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Effect of 8 Weeks of Modified Dynamic Neuromuscular Stabilization Exercises on Core Region Function and Shoulder Pain in Patients with Incomplete Paraplegic Spinal Cord Injury

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ABSTRACT

Background: Spinal cord injury (SCI) often results in reduced core region function and shoulder pain among wheelchair users. This study aimed to investigate the effectiveness of modified dynamic neuromuscular stabilization (DNS) exercises on core region function and shoulder pain in patients with incomplete paraplegic SCI.

Methods: In this semi-experimental study, ten male patients with SCI were purposefully selected based on inclusion criteria and participated as an experimental group. Core region function and shoulder pain were measured before intervention using the modified plank test, an abdominal pressure cuff device, and the Wheelchair Users' Shoulder Pain Index (WUSPI) questionnaire. Participants first completed an eight-week non-exercise period, followed by an intermediate assessment. They then engaged in eight weeks of modified DNS exercises, after which measurements were repeated. Data were analyzed using SPSS version 26, with repeated measures ANOVA applied ($P \leq 0.05$).

Results: Significant improvements were observed in core function, transverse abdominal muscle strength, and shoulder pain (measured by WUSPI scores) after the exercise period compared to the non-exercise phase. These improvements were statistically significant ($P \leq 0.05$).

Conclusion: The findings suggest that modified DNS exercises can be an effective and low-cost addition to the physical rehabilitation of patients with incomplete paraplegic SCI.

Introduction

Spinal cord injury (SCI) is a sudden, unexpected, and life-changing event that profoundly affects both individual and social functioning [1]. In patients with SCI, trunk control, lower limb function, and mobility are impaired, often requiring the use of wheelchairs or crutches for ambulation and daily activities. This excessive reliance on the upper limbs places significant stress on the shoulders and arms, leading to

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musculoskeletal disorders and chronic shoulder pain [2-4]. Rehabilitation programs for individuals with SCI primarily aim to restore functional independence in self-care and mobility [5]. Maintaining postural stability in the seated position is essential for carrying out daily functional activities [6]. However, SCI—combined with trunk muscle weakness or paralysis—severely compromises trunk control, improving seated postural stability a key objective in most SCI rehabilitation strategies [7]. Because SCI patients depend heavily on their upper limbs for mobility and self-care, they are particularly vulnerable to repetitive strain injuries and shoulder musculoskeletal pain, which can ultimately result in loss of function and reduced independence [8, 9]. Consequently, therapeutic interventions that protect and strengthen the upper limbs and shoulder girdle are critical for reducing pain, a priority consistently identified by patients seeking functional improvement [10-12]. A variety of exercise-based rehabilitation programs, including rebound therapy, hydrotherapy, body weight-supported treadmill training, and Tai Chi, have been implemented for SCI patients, offering non-invasive treatment options that actively or passively alleviate SCI-related complications [13-15].

Neuromuscular exercises are among the most widely utilized therapeutic approaches, with dynamic neuromuscular stabilization (DNS) exercises being particularly recognized. DNS is founded on functional exercises that replicate the developmental kinesiology positions observed in healthy infants during their first year of life. This approach engages the central nervous system to optimize sensory–motor pathways, thereby forming the basis for preventing and treating various abnormalities and disorders [16]. DNS emphasizes proper breathing patterns and core trunk stabilization before initiating any movement, ensuring a stable foundation for subsequent functional activities [17]. Once breathing patterns are corrected, DNS progressively addresses the specific movement patterns that naturally emerge during an infant’s first year of development. During this critical growth stage, infants experience fundamental movements in multiple positions, requiring precise coordination between the nervous and muscular systems to counteract gravity, maintain posture, and enhance mobility. According to the DNS framework, these basic motor patterns are genetically programmed in healthy infants. They can be “recalled” by the central nervous system when needed for postural and movement rehabilitation [18]. DNS, therefore, functions as both a diagnostic and therapeutic neuromuscular method, targeting movement disorders by first correcting neuromuscular dysfunctions [18, 19]. Sharma and Yadav (2020), in a review study on DNS exercises, described DNS as a developmental kinesiology-based method designed to facilitate the correct activation of the spinal stabilizing system before limb movement [17]. Similarly, Frank et al. (2013) emphasized that body stability and balance are not achieved solely by strengthening core muscles but also require the integration and coordination of spinal stabilizing systems [18].

Studies have demonstrated the effectiveness of DNS exercises in enhancing strength and functional abilities in individuals with various disabilities, including stroke, multiple sclerosis (MS), Charcot-Marie-Tooth disease (CMT), and age-related decline [20-23]. However, despite these promising outcomes, no research to date has examined the effects of DNS exercises on patients with spinal cord injury (SCI). Given the significant trunk instability and shoulder pain experienced by this population, this study aimed to investigate the impact of a modified DNS exercise program on core region function and shoulder pain in individuals with incomplete paraplegic SCI.

Methods

This study was approved by the Ethics Committee (Ethics ID: IR.UI.REC.1399.089) and the Research Council of the University of Isfahan. A semi-experimental design with a pre-test, intermediate test, and post-test was employed. Ten patients with spinal cord injuries (SCI) at the L4 and L5 levels were purposefully and conveniently selected from the Isfahan Spinal Cord Injury Association (HANA) to participate.

Written informed consent was obtained from all participants after a full explanation of the study protocol. Because of the difficulty in matching SCI patients and assigning them to separate groups, participants served as their control during a non-exercise phase. First, a pre-test was conducted to assess all study variables. Participants then completed an eight-week non-exercise period, after which an intermediate test was performed. This was followed by an eight-week intervention period involving modified DNS exercises, concluding with a post-test to evaluate the effects of the intervention.

Participants were eligible for the study if they met the following conditions: 1) At least one year since the onset of SCI (confirmed by medical records), 2) No medical contraindications for exercise participation (verified by specialist physicians), 3) No participation in other sports or therapy programs during the study period, 4) Diagnosed with incomplete lumbar paraplegia (confirmed by a neurologist) and using a wheelchair, 5) No history of respiratory, neuromuscular, or cardiovascular diseases (based on medical records), 6) No chest deformities that could interfere with proper breathing, 7) Ability to perform basic DNS movements, and 8) Presence of shoulder pain for at least six months. Participants were excluded if they: 1) withdrew voluntarily from the study, 2) experienced injury or unforeseen problems that prevented continued participation, and 3) demonstrated irregular attendance in exercise sessions or testing.

Figure 1: Modified Planck test

Information was collected through field tests and questionnaires, and statistical analyses were conducted on data from all ten participants. Core muscle function was assessed using the modified plank test, an established abdominal muscle function test.

In this test, the upper body is supported by the elbows and forearms, while the knees support the lower body. Participants raise their hips off the ground to form a straight line from the head to the knees. A stopwatch is started as soon as the correct posture is achieved and stopped when the participant can no longer maintain the position. The elapsed time is recorded as the final score for core muscle endurance and stability [7].

The abdominal pressure cuff device was used to evaluate the strength of the transverse abdominal (TrA) muscle. The cuff was positioned beneath the participant's abdomen, ensuring that the navel was centered on the cuff and aligned with the anterior superior iliac spines (ASIS) for accurate placement. The cuff was inflated to 70 mmHg, and participants were instructed to gently draw in their lower abdomen without moving the spine or pelvis. The reduction in pressure achieved through this contraction was held for 10 seconds. This procedure was repeated 10 times, and the average pressure reduction value was recorded as the measure of TrA strength [24].

The Wheelchair Users' Shoulder Pain Index (WUSPI) questionnaire is a simple and effective tool for quickly assessing the degree of discomfort caused by shoulder pain during various daily activities. This self-reported index consists of 15 questions, each rated on a 0–10 scale (0 = no pain, 10 = maximum pain). The total score ranges from 0 (no pain) to 150 (maximum pain)[25]. The modified pain score is calculated using the following formula:

$$\text{WUSPI} = \frac{\text{Total WUSPI score} \times 15}{\text{Number of performed activities}}$$

Due to the participants' disabilities and inability to perform all DNS movements, the exercise program was modified based on their functional abilities and designed as an eight-week intervention, with three sessions per week, each lasting 60 minutes. Every session consisted of 10 minutes of warm-up, 40 minutes of DNS-based exercises incorporating breathing techniques, and 10 minutes of cool-down.

Before implementation, the program was piloted on two volunteers to identify and address potential challenges; these volunteers were later excluded from the study sample.

Following the DNS approach, diaphragmatic breathing was corrected in supine, prone, and sitting positions, progressing to developmental positions including supine, prone, side-sitting, and quadruped (see Image 2).

The FITT principle (Frequency, Intensity, Time, and Type) guided program design, with progressive overload achieved by incorporating new tasks—such as elastic band and light dumbbell resistance—every week. Exercise intensity was monitored through heart rate tracking and participants' verbal feedback [18, 26].

Figure 2: Modified dynamic neuromuscular stabilization (DNS) exercise protocol positions

For statistical analysis, repeated measures ANOVA was used to evaluate significant differences between group means across the pre-test, intermediate test, and post-test phases. When significant main effects were identified, LSD post-hoc tests were applied to determine where those differences occurred.

Mauchly's sphericity test confirmed that the assumption of sphericity was met for all measured variables. All analyses were conducted using SPSS version 26 (IBM Corp., Armonk, NY, USA), with the level of statistical significance set at $P \leq 0.05$.

Results

Table 1 presents the demographic data of the participants, including age, weight, height, and injury duration.

Based on the results obtained from the repeated measures ANOVA, changes during the non-training and training periods can be clearly distinguished. As illustrated in Figures 3, 4, and 5, and confirmed by the Tukey post hoc test, the differences between the pre-test and mid-test were not statistically significant for any of the three variables: modified plank ($P = 0.85$), abdominal pressure cuff ($P = 0.619$), and shoulder pain ($P = 0.511$). In contrast, the differences between both the pre-test and mid-test with the post-test were statistically significant across all three variables: modified plank ($F(2,18) = 9.07$, $P = 0.002$), abdominal pressure cuff ($F(2,18) = 11.87$, $P = 0.001$), and shoulder pain ($F(2,18) = 7.54$, $P = 0.004$) at the $P \leq 0.05$ significance level. These results indicate that changes and improvements occurred primarily during the training period, with no meaningful changes in the non-training period. Moreover, the slope of the trend line during the training phase was notably steeper, reflecting substantially greater improvements during the exercise intervention compared to the non-exercise phase.

Table 1: Demographic Characteristics of Participants

Variable	Mean ± SD
Age [years]	34.7 ± 7.4
Weight [kg]	68.9 ± 11.7
Height [cm]	175.8 ± 8.75
Injury Duration [months]	16.9 ± 3.54

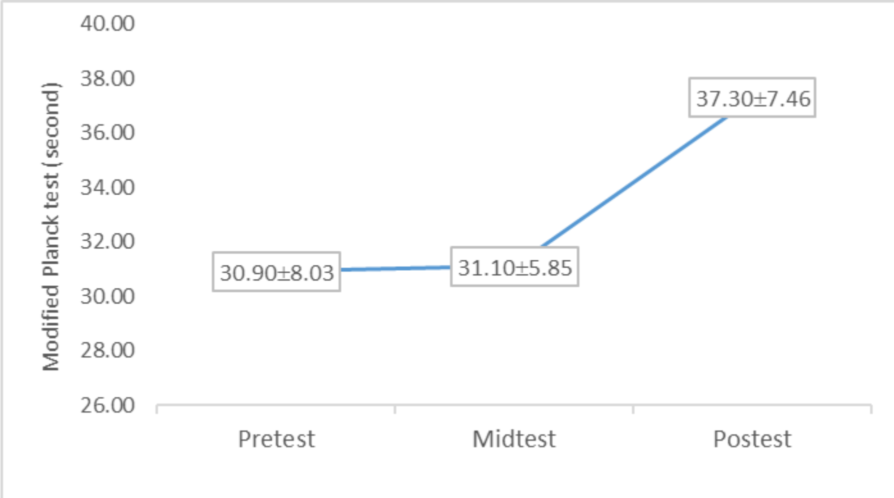

Figure 3: Linear diagram of modified Planck's test changes in three stages of measurement

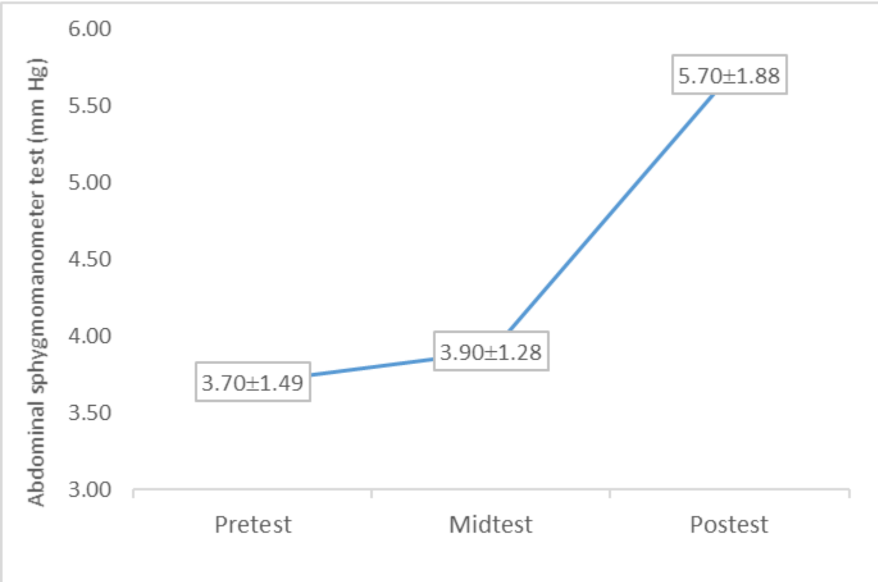

Figure 4: Linear diagram of changes in the abdominal sphygmomanometer in three stages of measurement

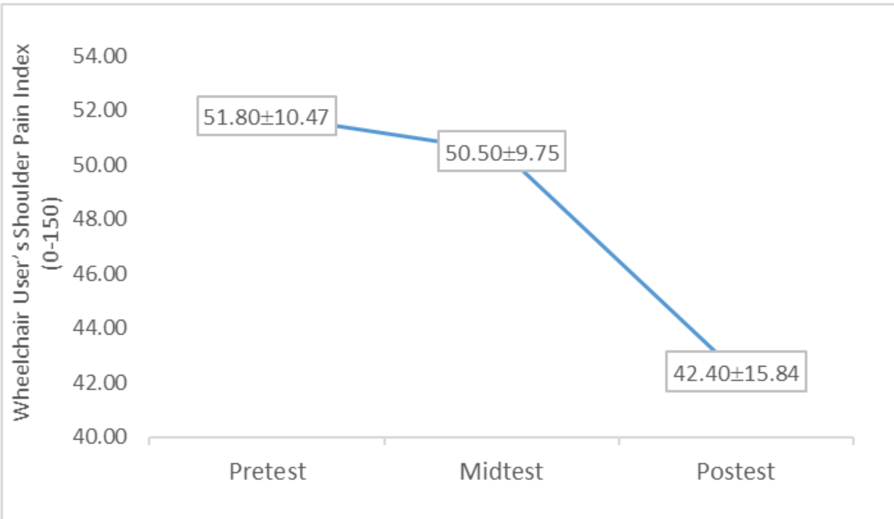

Figure 5: Linear diagram of changes in the shoulder pain questionnaire of wheelchair users in three stages of measurement

Discussion

This study investigated the effectiveness of modified dynamic neuromuscular stabilization (DNS) exercises on core region function and shoulder pain in individuals with incomplete paraplegic spinal cord injury (SCI). The results demonstrated that the intervention led to significant improvements in core muscle function (19.93%), abdominal pressure cuff performance (46.15%), and shoulder pain reduction (16.03%) ($P \leq 0.05$). These findings suggest that modified DNS exercises can contribute meaningfully to enhancing core region stability and alleviating shoulder pain in individuals with SCI.

While no prior research has directly examined the effects of DNS exercises in the SCI population, previous studies have documented the benefits of DNS exercises in improving core muscle strength and function, upper limb performance, and reducing musculoskeletal pain across various conditions

(20-23, 27-29). The findings from these researchers align with the current study's results, indicating that DNS exercises positively affect core region function and upper limb pain in participants.

Various factors, including core muscle activity and respiratory muscles, play a pivotal role in postural control. DNS exercises enhance intra-abdominal pressure through the co-contraction of the diaphragm, internal obliques, transverse abdominis, pelvic floor muscles, multifidus, and even superficial abdominal muscles, thereby improving trunk stability. Incorporating diaphragmatic breathing exercises within DNS movement patterns further increases spinal stability and neuromuscular coordination, ultimately enhancing muscle strength and endurance and optimizing posture—an essential element for effective movement across various positions [28].

Given that respiratory and core muscles are integral to both dynamic and static postural stability, strengthening this system can significantly impact transverse abdominal muscle performance and modified plank scores in SCI individuals [30]. Moreover, DNS emphasizes activating the stabilizing muscle system, enabling individuals to maintain controlled positions and counteract gravity [16]. Marand et al. (2023) also underscored the substantial effects of DNS exercises on trunk balance and functional performance in MS patients, identifying DNS as an effective intervention for stimulating core muscle chains [22]. By engaging sensory-motor centers and reinforcing trunk stability, DNS training appears capable of enhancing core region performance in SCI individuals across different functional conditions.

SCI individuals rely on manual wheelchairs for mobility, which places significant demands on upper limb coordination. Veeger and Van (2007) emphasized that hand movement depends on the three-dimensional mobility of the shoulder complex, which, in turn, is contingent on trunk muscle coordination. The pectoralis major and latissimus dorsi transmit arm forces directly to the rib cage, while the serratus anterior and rhomboids stabilize the scapula against the rib cage, creating a secure base for efficient arm movement [31]. Importantly, the neuromuscular stability pattern establishes core stability and neuromuscular coordination before any limb movement [17].

This interdependence means that trunk muscle coordination and stability are critical for upper limb function. Consequently, SCI individuals are highly susceptible to repetitive strain injuries in the upper limbs, with spinal column dysfunction contributing to the etiology of much of their musculoskeletal pain. The DNS approach addresses these issues by optimizing posture, promoting efficient breathing mechanics, enhancing the function of joint chains, and restoring intra-abdominal pressure regulation within the integrated spine stabilization system (ISSS). Together, these mechanisms improve movement efficiency and reduce excessive joint loading, thereby enhancing upper limb performance and alleviating musculoskeletal pain [17, 32, 33].

Kolar described DNS as the activation of specific muscle chains, with a key principle being that each joint position depends on the functional stability and coordination of both local and global muscles to maintain a neutral joint alignment within the movement chain. The quality of this coordination not only influences joint performance but also impacts broader biomechanical and anatomical parameters [34]. y promoting optimal stability patterns, DNS minimizes the risk of injuries and pain syndromes caused by repetitive overload, while simultaneously improving overall functional efficiency [35]. This mechanism provides a plausible explanation for the reduction in upper limb pain observed in SCI individuals, particularly during manual wheelchair propulsion.

Conclusion

The findings of this study demonstrate that DNS exercises significantly improve core region function and shoulder pain in individuals with spinal cord injury (SCI). Accordingly, DNS can be recommended as a complementary and cost-effective rehabilitation method for SCI patients and other wheelchair users who are capable of performing basic DNS exercises.

Author Contributions

All authors contributed equally to the design, execution, and writing of this article.

Conflict of Interest: The authors declared no conflict of interest in this study.

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