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The Effect of Eight Weeks of Dynamic Neuromuscular Stabilization Training on Functional Movement Screening and Postural Control in Athletes with Lower Crossed Syndrome

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ABSTRACT

Background: The present study aimed to evaluate the effectiveness of Dynamic Neuromuscular Stabilization (DNS) training on movement patterns and postural control in female athletes with lower cross syndrome (LCS).
Methods: This research employed a quasi-experimental, pre-and post-test design. Thirty healthy female athletes with an average age of 24.98±2.26 years and diagnosed with LCS were randomly divided into an experimental group (15 subjects) and a control group (15 subjects). Participants in the experimental group completed the DNS training protocol, which consisted of three sessions per week for eight weeks. Postural control and functional movements were assessed using the Y-balance test and Functional Movement Screening (FMS) before and after the intervention. Statistical analysis included paired t-tests, ANCOVA, and the Wilcoxon test.
Results: ANCOVA revealed a significant difference in the Y-balance test and FMS scores between the experimental and control groups for participants with LCS. Within-group analysis indicated that the post-test mean scores of the experimental group were significantly improved compared to pre-test scores following DNS training ($P<0.05$).
Conclusion: The results indicate that eight weeks of DNS training significantly improved functional movement screening and Y-balance test scores in female athletes with LCS. Therefore, DNS exercises may be recommended to athletes to enhance balance and lower limb performance.

Introduction

Prolonged inappropriate posture can lead to widespread adverse adaptations in joints and soft tissues over time, including muscle shortening and stiffening on one side, elongation, and weakness on the opposite side, resulting in abnormalities and muscle imbalance [1, 2]. According to the muscle imbalance theory, derived from Janda's approach, three main patterns of imbalance are classified: upper cross syndrome (UCS), lower cross syndrome (LCS), and layer syndrome (LS). LCS is a muscle imbalance pattern characterized by a cross-imbalance in the lumbar and hip muscle segments; it involves stiffness in the lumbar extensors and hip flexors, along with weakness in the hip extensors and trunk flexors. This syndrome contributes to significant issues such as joint function disorder, anterior pelvic tilt, increased lumbar lordosis curve, tibial lateral rotation, and knee hyperextension in the affected individual's posture [3].

Muscle imbalances can sometimes impair postural control and contribute to structural abnormalities. Vladimir Janda highlighted the interconnection between

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the nervous, muscular, and skeletal systems, suggesting that defects in any joint or muscle group can affect the function and quality of other muscles and joints [2, 4]. Changes or disorders in one area's muscles and joints can trigger chain reactions impacting other body parts. According to scientific literature, these chain reactions in posture occur across three systems—articular, muscular, and neural. These systems interact closely, and changes in one chain can disrupt another and vice versa [5, 6].

Training programs that integrate all body segments and enhance their coordinated function are essential for addressing musculoskeletal abnormalities. Furthermore, the effect of these abnormalities on an individual's motor function and balance should not be underestimated. Among such holistic training methods, the dynamic neuromuscular stabilization (DNS) technique has gained recognition in sports rehabilitation. DNS emphasizes not only muscular strength but also the involvement of the nervous system, offering a comprehensive approach to rehabilitation [7].

Dynamic Neuromuscular Stabilization (DNS) therapy accurately assesses the quality of stability or movement restoration through a spine integration system incorporating specific exercises based on the ideal musculoskeletal position. These exercises follow Janda's chain reaction principles, inspired by the neuromuscular development observed in healthy infants. They aim to re-stimulate neuromuscular growth and enhance balance and motor function, which can benefit athletes.

The fundamental techniques in DNS therapy include core stabilization and control training, limb pattern training (both with and against limb movement for forward motion and support), evolutionary postural movement models for positional stabilization, and attention to muscle chain involvement. Additionally, DNS emphasizes postural function alignment with movement force, stability training alongside breathing techniques, maintaining spinal stability, and advancing movements from simple to complex without pathological patterns. Exercises begin after patients receive awareness training from healthcare providers [7].

Yi Lin Lim investigated the effects of DNS training on postural control and lumbar spine flexion in individuals with nonspecific chronic low back pain. The findings indicated that DNS exercises improved patients' balance, highlighting the need for further studies on DNS applications in physiotherapy settings [8].

Movement screening tests are valuable for evaluating general performance and various motor and functional capabilities. These tests serve three main objectives: (1) dynamic evaluation of the kinematic chain, (2) detection of body alignment, and (3) identification of weak movement patterns [9]. Movement screening tests assess an individual's susceptibility to injury, inefficiencies, and weaknesses within the kinematic chain. This, in turn, allows for developing effective exercise programs to enhance motor abilities. The Functional Movement Screening (FMS) test specifically challenges an individual's capacity to perform movement patterns that involve proprioception, coordination, range of motion, muscle strength, balance, and flexibility [10, 11].

Based on the principles underlying DNS exercises and their potential effectiveness for Lower Cross Syndrome (LCS), neuromuscular training appears to be a promising intervention for patients with this disorder. However, no studies to date have examined the impact of this type of neuromuscular training on postural control and movement function, specifically in athletes with LCS. Therefore, this study aimed to evaluate whether DNS training could improve postural control and motor function as measured by the Functional Movement Screening (FMS) test in female athletes with LCS.

Methods

This quasi-experimental study employed a pre-test and post-test design. The sample comprised 30 female athletes aged 20–30 years with Lower Cross Syndrome (LCS) from Mashhad, who were purposefully and randomly divided into control and experimental groups based on inclusion and exclusion criteria. Ethical considerations were followed per the Ethics Committee guidelines of Shahroud University (IR.SHAHROODUT.REC.1402.032). Postural control was evaluated using the Y-balance test, and functional movement was assessed through the Functional Movement Screening (FMS) test.

Inclusion criteria included: diagnosis of LCS syndrome, lumbar lordosis above 46.92 degrees, anterior pelvic tilt above 5 degrees, a minimum of three years of exercise experience, regular exercise (1-4 days per week) in both groups, voluntary participation, completion of an individual consent form, and adherence to health protocols for COVID-19 prevention [12, 13]. Exclusion criteria encompassed experiencing pain in the lower back or lower limbs, presence of a lumbar disc condition, pain during exercises, failure to complete the training program, irregular attendance, and failure to maintain the required time interval for sessions due to COVID-19 concerns.

Tools

Evaluating LCS: The selected indices for assessing LCS complications were lumbar hyperlordosis angle and anterior pelvic tilt. A flexible ruler [14] measured the lordosis angle, while a tilt gauge [15] assessed the pelvic tilt angle. For lordosis measurement, participants positioned themselves in the designated area for spinal arch assessment. The evaluator identified and marked the T12 and S2 spinous processes using palpation. The flexible ruler was placed between these marked points, with uniform pressure applied to ensure no space between the ruler and the skin. Without altering the arc, the evaluator transferred the ruler's curvature onto A3 paper by tracing the marked points. A straight line (labeled "I") was drawn connecting these points, and a perpendicular line from the deepest part of the arc was measured as the width (H). The lumbar curvature angle (ϴ) was calculated using the formula: $\Theta=4\text{Arctan}(2H/L)$ [14, 16].

For pelvic angle measurement, participants stood on a flat surface, placing one hand on the posterior superior iliac spine (PSIS) and the other on the anterior superior iliac spine (ASIS). Once aligned, the degree was read directly (Figure 1) [15, 17].

$$\text{Score} = \frac{\text{Access distance}}{\text{Limb length}} \times 100$$

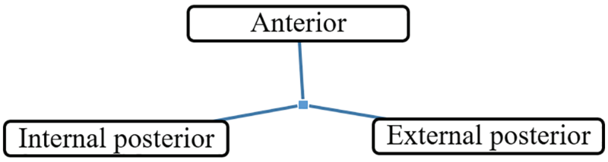

Figure 1: Y-balance test (left) and scoring method (right)

Y-Balance Test: This test was used to evaluate dynamic balance. Participants stood barefoot, positioning one foot at the center of the Y-board with the other foot adjacent to it. Maintaining balance on one foot, participants extended the free foot forward and diagonally backward in both the internal and external directions (Figure 3.3). The reach distance from the center was measured in centimeters. Each direction was tested three times. Before starting, the lower limb length was measured [18]. The balance test score in each direction was calculated individually using the following formula:

Functional Movement Screening (FMS) tests: The FMS test results are categorized into three scoring levels:

1. **Score of 3**: The task is performed correctly without errors or compensatory movements.
2. **Score of 2**: The task is performed correctly but with compensatory movements.
3. **Score of 1**: The task is completed with difficulty and requires compensatory movements.

If the subject experiences pain during any task or clearing test, no points are awarded for that movement. Consequently, a subject could receive a final score of zero if pain is reported in each movement test or a maximum score of 21 if they achieve a score of three on every movement test [11, 19].

Procedure

After visiting sports clubs in Mashhad, athletes with visible signs of anterior pelvic tilt and increased lumbar lordosis were identified. Those meeting the selection criteria who volunteered to participate were informed about the research process. Following confirmation of eligibility for Lower Crossed Syndrome (LCS) and other criteria, participants received a detailed explanation of the study's purpose and the DNS training protocol. They were then asked to complete a consent form confirming their willingness to participate, which allowed the research process to begin as scheduled.

Initial assessments were performed using a flexible ruler and tilt gauge, and participants meeting the criteria for lordosis and anterior pelvic tilt were designated as research subjects. Participants completed a personal information questionnaire detailing age, height, weight, lower limb length, and sports activity history. Thirty athletes were randomly assigned to either the control or experimental group. Before implementing the training protocol, Y-balance and FMS tests were administered to both groups to establish baseline (pre-test) data.

The experimental group then completed an eight-week training protocol with three sessions per week, held either at participating clubs or at home for those who could not attend in person. This study occurred in Mashhad in the summer of 2020, during the COVID-19 pandemic, and health precautions were implemented to minimize virus transmission during tests and training sessions. Each session allowed up to four participants to train over a two-and-a-half-hour period. After the eight-week program, the Y-balance and FMS tests were re-administered as a post-test, with the results recorded.

Statistical Method

Data were analyzed using SPSS version 22. Descriptive and inferential statistical analyses were conducted. The Shapiro-Wilk test was used to test data normality. Assuming a normal distribution, a paired t-test assessed within-group effects, while ANCOVA evaluated between-group effects. For non-normally distributed data, the Wilcoxon test was applied ($P \leq 0.05$).

Results

This section details the demographic and physical characteristics of the subjects, including height, weight, age, lordosis angle, anterior pelvic tilt, body mass index (BMI), and leg length. Table 1 summarizes these characteristics along with the results of the group homogeneity analysis.

The Shapiro-Wilk test indicated that the FMS test subscales exhibited a non-normal distribution ($P<0.05$). Consequently, the Wilcoxon test, with a 95% significance level and $P\leq0.05$, was applied to assess the impact of DNS training on FMS subscales. The test confirmed normal distribution for the FMS test's total score and the anterior, internal posterior, external posterior, and total Y-balance test scores ($P<0.05$). To examine the effect of DNS exercises on the Y-balance variable between the two groups (control and experimental), ANCOVA was conducted, and a paired t-test was used within each group at a 95% significance level ($P\leq0.05$).

According to the Wilcoxon test results shown in Table 2, there was a statistically significant difference in the mean test scores for Deep Squat ($P=0.014$), Shoulder Mobility ($P=0.003$), In-line Lunge ($P=0.039$), Hurdle Step ($P=0.008$), Trunk Stability Push-Up ($P=0.033$), and Rotary Stability ($P=0.002$) in the experimental group between the pre-test and post-test ($P<0.05$). In contrast, no statistically significant differences were found in the control group for the mean scores of Hurdle Step, In-line Lunge, Deep Squat, Active Straight Leg Raise, Rotary Stability, Shoulder Mobility, and Trunk Stability Push-Up between pre-test and post-test ($P<0.05$). Furthermore, no significant difference was observed between the two groups regarding the Active Straight Leg Raise variable.

The ANCOVA test was employed to compare the total FMS score and posture control test variable (across the three indices of anterior, internal posterior, external posterior, and total Y-balance score) between the control and experimental groups. The analysis of covariance revealed a significant difference between the control and experimental groups for the total FMS score and the posture control test variable in athletes with LCS (P=0.001), as determined by examining the mean scores (Table 3).

Table 4 summarizes the paired t-test results comparing the total scores of the FMS and Y-balance tests between the pre-test and post-test.

Table 1: Demographic information of samples (mean±standard deviation)

Variable	Groups	No.	Mean and standard deviation	t value	Significance level
Age (years)	Experimental	15	25.13±2.99	0.276	0.784
	Control	15	24.84±2.23		
Weight (kg)	Experimental	15	67±3.87	-0.689	0.496
	Control	15	68.06±4.57		
Height (cm)	Experimental	15	167.20±4.14	0.314	0.756
	Control	15	166.73±3.99		
BMI	Experimental	15	20.62±1.59	-1.144	0.262
	Control	15	21.33±1.76		
Lower limb length	Experimental	15	79.06±3.53	0.456	0.652
	Control	15	78.53±2.82		
Lordosis angle	Experimental	15	47.60±5.51	-0.665	0.512
	Control	15	48.80±4.29		
Anterior pelvic tilt	Experimental	15	9.93±2.31	-0.467	0.644
	Control	15	10.33±2.38		

BMI: Body mass index

Table 2: Wilcoxon test results comparing the mean score of the FMS subscales in the experimental and control groups

Variable	Groups	Score			Mean Score		Test statistics	
		Positive score	Negative score	Equal score	Positive score	Negative score	z	sig
Deep squat	Experimental	0	6	9	0	3.5	-2.449	*0.014
	Control	2	3	10	3	3	-0.447	0.655
Hurdle step	Experimental	0	7	8	0	4	-2.646	*0.008
	Control	1	1	11	2.5	2.5	-1	0.317
In-line lunge	Experimental	3	10	2	6	7.30	-2.066	*0.039
	Control	4	4	7	5	4	-0.302	0.763
Shoulder mobility	Experimental	0	9	6	0	5	-3	*0.003
	Control	2	2	11	3	2	-0.378	0.705
Active straight leg raise	Experimental	2	6	7	4	4.67	-1.508	0.132
	Control	3	4	8	4.17	3.88	-0.264	0.792
Trunk stability push-up and	Experimental	1	7	7	3.5	4.64	-2.126	*0.033
	Control	3	4	8	4.5	3.63	-0.090	0.928
Rotary stability	Experimental	0	10	5	0	5.5	-3.051	*0.002
	Control	2	1	12	2	2	-0.577	0.564

*Significance level P<0.05

Table 3: Results of the analysis of covariance: the effect of the independent and predictor variable on the post-test

Variable	Groups	Mean	F	Df	P	Eta Squared
Total FMS test score	Experimental	17.73±1.90	15.002	1	0.001	0.462
	Control	14.20±0.86				
Anterior	Experimental	92.52±6.50	18.818	1	0.001	0.420
	Control	80.14±8.27				
Medial posterior	Experimental	102.29±5.51	40.294	1	0.001	0.608
	Control	88.49±5.37				
Lateral posterior	Experimental	97.23±5.14	30.514	1	0.001	0.540
	Control	84.77±4.40				
The total score of Y	Experimental	97.34±4.55	10.184	1	0.004	0.281
	Control	83.99±4.65				

FMS: Functional Movement Screen

Table 4: The mean difference of the total variable of the Functional Movement Screen (FMS(test in the subjects before and after the training protocols

Variable	Experimental group			Control group		
	M±SD			M±SD		
	Pre-test	Post-test	P value	Pre-test	Post-test	P value
Total FMS score	14.10±0.84	17.73±1.90	0.001	14.06±0.86	14.20±0.86	0.701
Anterior	79.98±7.90	92.52±6.50	0.001	79.37±9.11	80.14±8.27	0.117
Medial posterior	88.64±7.52	102.29±5.51	0.001	87.89±6.74	88.49±5.37	0.403
Lateral posterior	83.27±6.09	97.23±5.14	0.001	84.23±5.54	84.77±4.40	0.481
The total score of Y	83.97±4.39	97.34±4.55	0.001	83.83±5.48	83.99±4.65	0.751

FMS: Functional Movement Screen

The mean total score of the FMS test in the experimental group increased from 14.10±0.84 before DNS exercises to 17.73±1.90 after participation. The paired t-test results indicated that this increase of 3.63 was statistically significant (P=0.001). Similarly, the mean total score of the Y-balance test in the experimental group rose from 83.97±4.39 to 97.34±4.55 following DNS exercises. The paired t-test confirmed that this increase of 13.37 in the Y-balance test score was also statistically significant (P=0.001).

Discussion

The current study investigated the impact of an 8-week DNS training protocol on motor function and postural control in 20–30-year-old female athletes with LCS. Results indicated a significant improvement in the FMS test scores of athletes in the experimental group. In contrast, the control group showed no statistically significant change between pre-and post-test scores. These findings align with previous research, including studies by Arazzadeh (2018) [20], Daneshjoo (2019) [21], Sheikhabadi (2020) [22], Sultan Doost (2020) [23], and Zoltkaf (2020) [24], which support the positive effect of exercise interventions on FMS outcomes. However, the training protocols differed across studies. Zoltkaf's (2020) research closely resembles the present study, examining DNS exercises' impact on motor function in 34 healthy students at the University of Isfahan. The pre- and post-test motor function was evaluated using five tests: FMS, SLS, YB, LESS, and LESS-RT. Zoltkaf's study applied a DNS protocol over 6 weeks, with each session lasting 50 minutes, resulting in improved FMS scores in the experimental group compared to the control group [24].

Various studies have assessed the influence of DNS training on factors such as anomaly correction and motor function. For instance, Ganji (2018) explored an 8-week DNS program's effects on function and quality of life in individuals recovering from a stroke, finding significant improvements in the LEAF scale and quality of life questionnaire points for both men and women [25]. Similarly, Won-Sik Bael (2019) investigated the impact of DNS training on reducing forward head posture, kyphosis, and lordosis, finding that after a 6-week intervention, the experimental group experienced significant decreases in these postural abnormalities compared to the control group [26].

Adopting incorrect body postures, often due to a lack of awareness and persistence of improper positioning in daily life, can lead to physical abnormalities. Such postures cause deviations from an aligned, upright structure, fostering compensatory movement patterns. Lower Crossed Syndrome (LCS) is one compensatory pattern Janda identified. Characterized by anterior pelvic tilt and an imbalance of lower extremity muscles, LCS negatively impacts the function of the lumbar-pelvic region, trunk, and lower limbs. The DNS training protocol may improve FMS test scores by strengthening weakened muscles such as the abdominals, gluteus maximus, and gluteus medius. DNS exercises establish coordination among the trunk and thigh muscles, stabilizing the pelvis and lower limbs in proper alignment during dynamic movements [27].

Therefore, weakness and decreased endurance of the posterior, anterior, and lateral trunk-stabilizing muscles reduce the strength and effectiveness of the muscles around the hip. During vertical or standing activities, the thigh muscles transmit force from the lower limbs to the spine. Consequently, weakness in the stabilizing core muscles can disrupt the alignment of the lower extremity during dynamic movements, leading to irregular movement patterns in the lower extremity [27, 28]. Other mechanisms impacting outcomes include reductions in anterior pelvic tilt and lumbar lordosis. Specific DNS exercises address torso flexibility, targeting abnormalities where muscles such as the erector spinae, rectus femoris, latissimus dorsi, and iliopsoas are shortened. Lengthening and enhancing flexibility in these areas can reduce lumbar lordosis in individuals with LCS, directly impacting certain FMS tests.

The total FMS test score was significantly improved by DNS training, with observed mean values increasing from 14.10±0.84 to 17.73±1.90 in the exercise group. In general, DNS exercises targeting stretching of shortened areas, strengthening of the core and serratus muscles, shoulder flexibility, Theraband-based strengthening for the scapula and shoulder joint, and movement patterns similar to FMS subscales—engaging relevant muscles and joints—all contributed to improvements in FMS scores. Additionally, increased core endurance and hamstring flexibility in the DNS training protocol positively influenced FMS test scores.

Moreover, the results showed that 8 weeks of dynamic neuromuscular stabilization (DNS) training had a significant effect on the Y-balance test in the anterior, medial posterior, and lateral posterior indices, as well as the total score in 20–30-year-old female athletes with LCS. The findings regarding the effectiveness of sports exercises on Y-balance test indices in athletes are consistent with the results of studies by Mahmoudkhani (2019) [29], Daneshjoo (2019) [21], Naderi (2016) [30], Zoltkaf (2020) [24], and Burro et al. (2015) [31]. Several articles have explored improvements in balance following DNS exercises, some of which are summarized here.

Son et al. (2017) investigated the effect of 4 weeks of DNS training on diaphragmatic movement, postural control, balance, and gait function in individuals with cerebral palsy, concluding that these exercises are effective interventions for facilitating activation of the abdominal and sedentary muscles, including the diaphragm and internal obliques, thereby enhancing posture, walking, and jumping in participants with cerebral palsy [32]. Zamani (2016) studied the effect of 8 weeks of DNS training on balance in women with multiple sclerosis, finding DNS exercises effective in improving balance. The researchers attributed this effectiveness to the design of DNS exercises based on reflex movements seen in infancy, which support regeneration and repair of movement patterns in patients and normal motor development [33]. Maintaining balance during many sports activities is a fundamental component of physical fitness that can be developed through targeted exercises [34]. DNS exercises, designed to improve neuromuscular coordination across strength, motion, and proprioception functions, are particularly important [35].

Neuromuscular training incorporates core stability, flexibility, balance, strength, agility, and plyometric training. Core stability, strength, and balance training have improved athletes' balance. Possible mechanisms of effectiveness include stronger abdominal muscles providing core stability, which facilitates lower extremity mobility. Key abdominal muscles, such as the transversus abdominis, internal and external obliques, and rectus abdominis, stabilize the spine during contraction and support lower limb movement [36]. When the transversus abdominis contracts, intra-abdominal pressure and thoracolumbar fascia tension increase, offering solid support for movement and muscle activation [36]. A muscle group, including the rectus abdominis and the internal and external obliques, is activated in specific patterns based on limb movement and postural control [37]. According to Kiebler's findings, activation of core muscles during lower extremity movement enhances postural control, allowing the body to generate rotational torque and limb movement via stabilizing core muscle activation [37].

The consistency of this research with other studies supports the role of resistance training with Theraband on balance. Research suggests that the increase in balance may be due to improved joint stabilization through enhanced muscle strength, deep receptor activity, and neuromuscular control, which are crucial for maintaining balance and achieving higher scores [38]. Thus, one reason for the balance improvement following resistance training may be attributed to increased lower limb strength post-training. The primary driver of strength increase in the early stages of strength training is nervous system adaptation, which can enhance balance [39]. It has been suggested that certain motor units, typically inactive in untrained individuals during maximal contractions, can be activated through exercise, facilitating the recruitment of high-contraction motor units. Additionally, muscle coordination improves as the nervous system gains proficiency with exercise repetition, thereby enhancing functionality [38, 39]. Given the effectiveness of this training protocol, DNS exercises can be recommended to athletes with LCS to improve their functional capacity and balance.

Conclusion

DNS training is a rehabilitation technique that has recently gained traction in studies that facilitate the neuromuscular system. The results showed that 8 weeks of DNS training significantly improved FMS and Y-balance test scores in female athletes with LCS. This exercise regimen enhances strength, agility, flexibility, balance, and core stability and can be conveniently performed at home or elsewhere without substantial costs. Therefore, DNS exercises are recommended for athletes with LCS to improve balance and lower limb function. These exercises may also have the potential to reduce the incidence of LCS. Experts in the field are encouraged to incorporate these exercises to mitigate the disorder. Further research is suggested to evaluate the extent of reduction in lumbar lordosis and anterior pelvic tilt in patients with LCS following these exercises.

Conflict of Interest: None declared.

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