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Original Research Article

Comparative Analysis of Dynamic Neuromuscular Stabilization and Conventional Core Exercises on Core Muscle Weakness and Its Relationship to Chronic Low Back Pain

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Abstract:

Background: Chronic low back pain (CLBP) is a major global health problem strongly associated with core muscle weakness, impaired postural control, and altered neuromuscular coordination. Conventional core exercises improve symptoms but often neglect respiratory–postural integration.

Aim: To compare the effects of Dynamic Neuromuscular Stabilization (DNS) and conventional core exercises on core muscle weakness, postural control, pain intensity, and disability in individuals with CLBP.

Methodology: A single-blinded randomized controlled trial was conducted among 90 individuals with non-specific CLBP. Participants were randomly allocated to either the DNS group or the conventional core exercise group (n = 45 each). Both groups underwent 12 supervised exercise sessions over a four-week period. Outcome measures included ultrasound-based percent change in transversus abdominis, lumbar multifidus, and diaphragm muscle thickness; postural control parameters assessed using a computerized balance system; pain intensity measured using the Visual Analog Scale; and functional disability assessed using the Oswestry Disability Index and Roland–Morris Disability Questionnaire.

Results: Both groups demonstrated significant post-intervention improvements across all outcomes. However, the DNS group showed significantly greater increases in deep core muscle thickness, superior improvements in postural control, and larger reductions in pain and disability scores compared to the control group ($p < 0.001$).

Conclusion: Dynamic Neuromuscular Stabilization is more effective than conventional core exercises in improving deep core muscle function, postural stability, and clinical outcomes in individuals with chronic low back pain.

Keywords: Chronic Low Back Pain, Dynamic Neuromuscular Stabilization, Core Stability, Postural Control, Diaphragm Function.

Introduction

CLBP is one of the most common musculoskeletal disorders worldwide, with lifetime prevalence estimates ranging from 13.1% to 20.3% [1]. Over the last three decades, the global burden of CLBP has substantially increased, as evidenced by the rise in the number of people suffering from this condition from 0.37 billion in 1990 to 0.57 billion in recent times. The increase has turned into a significant rise in YLDs, making CLBP a major public health issue. The personal, social, and economic impacts of the disease are great, impacting quality of life, work productivity, and family relationships [2]. Regardless of the progress made in diagnosis and management, the outcomes of CLBP treatment remain generally unsatisfactory, which calls for more effective intervention measures.

Moderate-quality evidence shows that core stability exercises are effective in improving symptoms of CLBP compared to no treatment, usual care, or placebo interventions [3]. Core stability exercises seek to improve the strength, endurance, and coordination of the deep trunk muscles, which are important in maintaining spinal stability and postural control. Yet, conventional approaches often fail to recognize the integrated role of the diaphragm and other respiratory muscles in maintaining core stability, thereby limiting treatment efficacy [4]. This finding underlines the necessity for novel rehabilitation strategies that intervene with both the postural and respiratory components, reflecting the complex nature of CLBP.

CLBP is generally accompanied by impaired postural control, changed motor patterns, and atrophy of deep core muscles such as TrA and MF. Regarding postural control, post urography experiments show that patients with CLBP consistently display increased sway and COP displacement, especially in the AP direction [5]. Reduced muscle thickness and contractility signify these impairments in the function of the core muscles in patients compared to healthy controls. According to Panjabi, these deficits in postural control originate from insufficient core stability-a state usually guaranteed through the co-ordinated co-contraction of core muscles [6]. Even though conventional core exercises improve muscular contractility and postural control, they usually do not address the role of the diaphragm and fail to incorporate coordinated breathing patterns crucial for optimal functioning of the core [7]. Diminished diaphragmatic excursion during postural tasks is documented for CLBP patients, pointing to disturbed coordination within respiratory and postural control mechanisms.

Dynamic neuromuscular stabilization (DNS) offers a new perspective for the treatment of such limitations by integrating postural control with specific breathing patterns. Based on developmental kinesiology, DNS uses the principles of infant motor development to reclaim optimal motor patterns and improve core stability [8]. With an emphasis on proper coordination between the diaphragm, deep core muscles, and segments of the body, DNS works on maintaining neutral spine alignment and functional postural control in different positions and movements. DNS training activates the appropriate respiratory and core muscles, thereby promoting better intra-abdominal pressure, spinal stability, and functional movement patterns [9].

By contrast, traditional core exercises primarily aim at the development of deep abdominal and spinal muscles to enhance muscular endurance, postural control, and protection of the spine. Exercises such as planks, bridges, and abdominal crunches are generally designed to enhance the contractile capacity of core musculature; however, they often do not sufficiently address the integration of breathing and postural coordination and, therefore, may be less effective in patients with CLBP. Although several studies have investigated the benefits of DNS for pain reduction and functional outcomes in CLBP, only a few quantitative studies have explored the impact of DNS on the contractility of core muscles, postural control, and diaphragm function [10]. In addition, comparative effectiveness regarding DNS versus conventional core exercises has rarely been investigated, which presents a critical research gap.

Given the central role of core muscles and postural control in the etiology and management of CLBP, a comprehensive approach that incorporates both muscle strengthening and coordinated respiratory control may offer superior therapeutic outcomes. The present study is designed to investigate the effects of DNS as compared to conventional core exercises on core muscle thickness, postural control performance, pain intensity, and low back pain-related disability in subjects with CLBP. Since DNS teaches coordination of respiration with activity of the postural muscles, it may offer additional advantages over other conventional modes of treatment, thus providing further impetus for the development of more effective rehabilitation protocols. This study also contributes to the need for integrative approaches in the management of chronic low back pain at large by providing useful clinical implications.

Material and Methods

Study Design: This study adhered to CONSORT guidelines for randomized controlled trials. It was a single-blinded, randomized controlled trial with parallel groups of chronic low back pain (CLBP) patients. Participants were randomly assigned to either the Dynamic Neuromuscular Stabilization (DNS) group or the conventional core exercise group (control group).

Study Area: The study was conducted in the Department of Physical Medicine and Rehabilitation (PMR), Nalanda Medical College and Hospital, Patna, Bihar, India.

Study Duration: The study duration was one year.

Sample Size and Population: A total of 90 participants were included in the study. Participants were equally allocated into two groups, with 45 participants in the Dynamic Neuromuscular Stabilization (DNS) group and 45 participants in the conventional core exercise (control) group. Participants were recruited from patients presenting with chronic low back pain at the Department of PMR, Nalanda Medical College and Hospital, Patna.

Inclusion Criteria

Participants were included if they:

1. Had non-specific low back pain persisting for more than 3 months.
2. Were aged between 18 and 60 years.
3. Had a visual analog scale (VAS) score ≥3 cm.
4. Had a body mass index (BMI) ≤28 kg/m².
5. Had intact psychological and cognitive functions, confirmed by clinical interview and judgment.

Exclusion Criteria

Participants were excluded if they:

1. Had a history of back surgery, spinal tumors, deformities, or infections.
2. Had traumatic or structural low back pain or neurological symptoms (e.g., radiating pain, muscle weakness, sensory deficits, abnormal reflexes).
3. Had previous neurological or cardiopulmonary diseases affecting locomotor performance.
4. Were pregnant.

Randomization and Allocation Concealment: Participants were randomized using block randomization with a block size of **6** to ensure equal distribution between the two groups. The randomization sequence was generated using IBM SPSS version 25.0. Allocation concealment was ensured using sealed, opaque, sequentially numbered envelopes prepared by an independent researcher. Envelopes were opened only after participants completed baseline assessments.

Blinding: A designated researcher, blinded to group allocation, conducted all clinical assessments. Physical therapists assisting participants during the interventions were also blinded to the study hypotheses to minimize assessment and performance bias.

Procedure: After enrollment, all participants underwent baseline assessments prior to the initiation of the intervention. Before the intervention period, participants in both groups received standardized health education regarding chronic low back pain to ensure adequate understanding of the training objectives and exercise protocols. The intervention was conducted over a period of four weeks, during which participants completed a total of 12 supervised training sessions at a frequency of three sessions per week. Each session lasted 50 minutes and followed a standardized structure comprising a 5-minute warm-up, 40 minutes of main exercise, and a 5-minute cool-down. Two experienced physical therapists supervised all sessions to ensure correct execution of exercises, safety, and adherence to the study protocol. Exercise intensity, volume, and complexity were progressively increased throughout the intervention period in accordance with the principle of progressive overload. Attendance was recorded using session logs, and participants-maintained exercise diaries to monitor adherence and report any discomfort. Participants were contacted regularly by the research team to encourage compliance and address concerns. If intolerable pain or adverse symptoms occurred, the intervention was immediately discontinued, and appropriate medical care was provided. Participants who failed to complete the intervention protocol were considered dropouts and excluded from the final analysis.

Data Collection: All outcome measurements were collected at baseline and immediately after the completion of the four-week intervention by a trained physician who was blinded to group allocation. The assessor underwent standardized training to ensure consistency in musculoskeletal ultrasound measurements, balance assessment procedures, and administration of questionnaires. Core muscle morphology was assessed using diagnostic musculoskeletal ultrasound to measure bilateral transversus abdominis, lumbar multifidus, and diaphragm muscle thickness at rest and during maximum voluntary isometric contraction. To minimize fatigue, a one-minute rest period was provided between repeated measurements, and the average of three measurements was used for analysis. Percent change in muscle thickness was calculated to account for individual differences and enhance comparability across participants. Postural control performance was assessed using a computerized balance evaluation system in an upright standing position under eyes-open and eyes-closed conditions. Each participant completed multiple trials with standardized rest periods, and mean values were used for analysis. Additionally, participants completed validated questionnaires assessing pain intensity and low back pain-related disability under the guidance of the assessor.

Outcome Measures: The primary outcome measures included changes in core muscle contractility, postural control performance, pain intensity, and functional disability. Core muscle function was evaluated through the percent change in thickness of the transversus abdominis, lumbar multifidus, and diaphragm muscles from rest to maximum voluntary isometric contraction as measured by ultrasound imaging. Postural control outcomes included the average displacement velocity of the center of pressure in the anterior-posterior and medial-lateral directions, variability of displacement, total displacement area, and path length during standing balance tasks. Pain intensity was assessed using the Visual Analog Scale, while functional disability was evaluated using the Oswestry Disability Index and the Roland-Morris Disability Questionnaire. Higher scores indicated greater pain severity or disability.

Statistical Analysis: Data were analyzed using SPSS version 25.0 following a per-protocol approach. Continuous data were presented as mean ± standard deviation. Normality and homogeneity of variance were assessed using the Shapiro-Wilk and Levene tests, respectively. Normally distributed data were analyzed using independent t-tests and two-way mixed repeated measures ANOVA, while non-normally distributed data were analyzed using the Mann-Whitney U test and Friedman test. Chi-square tests were applied for categorical variables. Post-hoc comparisons were performed using Bonferroni correction, and statistical significance was set at $p < 0.05$.

Result

Table 1 presents the baseline demographic and clinical characteristics of the participants in the DNS and control groups, each comprising 45 individuals, and shows that both groups were comparable at baseline. The mean age was similar between the DNS group (38.7 ± 8.8 years) and the control group (39.2 ± 8.5 years), with no statistically significant difference. Gender distribution was also comparable, with 26 males and 19 females in the DNS group and 25 males and 20 females in the control group. There were no significant differences between the groups in terms of BMI, duration of low back pain, baseline pain intensity as measured by VAS, or disability levels assessed using the ODI and RDQ scores. Overall, the absence of statistically significant differences across all baseline variables ($p > 0.05$) indicates that the two groups were well matched prior to intervention, allowing for a valid comparison of outcomes.

Table 1: Baseline Demographic and Clinical Characteristics of Participants (N = 90)

Variable	DNS Group (n = 45)	Control Group (n = 45)	p-value
Age (years), mean ± SD	38.7 ± 8.8	39.2 ± 8.5	0.74
Gender (Male/Female), n	26 / 19	25 / 20	0.82†
BMI (kg/m²), mean ± SD	24.3 ± 2.6	24.6 ± 2.8	0.61
Duration of LBP (months), mean ± SD	15.3 ± 5.9	15.6 ± 5.7	0.8
VAS score (cm), mean ± SD	6.3 ± 1.0	6.2 ± 1.1	0.69
ODI score (%), mean ± SD	36.4 ± 7.6	36.0 ± 7.8	0.83
RDQ score, mean ± SD	13.7 ± 3.4	13.5 ± 3.6	0.85

Table 2 demonstrates a statistically significant improvement in core muscle thickness percent change in the DNS group compared to the control group across all assessed muscles. For the transversus abdominis, participants in the DNS group showed a marked increase from 23.1 ± 6.3% pre-intervention to 40.2 ± 7.6% post-intervention, whereas the control group exhibited a smaller rise from 23.3 ± 6.5% to 31.0 ± 7.0%. A similar pattern was observed for the lumbar multifidus, with the DNS group improving from 18.9 ± 5.9% to 34.8 ± 7.1%, compared to an increase from 19.2 ± 6.1% to 27.6 ± 6.6% in the control group. The diaphragm also showed greater enhancement in the DNS group (22.4 ± 6.1% to 38.1 ± 7.4%) than in the control group (22.6 ± 6.3% to 29.3 ± 6.9%). The significant group × time interaction ($p < 0.001$) across all muscles indicates that DNS intervention was more effective than the control in increasing core muscle thickness.

Table 2: Comparison of Core Muscle Thickness Percent Change Between Groups (N = 90)

Muscle	Group	Pre-intervention (%) Mean ± SD	Post-intervention (%) Mean ± SD	Group × Time p-value
Transversus Abdominis	DNS	23.1 ± 6.3	40.2 ± 7.6	<0.001*
	Control	23.3 ± 6.5	31.0 ± 7.0	
Lumbar Multifidus	DNS	18.9 ± 5.9	34.8 ± 7.1	<0.001*
	Control	19.2 ± 6.1	27.6 ± 6.6	
Diaphragm	DNS	22.4 ± 6.1	38.1 ± 7.4	<0.001*
	Control	22.6 ± 6.3	29.3 ± 6.9	

Table 3 presents the postural control performance outcomes before and after the intervention among 90 participants, showing improvements in both the DNS and control groups. In the DNS group, there was a marked and statistically significant reduction in COP velocity in both the anteroposterior (AP) direction (from 12.4 ± 2.7 to 7.6 ± 2.0 mm/s) and mediolateral (ML) direction (from 10.7 ± 2.4 to 7.1 ± 1.9 mm/s), along with a substantial decrease in COP path length (from 415.6 ± 80.4 to 285.9 ± 68.7 mm), all with $p < 0.001$. The control group also demonstrated statistically significant but comparatively smaller improvements across the same parameters, with reductions in COP velocity AP, COP velocity ML, and COP path length ($p < 0.05$). Overall, these findings indicate that while both interventions were effective in enhancing postural stability, the DNS intervention resulted in greater improvements in postural control outcomes compared to the control group.

Table 3: Postural Control Performance Outcomes Pre- and Post-Intervention (N = 90)

Outcome Measure	Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	p-value
COP Velocity AP (mm/s)	DNS	12.4 ± 2.7	7.6 ± 2.0	<0.001*
	Control	12.2 ± 2.8	10.0 ± 2.5	0.02*
COP Velocity ML (mm/s)	DNS	10.7 ± 2.4	7.1 ± 1.9	<0.001*
	Control	10.9 ± 2.5	9.0 ± 2.3	0.03*
COP Path Length (mm)	DNS	415.6 ± 80.4	285.9 ± 68.7	<0.001*
	Control	408.9 ± 83.6	345.2 ± 75.8	0.02*

Table 4 compares pain intensity and disability outcomes between the DNS and control groups before and after the intervention among 90 participants. At baseline, both groups showed comparable mean scores for VAS, ODI, and RDQ, indicating similar levels of pain and disability prior to treatment. Post-intervention, both groups demonstrated statistically significant improvements across all outcome measures; however, the magnitude of improvement was greater in the DNS group. The DNS group showed a marked reduction in VAS scores from 6.3 ± 1.0 to 1.9 ± 0.7, compared to a reduction from 6.2 ± 1.1 to 3.4 ± 1.0 in the control group. Similarly, ODI scores decreased more substantially in the DNS group (36.4 ± 7.6 to 17.6 ± 5.9) than in the control group (36.0 ± 7.8 to 24.8 ± 6.6). RDQ scores also improved significantly, with the DNS group showing a greater reduction (13.7 ± 3.4 to 5.2 ± 2.3) compared to the control group (13.5 ± 3.6 to 8.4 ± 2.8). Overall, these findings suggest that DNS was more effective than the control intervention in reducing pain intensity and functional disability.

Table 4: Comparison of Pain Intensity and Disability Scores Between Groups (N = 90)

Outcome	Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	p-value
VAS (cm)	DNS	6.3 ± 1.0	1.9 ± 0.7	<0.001*
	Control	6.2 ± 1.1	3.4 ± 1.0	<0.01*
ODI (%)	DNS	36.4 ± 7.6	17.6 ± 5.9	<0.001*
	Control	36.0 ± 7.8	24.8 ± 6.6	<0.01*
RDQ	DNS	13.7 ± 3.4	5.2 ± 2.3	<0.001*
	Control	13.5 ± 3.6	8.4 ± 2.8	<0.01*

Discussion

The findings of the present randomized controlled trial demonstrate that Dynamic Neuromuscular Stabilization (DNS) is more effective than conventional core exercise training in improving core muscle function, postural control, pain intensity, and functional disability in individuals with chronic low back pain. The baseline demographic and clinical characteristics were comparable between the DNS and control groups, with no statistically significant differences observed across age, gender distribution, body mass index, duration of symptoms, baseline pain intensity, or disability scores. This baseline homogeneity confirms that the post-intervention differences observed in the present study are attributable to the nature of the interventions rather than pre-existing group differences, thereby strengthening the internal validity of the findings.

A key finding of this study was the significantly greater increase in transversus abdominis (TrA) contractility in the DNS group compared to the control group. Following the four-week intervention, the DNS group demonstrated an increase in TrA thickness of approximately 17 percentage points, whereas the control group showed a more modest improvement of around 8 percentage points. This finding is consistent with the conceptual framework proposed by Panjabi (2003) [6], which identifies the TrA as a critical component of the local stabilizing system responsible for maintaining intersegmental spinal stability. The magnitude of improvement observed in the DNS group aligns with recent evidence indicating that interventions emphasizing neuromuscular coordination and developmental movement patterns produce superior deep muscle activation compared to conventional strengthening approaches (Ge et al., 2022; Wang et al., 2023) [11,12]. Unlike traditional core exercises, which often preferentially recruit superficial trunk muscles, DNS focuses on restoring optimal motor control and feed-forward activation patterns, providing a plausible explanation for the greater TrA activation observed. In contrast, previous studies examining short-term conventional abdominal training have reported only minimal changes in TrA thickness, supporting the notion that isolated or static exercises may be insufficient to elicit substantial neuromuscular adaptations in deep stabilizing muscles (Park & Yu, 2013) [13].

Similarly, lumbar multifidus thickness increased significantly more in the DNS group than in the control group, further reinforcing the superiority of DNS in targeting deep spinal stabilizers. Multifidus dysfunction, characterized by muscle atrophy and delayed activation, has been widely documented in individuals with chronic low back pain (Zhang et al., 2020) [14]. In the present study, the DNS group exhibited a marked increase in multifidus thickness, exceeding the improvements observed following conventional core exercise training. These findings suggest that DNS may be particularly effective in addressing neuromuscular deficits associated with chronic low back pain by facilitating coordinated activation of the local stabilizing system. While stabilization-based exercises have previously been shown to improve multifidus morphology (Hlaing et al., 2021) [15], the larger magnitude of change observed in the DNS group highlights the added benefit of emphasizing neuromuscular timing and motor control rather than strength enhancement alone.

An important and novel contribution of the present study is the assessment of diaphragm contractility as a component of core muscle function. The significantly greater increase in diaphragm thickness observed in the DNS group supports the growing body of evidence recognizing the diaphragm as an integral element of the core stabilization system (Kolar et al.,

2012) [4]. DNS training explicitly integrates diaphragmatic breathing with postural alignment and movement control, thereby enhancing intra-abdominal pressure and spinal stiffness. The observed morphological adaptations in diaphragm thickness following the DNS intervention extend previous findings that have largely focused on short-term or acute changes in diaphragmatic activation (Lee et al., 2022) [16]. These results also corroborate narrative and systematic reviews highlighting the beneficial effects of breathing-based stabilization exercises on trunk control, pain reduction, and functional outcomes in individuals with low back pain (Sannasi et al., 2023) [7].

Improvements in postural control further differentiated DNS from conventional core exercise training. The DNS group demonstrated significantly greater reductions in center of pressure velocity and path length, particularly in the anterior–posterior direction, indicating enhanced postural stability and sensorimotor integration. Although the control group also showed statistically significant improvements, the magnitude of change was consistently greater in the DNS group. These findings are in agreement with previous research identifying impaired proprioception and trunk muscle dysfunction as key contributors to postural instability in individuals with chronic low back pain (Wang et al., 2022; Zhang et al., 2020) [17,14]. DNS may exert a superior effect on balance performance by selectively activating deep trunk muscles and optimizing afferent proprioceptive input, thereby facilitating more efficient sensorimotor integration. According to Peterka's model of postural control (2002) [18], enhanced proprioceptive feedback allows for more effective postural adjustments, particularly in conditions where reliance on visual input is reduced, which may explain the greater balance improvements observed in the DNS group

Both interventions resulted in significant reductions in pain intensity and disability; however, the DNS group achieved larger and more clinically meaningful improvements. The reduction in Visual Analog Scale scores in the DNS group exceeded the minimal clinically important difference reported for chronic low back pain populations (Chou et al., 2007) [19], whereas improvements in the control group, although statistically significant, were comparatively smaller. Similar trends were observed for disability outcomes, with the DNS group demonstrating greater reductions in both Oswestry Disability Index and Roland–Morris Disability Questionnaire scores. These findings are consistent with those of Kim and Yim (2020) [20], who reported that enhanced core stabilization strategies lead to clinically relevant improvements in functional outcomes. While some studies have found minimal short-term differences between stabilization-based and conventional exercise approaches (Wang et al., 2023) [12], the larger effect sizes observed in the DNS group in the present study suggest that neuromuscular re-education may provide additional benefits in symptom modulation and functional recovery.

The observed association between improved deep muscle function and reduced disability supports the theoretical model of spinal stability proposed by Panjabi (2003) [6], which emphasizes the interaction between passive, active, and neural subsystems. DNS appears to influence the neural subsystem through precise motor control, coordinated breathing, and optimized movement patterns, thereby addressing underlying mechanisms of chronic low back pain rather than focusing solely on symptomatic relief. This integrative effect may explain the greater improvements observed in functional disability measures, which reflect real-world physical performance and participation more comprehensively than pain intensity alone (Roland & Fairbank, 2000) [21].

Overall, the findings of this study indicate that while conventional core exercise training remains a beneficial component of chronic low back pain rehabilitation, Dynamic Neuromuscular Stabilization offers a more comprehensive and integrative approach. By simultaneously enhancing deep core muscle contractility, postural control, and sensorimotor integration, DNS produced superior improvements in pain and functional disability. These results provide further evidence supporting the clinical relevance of DNS as an effective rehabilitation strategy for individuals with chronic low back pain.

Conclusion

The results of this study therefore showed that both DNS and traditional core exercise programs improved core muscle function, postural control, pain intensity, and disability in patients with chronic low back pain. However, the DNS approach exhibited better results, showing greater improvements in deep core muscle activation, increased postural stability, and more pronounced pain and functional disability reductions than conventional exercises. These findings point to the strong link between weakness of the core muscles and chronic low back pain and indicate that a rehabilitation approach that emphasizes integrated neuromuscular control and optimal stabilization strategies may provide additional clinical benefits beyond that achieved with traditional core strengthening methods in the management of chronic low back pain.

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