was implemented by increasing the complexity of the exercises, while in fitness exercises, it is implemented by increasing weights, repetitions, duration, and distance.

The control group had no other treatment during this study and continued their ordinary life activities.

Statistical analysis

SPSS software, v. 21 (SPSS Inc., Chicago, USA) was used for data analysis. The Shapiro-Wilk test was performed to evaluate the normality of data distribution and Levene's test to assess the homogeneity of the variances. In addition, 1-way analysis of variance (ANOVA) and Bonferroni post-hoc test were used to evaluate the differences between the study groups in the pretest. The analysis of covariance (ANCOVA) and mixed-design ANOVA were also used to determine the effects of the interventions on the study variables. The Eta-squared (η^2; small: 0.01, medium: 0.06, large: 0.14) was used to determine the effects of the interventions [22]. In all the statistical analyses, the significance level was 0.05.

3. Results

In this study, we investigated the effects of DNS exercises on the pain and disability management and LPC of participants with NSLBP and compared the results with those of AEs. In total, 45 eligible patients have enrolled this research. Two participants in the AE group declined to participate for family reasons, and one subject was unable to participate in the posttest. In the DNS group, three participants withdrew from the research, and three subjects in the control group did not attend the posttest. Table 2 presents the demographic characteristics of the participants.

One-way ANCOVA was used to compare the effectiveness of the DNS and AEs in improving pain inten-

Table 2. Demographic characteristics of participants

Groups	Mean±SD			
	BMI (kg/m²)	Weight (kg)	Height (cm)	Age (y)
Control (n=12)	28.28±7.10	75.66±19.72	163.85±6.54	35.33±12.91
AEs (n=12)	3.46±25.75	71.01±10.83	159.75±14.18	36.91±10.96
DNS (n=12)	24.56 ±7.33	65.15±52.18	168.23±5.58	38.19±8.54
P*	0.73	0.84	0.82	0.64

* One-way ANOVA.

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AEs: Aquatic exercises; DNS: Dynamic neuromuscular stabilization.

sity in the subjects with NSLBP, and the pretest scores of pain intensity were considered as covariates. A significant difference was observed between the groups in terms of pain intensity after correcting the pretest scores ($F_{1,32}$=28.43; P=0.0001; η^2=0.64). Moreover, the results of the Bonferroni post-hoc test on the comparison of pain intensity indicated a significant difference between the control and AE groups (P=0.0001) and between the DNS and control groups in this regard (P=0.0001). Nonetheless, no significant difference was observed between these interventions regarding their impact on pain intensity (P>0.05).

The mixed-model ANOVA was used to evaluate the effects of DNS and AEs on the disability scores between and within the subjects before and after the intervention, and a significant correlation was observed between the duration and type of the intervention ($F_{2,33}$=30.87, P=0.0001, η^2=0.65). Furthermore, exercise duration had a significant main effect ($F_{2,33}$=23.16, P=0.0001, η^2=0.41), and the groups were significantly different in terms of the disability scores ($F_{2,33}$=7.60, P=0.002, η^2=0.31). In addition, the paired comparison of the study groups indicated a significant difference between the AE and control groups (P=0.009) and the DNS and control groups (P=0.004) (Figure 3). However, no significant difference was observed between these interventions regarding their impact on pain intensity (P>0.05) (Table 3).

A mixed analysis between and within the subjects was executed to assess the effects of the DNS and AE interventions on the LPC scores of the patients with NSLBP before and after the interventions. In the ASLR test, a significant correlation was obtained between the type and duration of the intervention ($F_{2,33}$=66.62, P=0.0001, η^2=0.72), and duration had a significant main impact ($F_{2,33}$=36.17, P=0.0001, η^2=0.52). Moreover, a significant difference was observed between the ASLR scores ($F_{2,33}$=7.91, P=0.002, η^2=0.32). In the KLAT test, a significant correlation was observed between the type and duration of the intervention ($F_{2,33}$=46.93, P=0.0001, η^2=0.74), and duration had a significant main impact ($F_{2,33}$=32.19, P=0.0001, η^2=0.49). Moreover, a significant difference was observed between the study groups in terms of the KLAT scores ($F_{2,33}$=10.52, P=0.0001, η^2=0.38).

In the BKFO test, a significant correlation was observed between the type and duration of the intervention ($F_{2,33}$=24.33, P=0.0001, η^2=0.59), and duration had a significant main impact ($F_{2,33}$=15.67, P= 0.0001, η^2=0.32). In addition, the study groups were significantly different regarding the BKFO scores ($F_{2,33}$=3.39, P=0.049, η^2=0.17). In the prone test, a significant correlation was observed between the type and duration of the intervention ($F_{2,33}$=56.94, P=0.0001, η^2=0.77), and duration had a significant main impact ($F_{2,33}$=27.94, P=0.0001, η^2=0.45). Furthermore, a significant difference was observed between the study groups in terms of the prone test scores ($F_{2,33}$=11.67, P=0.0001, η^2=0.41) (Table 3). Figure 2 shows the paired comparison of the study groups regarding the level of changes at the pretest and post-test.

No significant correlation was observed between the type and duration of the interventions in the kyphosis and lordosis scores, and duration had no significant main impact. Moreover, no significant differences were observed between the study groups regarding the kyphosis and lordosis scores (P>0.05), while a significant correlation was observed between the type and

Table 3. Comparison of outcome measures

Outcome Measures		Groups	Mean±SD Baseline	Mean±SD Six Weeks	P[1]	P[2] Duration×Group
VAS (0-10)		AEs DNS Control	8.00±1.85 6.00±1.85 4.91±1.87	2.14±0.60 2.44±0.53 7.82±0.58	0.0001** 0.0001** 0.01*	0.0001** (0.72)/0.0001**(0.52)
ODI (0-100)		AEs DNS Control	43.00±13.00 41.50±16.29 36.84±17.48	14.33±13.15 15.83±9.35 33.53±14.99	0.0001** 0.0001** 0.7	0.0001** (0.41)/0.0001** (0.65)
LPC	ASLR (mmHg)	AEs DNS Control	11.50±13.00 10.83±3.85 8.31±4.48	3.16±1.99 2.66±2.44 14.33±4.07	0.0001** 0.0001** 0.0001**	0.0001** (0.72)/0.0001** (0.52)
LPC	KALT (mmHg)	AEs DNS Control	10.52±4.67 12.00±4.67 8.17±2.75	1.33±1.30 1.16±1.80 14.16±5.28	0.0001** 0.0001** 0.0001**	0.0001** (0.49)/0.0001** (0.74)
LPC	BKFO (mmHg)	AEs DNS Control	13.16±6.79 11.50±7.29 7.21±4.1	2.83±1.80 1.50±1.50 13.91±6.03	0.0001** 0.0001** 0.0001**	0.0001** (0.32)/0.0001** (0.59)
LPC	PRONE (mmHg)	AEs DNS Control	14.50±4.44 15.50±5.66 11.50±4.35	4.33±2.22 6.00±2.48 19.33±11.4	0.0001** 0.0001** 0.0001**	0.0001** (0.45)/0.0001** (0.77)
Spinal Posture Standing	Kyphosis (0)	AEs DNS Control	46.91±7.40 45.33±13.49 53.58±9.51	49.00±7.22 53.08±10.99 55.83±11.97	0.433 0.245 0.530	0.123(0.71) /0.730 (0.19)
Spinal Posture Standing	Lordosis (0)	AEs DNS Control	23.66± -7.21 22.50± -9.18 20.66± -6.32	23.41± -6.61 -22.33±11.23 20.00± -8.97	1.000 1.000 1.000	0.740(0.003)/0.735(0.18)
Spinal Posture Standing	Incline (0)	AEs DNS Control	7.66±9.48 3.50±3.45 4.75±1.48	1.91±1.08 3.16±1.74 4.16±2.24	0.03 1.000 0.911	0.039* (0.123)/0. 05*(0.151)
ROM (Flexion/Extension)	Kyphosis (0)	AEs DNS Control	22.90±10.96 16.70±7.50 19.40±22.25	14.60±6.53 12.40±6.00 24.01±10.64	0. 23 0.484 0.583	0.422 (0.24)/0.260(0.95)
ROM (Flexion/Extension)	Lordosis (0)	AEs DNS Control	45.30±6.12 46.90±8.34 35.80±19.24	53.10±12.85 50.60±8.32 43.20±15.92	0.097 0.291 0.106	0.076 (0.112)/0.120(0.146)
ROM (Flexion/Extension)	Incline (0)	AEs DNS Control	108.00±27.40 118.70±15.40 75.50±33.10	127.70±15.32 114.40±36.28 80.70±23.42	0.050* 0.231 0.087	0.146 (0.077)/0.049* (0.196)

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P[1]: Paired sample t-test; P[2]: 3×2 repeated measures mixed-model ANOVA. Figures in parentheses show effect sizes. * P<0.05; **P<0.01.

AEs: aquatic exercises; DNS: dynamic neuromuscular stabilization; ES: effect size; ROM: range of motion; VAS: visual analog scale; ODI: Oswestry disability index; KLAT: knee lift abdominal test; BKFO: bent-knee fall-out; ASLR: active straight leg raising; LPC: lumbopelvic control.

duration of the interventions in the spinal slope scores ($F_{2,33}$=4.64, P=0.05, η^2=0.151), and duration had a significant main impact ($F_{2,33}$=4.66, P=0.039, η^2=0.123). No significant difference was observed between the study groups regarding the spinal slope scores in the standing position (P>0.05).

A mixed analysis between and within the subjects was carried out to assess the effects of the two interventions (DNS and AEs) on the spinal flexion-extension ROM scores of the patients with NSLBP at the pretest and posttest. The obtained results indicated no significant correlation between the duration and type of the interventions, and duration had no significant main impact. Moreover, no significant difference was

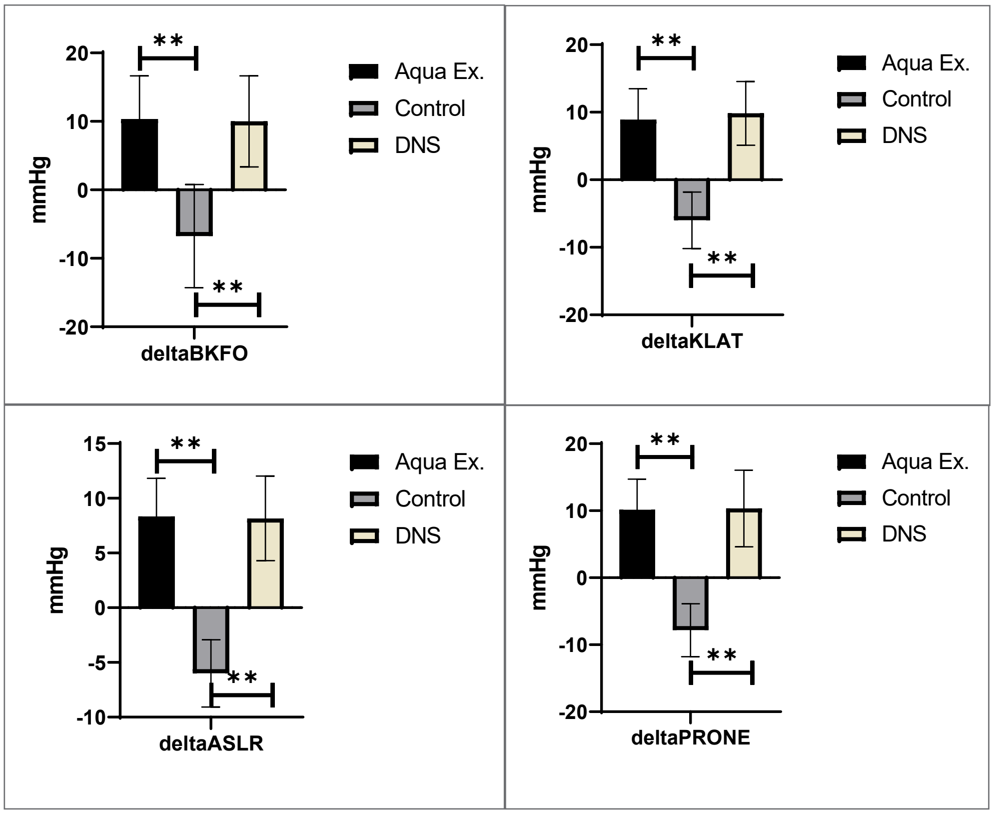

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Figure 3. Paired comparison of study groups regarding improvement of LPC scores

* Pre-test and post-test; * P≥0.05, ** P=≥0.01.

observed between the study groups regarding the kyphosis scores. As for the lordosis scores, no significant difference was observed between the duration and type of the interventions, and duration had no significant main impact. However, a significant difference was observed between the study groups in this regard ($F_{2,33}$=6.08, P=0.007, η^2=0.311). Our findings also demonstrated a significant relationship between the duration and type of the interventions in the spinal slope scores ($F_{2,33}$=3.28, P=0.05, η^2=0.196), and duration had no significant main impact (P>0.05). Furthermore, no significant difference was observed between the study groups for the spinal slope scores ($F_{2,33}$=6.99, P=0.004, η^2=0.341) (Table 3).

4. Discussion

Based on the results of the current study, both interventions reduced the pain and disability of the patients with NSLBP by approximately equal proportions, which confirmed the first hypothesis of the research. Specialists recommend aquatic therapy for patients with problems, such as hydrostatic pressure, weight loss, heat loss, stimulation of sensory receptors, and inhibition of pain receptors [23]. This has also been confirmed in the review studies conducted by Shi et al. and Waller et al., who concluded that AEs can significantly decrease pain and improve the function of subjects with chronic LBP [23, 24]. Meanwhile, a considerable number of these patients are unable to enjoy the benefits of water exercises and water training due to high costs, pool hygiene, and lack of hydrotherapy facilities. Therefore, we sought a non-aquatic rehabilitation method with similar effects on reducing pain and disability in these patients.

DNS invokes ideal movement patterns from the central nervous system (CNS). Overall, DNS is based on the assumption that certain fundamental motor patterns in healthy children are pre-planned and remain in the CNS during adulthood. The brain forgets primary movements with the movements that are performed incorrectly in daily life. DNS exercises restore an ideal exercise program that has been misunderstood and forgotten by the CNS since childhood. DNS is also based on comparing an athlete's movement pattern with a healthy child's movement pattern so that a disturbed movement pattern could be transformed into an optimal growth kinesiology pattern [11, 25].

DNS has recently been introduced as a sports rehabilitation protocol. However, limited research has investigated the effects of this approach on the rehabilitation of patients. In a study regarding dynamic neuromuscular stabilization and sports rehabilitation, Frank et al. reported that the DNS protocol provided practical tools to evaluate and activate the inner spinal stabilizers to enhance the motion system for the rehabilitation of sports injuries [11]. In another research, Lim et al. evaluated the effects of DNS training on the lumbar and postural kinematic flexion of adults with chronic LBP and reported that DNS had more effective results compared to physiotherapy [26]. The results of the aforementioned studies are consistent with our results.

Poor LPC is a major issue detected in patients with LBP, and two classifications of patients with LBP have been determined. Torso movement adaptation in response to pain is induced by the CNS in the first category of these patients, while impaired motion control has been reported in the second category due to abnormal movement patterns in the lumbopelvic region [12, 27]. In the present study, LPC was assessed by four tests, and no significant differences were denoted between the AEs and DNS exercises regarding their impact on uncontrolled lumbopelvic movements. This confirmed the second hypothesis of the research since some DNS exercises target the stability of the central area and co-contraction of the agonist and antagonist muscles in the torso, thereby affecting the activation of lumbar stabilizing muscles and preventing several unwanted movements. In AEs, part of the exercises is focused on the strengthening of the core region. In addition, coordination exercises in the aquatic environment can be effective in controlling the compensatory movements in the lumbopelvic area. This probability has been confirmed based on the results reported by Paungmali et al., which indicated a significant improvement in the lumbopelvic stability of patients with chronic LBP after performing core strengthening exercises [28]. In this regard, Inani and Selkar reported the more significant effect of core exercises on reducing pain and improving the performance of patients with chronic LBP compared to traditional exercises [29].

Limited studies have investigated the effectiveness of DNS exercises in rehabilitation, and the findings are mostly consistent with the results of the current study. For example, Mahdieh et al. evaluated the effect of DNS exercises on improving functional movement and observed that fundamental DNS movements can enhance functional movements [21]. In another study, Son et al. assessed the effects of DNS on the diaphragm, balance, and gate movements of patients with Cerebral Palsy (CP) and confirmed that DNS is an effective intervention to facilitate the activation of deep core, diaphragm, and abdominal muscles, as well as a proper technique to improve standing, walking, and leaping in patients with spastic diplegia CP [30]. In a case study conducted by Ross, DNS-based core exercises were more effective in the rehabilitation and pain relief of patients with chronic NSLBP compared to belt fastening [31]. In this regard, our findings are consistent with the results of the aforementioned studies.

Despite the relatively equal effect of the two interventions on the improvement of pain, function, and LPC, the results obtained from posture and spinal movement assessment showed a significant impact of AEs only on improving the spinal inclination angle in the standing position compared to the DNS exercises. The spinal inclination is the same as pelvic tilt, and increasing this angle is associated with an increased pelvic tilt angle, while a zero angle shows the vertical position of the pelvis. This issue can be due to the stretching exercises performed in the AE intervention in the current research, such that the flexor muscles of the thigh (i.e., iliopsoas and rectus femoris) may be stiff in these individuals and cause anterior pelvic tilt due to their connections on the pelvis. In the present study, various stretching exercises were performed on these muscles during the AE sessions, which may decrease the anterior tilt angle in the patients of this group. The hydrostatic pressure of water and massaging properties of water molecules can provide optimal treatment for stiffened muscles and lead to an anterior tilt. In this regard, our findings are consistent with the results obtained by Kalkhoran and Khanjari, which indicated the positive impact of aquatic therapy on improving muscle balance in patients with LBP [32].

In another research, Ansari et al. confirmed the effects of AEs on improving muscle balance and reducing pain in subjects with LBP [20]. Based on the results of the current study, the ROM of the spine (total trunk flexion+full trunk extension) of the patients in the standing position has significantly improved in the AE group, which can be attributed to the effects of water on muscle flexibility and the relaxation of the patients participating in the AEs. In this regard, our findings are consistent with the results obtained by Ansari et al., who reported the positive impact of aquatic therapy on the pain, performance, and electromyography of the muscles in women with chronic LBP [20]. In contrast, Nemčić et al. stated that aquatic and non-aquatic exercises can improve pain, disability, and lumbar ROM while reporting no significant difference between these exercises [33]. In another study conducted by Bello et al., AEs were reported to have a more significant impact on spin flexibility compared to alternative clinical exercises [34].

Some of the limitations of the present study were the small sample size and the treatment of the patients with LBP. Therefore, it is recommended that similar investigations be performed on larger sample sizes in different conditions to obtain more accurate results. Another limitation was the lack of appropriate training and poor understanding of the DNS exercises in some subjects. A few days of DNS training before the actual intervention may yield more accurate results, and appropriate training is recommended for further investigations. In addition, we did not consider the psychological issues associated with NSLBP that may affect exercise performance.

5. Conclusion

According to the results, no significant differences were observed between the study groups regarding the impact of the interventions on improving pain and disability. Also, no significant difference was observed between the AEs and DNS groups regarding the improvement of LPC disorders. The spinal inclination angle of the posture and inclination of range of motion was significantly improved only by the AEs. According to the results, the DNS exercises and AEs had no significant differences in terms of impact on improving pain, disability, and LPC. Therefore, proper alternatives can be used to enhance such dysfunctions in case of the lack of access to pools and hydrotherapy pools.

Ethical Considerations

Compliance with ethical guidelines

This study was conducted in accordance with the Helsinki-Tokyo Declaration, and the study protocol was confirmed by the Ethics Committee of Razi University, Iran (Code: IR.RAZI.REC.1399.005). The study has also been approved by the Iranian Registry of Clinical Trials (Code: IRCT20200704048002N1). A written informed consent was obtained from the subjects, and they were allowed to withdraw from the study at any given time.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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