BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

Spinal Manipulation, Dynamic Neuromuscular Stabilization, and Their Combination in Chronic Non-Specific Low Back Pain: A Four-Group Randomized Clinical Trial

İsmail Alak [1], Sefa Haktan Hatik [2,*], İlker Can Büyükkirli [3] and Emine Busra Aydin [4]

1 PT, MSc., Graduate Education Institute, Bahçeşehir University, İstanbul, Türkiye;
2 Assist. Prof., Department of Health Care Services, Türkeli Vocational School, Sinop University;
3 PT, MSc., PhD(c), Graduate Education Institute, Bahçeşehir University, İstanbul, Türkiye;
4 Assist. Prof.,, Vocational School of Health Service, Gümüşhane University, Gümüşhane, Türkiye

* Correspondence: haktanhtk@gmail.com

Citation: Alak İ, Hatik S.H., Büyükkirli İ.C., Aydin E.B. - Spinal Manipulation, Dynamic Neuromuscular Stabilization, and Their Combination in Chronic Non-Specific Low Back Pain: A Four-Group Randomized Clinical Trial *Balneo and PRM Research Journal* **2026**, *17(1): 961*

Academic Editor(s): Constantin Munteanu

Reviewer Officer: Viorela Bembea

Production Officer: Camil Filimon

Received: 07.02.2026
Published: 31.03.2026

Reviewers:
Sebastian Giuvara
Mariana Rotariu

Publisher's Note: Balneo and PRM Research Journal stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Spinal manipulation (SM) and stabilization-focused exercise are commonly used in chronic low back pain, yet evidence on their combined effects is limited. This randomized controlled trial compared SM and dynamic neuromuscular stabilization (DNS), alone or combined, in chronic non-specific low back pain. Forty-eight participants were randomized (1:1:1:1; n=12/group) using a computer-generated sequence with opaque sealed-envelope concealment to Control, SM, DNS, or SM+DNS (SMDNS). Interventions (except Control) were delivered twice weekly for 4 weeks. Outcomes (VAS, ODI, RMDQ, DNS-HS, PostureScreen) were assessed at baseline and follow-up. Assessor blinding was not feasible (treating physiotherapist also assessed outcomes); analyses used coded group labels.Within-group analyses showed significant improvements in most outcomes ($p<0.05$), except for postural deviation in the SM group and frontal postural deviation in the DNS and SMDNS groups. Between-group comparisons indicated greater early pain reduction with SMDNS at the second assessment ($p<0.05$). By week 4, pain decreased most in DNS and SMDNS (VAS $\Delta=-3$), while SM showed $\Delta=-2$ and Control showed no change. Disability improved most in DNS/SMDNS (ODI $\Delta=-13.39/-15.38$; RMDQ $\Delta=-5.24/-5.77$). Week-4 effect sizes favored SMDNS over Control and SM for key outcomes (VAS D2 g=2.07 vs Control, 1.24 vs SM; ODI PC2 g=1.73 vs Control, 1.05 vs SM; RMDQ PC2 g=1.34 vs Control, 0.23 vs SM). Overall, adding SM to DNS may enhance early pain relief; the magnitude of between-group differences (effect sizes with 95% CIs) supports interpretation, while clinical relevance should be considered alongside established MCIDs and confirmed in larger trials with longer follow-up.

Keywords: Spinal Manipulation, Dynamic Neuromuscular Stabilization, Exercise, Low Back Pain, Chronic

1. Introduction

Chronic non-specific low back pain (CNSLBP) refers to persistent low back pain for which no single, clearly identifiable specific pathology can be established. Although various structural findings, such as degenerative changes in the intervertebral discs or facet joints, may be observed, particularly on imaging, these findings often show limited correlation with symptoms and therefore should not be regarded as the primary cause of CNSLBP [1]. CNSLBP may adversely affect body structure and function, contributing to reduced trunk muscle strength and endurance as well as limitations in activities of daily living. In some individuals, myofascial pain features, including trigger points, may also coexist with chronic low back pain [2]. Low back pain (LBP) affects nearly 23% of the general population and represents one of the most prevalent chronic conditions among individuals younger than 65 years [3].

Although there is no universal consensus regarding the optimal treatment of chronic low back pain, a range of interventions is commonly used in clinical practice, including electrotherapy, exercise therapy, manual therapy, pharmacological treatment, and invasive methods. In general, combining different treatment strategies is recommended to improve outcomes [1]. Contemporary clinical practice guidelines emphasize multimodal, non-surgical management for chronic low back pain, with exercise-based rehabilitation considered a core component and manual therapy regarded as an adjunctive option for selected patients. Similarly, recent WHO-related guidance, NICE guidance summaries, and the ACP clinical practice guideline prioritize non-pharmacological care, particularly exercise, while positioning manual therapy, including spinal manipulative therapy, within a multimodal package of care [37,38,39]. Recent algorithm-based frameworks have likewise highlighted the importance of red-flag screening and a stratified, conservative management approach aligned with contemporary guideline recommendations [40].

One of the treatment approaches used in chronic low back pain is spinal manipulation. Spinal manipulation is a high-velocity, low-amplitude thrust maneuver applied to a specific spinal segment and is often accompanied by an audible cavitation sound arising from one or more joints. Although the effectiveness of manipulative treatments has been demonstrated more consistently in acute and subacute low back pain, findings in chronic low back pain remain inconclusive [4,5,6]. Nevertheless, some studies have reported that spinal manipulation may be superior to certain alternative treatments in individuals with chronic low back pain [4]. In addition, stabilization exercises have been reported to improve pain, disability, and physical performance in patients with chronic low back pain [7,8].

Although previous studies have compared spinal manipulation with stabilization-oriented exercise approaches, it remains clinically unclear how chiropractic high-velocity low-amplitude (HVLA) manipulation performs relative to Dynamic Neuromuscular Stabilization (DNS). DNS is a stabilization-based approach that emphasizes reflex-mediated activation and the restoration of efficient movement patterns grounded in ontogenetic motor development. It aims to promote gains in core muscle function and motor reorganization without requiring consciously driven, cognitively demanding control [9,10]. Therefore, the present study aimed to address this clinically relevant uncertainty by comparatively examining the effects of DNS and chiropractic HVLA manipulation on pain, pain-related functional impairment (disability), physical competence, dynamic core muscle fitness, and postural deviations in individuals with chronic non-specific low back pain.

We hypothesized that: (i) the combined intervention (SM+DNS) would produce greater improvements in pain and disability than either intervention alone or the control condition; and (ii) SM and DNS applied separately would result in better outcomes than the control condition.

2. Materials and Methods

Participants who met the inclusion criteria were enrolled in the study after their demographic information had been recorded on the data-tracking form. Subsequently, the participants were randomly allocated into four groups. The group receiving chiropractic manipulation was designated as the SM Group, the group receiving Dynamic Neuromuscular Stabilization exercises as the DNS Group, the group receiving the combined chiropractic manipulation and Dynamic Neuromuscular Stabilization intervention as the SMDNS Group, and the group receiving no treatment as the Control Group. All active interventions were administered by, or under the supervision of, the same physiotherapist responsible for the treatment procedures in all groups.

The SM group received High-Velocity Low-Amplitude (HVLA) spinal manipulation twice weekly for 4 weeks, for a total of 8 sessions. The DNS group received Dynamic Neuromuscular Stabilization (DNS) exercises twice weekly for 4 weeks, also for a total of 8 sessions, with each session lasting 50 minutes. The SMDNS group received a combination of DNS exercises and HVLA spinal manipulation twice weekly for 4 weeks, totaling 8 sessions. Participants in the Control group received no intervention during the study period. They were instructed to maintain their usual activity levels and not to initiate any new physiotherapy, exercise program, or other treatment for low back pain during the follow-up period. After the final assessment, participants in the Control group were offered free treatment.

Participants were assessed at a total of three time points during the study: immediately before the intervention (baseline), at week 2 after the initiation of treatment (following the 4th session), and at week 4 after completion of the intervention period (following the 8th session). The Dynamic Neuromuscular Stabilization–Heel Sliding (DNS-HS) Test was used to evaluate dynamic core muscle fitness. The Visual Analog Scale (VAS) was used to assess the subjective intensity of low back pain. The Roland–Morris Disability Questionnaire (RMDQ) was used to determine physical competence, while the Oswestry Disability Index (ODI) was used to evaluate the degree of restriction in daily life due to low back pain. In addition, the PostureScreen Mobile application was used to assess postural deviations..

2.1.Participants

This study was conducted at a private physiotherapy clinic in Zonguldak, Türkiye. Participant recruitment, as well as all baseline and follow-up assessments, was carried out at the same clinic. Participants were screened by a physiotherapist through clinical examination and a detailed medical history assessment. Individuals aged 20 to 45 years were eligible for inclusion if they had experienced low back pain for at least 6 months, had an Oswestry Disability Index score of 7 or higher, a Visual Analog Scale pain score of 3 or above, and normal radicular test findings. Eligible participants were also required to demonstrate adequate cooperation with the clinicians and to provide written informed consent before participation.

Individuals were excluded if they were pregnant; had a history of spinal surgery, neurological deficits, malignancy, inflammatory disease, or rheumatologic disease; or had received physical therapy within the previous month. Participants were also withdrawn from the study during follow-up if they missed two consecutive treatment sessions, interrupted the treatment or assessment protocol, chose to withdraw voluntarily, or developed any condition meeting the exclusion criteria, such as trauma or initiation of physical therapy during the study period.

2.2. Sample Size

An a priori sample size calculation was performed using G*Power software (version 3.1.9.7), which indicated that a minimum of 48 participants was required for comparisons among four independent groups, assuming an effect size (d) of 0.55, an alpha level of 0.05, and a statistical power of 85%. Accordingly, the study included 48 participants, with 12 individuals assigned to each group.

2.3.Intervention

Participants allocated to the active treatment groups received their respective interventions twice weekly for 4 weeks, for a total of 8 sessions. The SM group received lumbar high-velocity low-amplitude (HVLA) spinal manipulation, the DNS group

received dynamic neuromuscular stabilization exercises, and the SM+DNS group received both interventions during the same treatment period. In the combined-intervention group, spinal manipulation was performed first, followed by DNS exercises within the same session. All active interventions were delivered by the same physiotherapist to ensure procedural consistency. The control group did not receive any active therapeutic intervention during the study period.

2.3.1.Spinal manipulation

The HVLA thrust was delivered to the lumbar region using a standardized side-lying technique, with reference to Gyer [17]. The participant was positioned in side lying, with the lower leg extended and the upper hip and knee flexed. The physiotherapist then guided the participant into an assisted trunk rotation using the upper arm until the end range of lumbar motion was reached. During the application, the physiotherapist placed the hypothenar eminence over the transverse process of the clinically relevant lumbar segment, identified according to predefined clinical criteria including palpatory tenderness, segmental motion restriction, and reproduction of the participant's familiar pain. To ensure procedural consistency, the same treatment algorithm was applied to all participants, and manipulation was limited to a maximum of one to two lumbar levels per session. Each session included a standardized safety screening for red flags and contraindications, as well as a pre-manipulative positioning check. The thrust direction and amplitude were kept consistent according to the study protocol. All manipulations were performed by the same experienced clinician, and the treated level(s) were recorded after each session.

2.3.2. Dynamic neuromuscular stabilization exercises

Individualized DNS exercises were administered under the supervision of a physiotherapist to participants in the groups receiving DNS therapy. Initially, participants were taught posterior diaphragmatic activation in the supine position and the ability to direct intra-abdominal pressure caudally while preventing cranial elevation of the rib cage, thereby maintaining the chest and pelvis in a neutral position and aligning the thoracic diaphragm and pelvis in parallel. Participants were then instructed to perform a chin tuck without disturbing rib cage alignment, with the aim of achieving parallel alignment of the cervical, thoracic, and pelvic diaphragms. This alignment was intended to facilitate reflex activation of the deep stabilizing system through appropriate diaphragmatic movement and intra-abdominal pressure regulation. Participants were instructed to maintain this alignment throughout the DNS exercise patterns [18]. DNS was delivered according to a predefined progression framework. Sessions began with breathing and intra-abdominal pressure control exercises, including diaphragmatic breathing and abdominal wall co-activation, and then progressed to developmental positions such as supine 90/90, prone support, quadruped, side support, and functional stabilization tasks. Progression to the next level was allowed only when the participant met the following operational criteria: (i) maintenance of neutral spine and pelvic alignment, (ii) controlled breathing with stable intra-abdominal pressure, (iii) absence of symptom exacerbation during and after the task, and (iv) completion of the prescribed repetitions with correct form. If these criteria were not met, the exercise was regressed by reducing the lever arm or support demand, decreasing the number of repetitions, or providing additional tactile and verbal cues. Dosage parameters, including sets, repetitions, rest periods, and exercise modifications, were documented after each session to improve reproducibility.

2.4. Randomization

After eligibility screening and baseline assessment, participants were randomly assigned in a 1:1:1:1 ratio to the Control, SM, DNS, or SM+DNS group. The randomization sequence was generated using a computer-based simple randomization method by an independent researcher who had no role in participant recruitment, treatment administration, or outcome assessment. Allocation concealment was maintained through sequentially numbered, opaque, sealed envelopes, which were opened by the enrolling researcher only after the baseline assessments had been completed.

2.5. Blinding

Due to the nature of the interventions, participant and therapist blinding was not feasible. The treating physiotherapist also conducted outcome assessments; therefore, assessor blinding was not possible. To reduce bias, assessments followed a standardized protocol, and data were analyzed using anonymized, coded group labels (A–D) revealed only after analysis.

2.6. Outcome Measures

2.6.1. Demographic characteristics

Participants' age, sex, body weight, height, and body mass index (BMI) were recorded. BMI was calculated as weight in kilograms divided by height in meters squared.

2.6.2. Visual analog scale (VAS)

A Visual Analog Scale (VAS) was used to assess pain intensity in the participants. The scale consists of a 10-cm horizontal line ranging from 0 ("no pain") to 10 ("the worst pain imaginable"). The VAS is one of the most widely used and reliable quantitative tools for pain assessment in clinical research [11].

2.6.3. Roland Morris Disability Questionnaire (RMDQ)

The Roland–Morris Disability Questionnaire (RMDQ) is a 24-item self-reported questionnaire and one of the most commonly used instruments for assessing disability related to low back pain. Total scores range from 0 to 24, with higher scores indicating greater disability severity [11].

2.6.4. Oswestry disability index (ODI)

The Oswestry Disability Index (ODI) is one of the most widely used instruments for assessing disability related to low back pain, and its validity and usefulness have been demonstrated in various studies. It consists of 10 items, each scored from 0 to 5, with higher scores indicating greater disability. The final score is calculated by summing the item scores and multiplying the total by 2, resulting in a percentage score ranging from 0 to 100% [12].

2.6.5. DNS-HS dynamic neuromuscular stabilization-heel sliding test (DNSHS)

The DNS-HS test is a promising tool for assessing the dynamic function of the core muscles and for evaluating dynamic stabilization, particularly in individuals with low back pain and core instability. It has been described within the Dynamic Neuromuscular Stabilization approach proposed by Pavel Kolar for spinal rehabilitation and functional postural stabilization assessment [13]. In the DNS-HS test, participants are positioned supine in a hook-lying posture with the hips flexed and the knees bent, and a pressure biofeedback unit (PBU) is placed beneath the lumbar

spine. Participants are instructed to breathe normally, activate the diaphragm appropriately, and maintain lumbopelvic stability during the task. The test is repeated three times, with emphasis on core stabilization performance [13].

In the present study, the DNS-HS test was used to assess lumbopelvic stabilization during a lower-limb heel-sliding task. Participants lay supine in a hook-lying position with the arms relaxed and were instructed to maintain a neutral lumbopelvic alignment while breathing normally. From the starting position, each participant slowly slid one heel along the examination surface toward near full knee extension and then returned to the initial position while attempting to keep the pelvis and lumbar spine stable. The same procedure was then repeated on the contralateral side. A trial was considered faulty if any of the following occurred: visible pelvic rotation or tilt, increased lumbar lordosis or loss of neutral alignment, rib flare or breath-holding, loss of smooth and controlled movement, or pain provocation requiring interruption. Each side was scored as pass (1) if the task was completed without faults and fail (0) if one or more faults occurred. Participants performed three trials on each side, and the final score for each side was determined according to the modal result across the three trials. The overall DNS-HS score was calculated as the sum of the right and left side scores, ranging from 0 to 2, with higher scores indicating better lumbopelvic stabilization [41].

2.6.6. Posture screen mobile (PSM)

The PostureScreen Mobile application is a reliable tool for posture assessment that uses a camera-based system on mobile devices operating with Android and iOS platforms to generate numerical postural data. Participants were asked to wear appropriate clothing and were photographed in a standardized static standing posture. The software was then used to calculate postural asymmetry values and degrees of deviation from normal posture. The application provides postural deviation measures from the anterior, posterior, right lateral, and left lateral views [14,15,16].

In the present study, postural variables obtained from PostureScreen Mobile (PSM) were recorded as translation totals, including ATT (Anterior Translations Total), PTT (Posterior Translations Total), RLTT (Right Lateral Translations Total), and LLTT (Left Lateral Translations Total), as reported by the application output. These variables represent the anterior–posterior and right–left translation components of posture quantified from standardized photographs according to the PSM protocol.

2.7. Data Analyses

Statistical analyses were performed using Excel 2016, Minitab 17.1.0, and R-Studio 1.4.1103. Sample size analysis (G*Power 3.1.9.7) indicated that at least 48 participants aged 20–45 years were required for four independent groups (effect size d = 0.55, α = 0.05, power = 0.85). Qualitative variables were summarized with frequency and percentage, and quantitative variables with mean, SD, median, minimum and maximum. Normality was assessed using the Shapiro–Wilk test. Pearson Chi-square was used for group comparisons of qualitative data. Kruskal–Wallis was used for independent quantitative comparisons, followed by Bonferroni-adjusted Mann–Whitney U for post-hoc pairwise tests. Spearman correlation was used to assess relationships between quantitative variables.

3.Result

There was no difference between the study groups in terms of BMI (p=0.480), age (p=0.189) and gender (p=0.324). (Table 1)

Table 1. Demographic data of participants

Parameters		Mean±Standard Deviation / Median (Minimum – Maximum)				P
		Control Group (CG)	SM Group	DNS Group	SMDNS Group	
BMI		25.5 ± 4.60 / 25.23 (18.20-34.64)	23.56 ± 1.77 / 22.75 (21.95-22.48)	24.91 ± 3.39 / 24.81 (19.14 – 30.06)	26.88 ± 8.67 / 24.83 (18.07-53.7)	0.480[a]
AGE		35.83 ± 7.15 / 3 7(23-45)	34.67 ± 5.99 / 32.50 (27-45)	39.08 ± 5.01 / 40 (27 - 45)	33.7 ± 7.67/ 35 (22- 45)	0.189[a]
GENDER	**MALE**	6 (%50.0)	3 (%25.0)	6 (%46.2)	8 (%61.5)	0.324[b]
	FEMALE	6 (%50.0)	9 (%75.0)	7 (%53.8)	5 (%38.5)	

[a]One-way analysis of variance, [b]Pearson chi-square test, BMI: Body Mass Index, CG: Control Group, SM: Spinal Manipulation, DNS: Dynamic Neuromuscular Stabilization, SMDNS: Spinal Manipulation and Dynamic Neuromuscular Stabilization

In the second measurement, significant between-group differences were observed for VAS ($p = 0.006$), DNSHS ($p = 0.001$), and PTT ($p = 0.009$) (Table 2). Post-hoc comparisons indicated that VAS values were higher in the Control group than in the DNS and SMDNS groups. DNSHS also differed between groups, with lower values in the DNS and SMDNS groups compared with the Control and SM groups. For PTT, the DNS group showed lower values than the SMDNS and SM groups (Table 2).

In the third measurement, significant between-group differences were found for VAS ($p < 0.001$), ODI ($p = 0.008$), RMDQ ($p = 0.022$), RLTT ($p = 0.013$), and LLTT ($p = 0.018$) (Table 2). Post-hoc comparisons showed that VAS values were higher in the Control group than in the DNS and SMDNS groups. ODI differed between groups, with higher values in the Control group than in the SMDNS group. For postural translations, RLTT values were higher in the Control group compared with the intervention groups, and LLTT values were lower in the DNS group compared with the Control group (Table 2).

Table 2. Intra-group and Inter-group comparison

Parameters		Mean±Standard Deviation / Median (Minimum – Maximum)				p
		Control Group (CG)	SM Group	DNS Group	SMDNS Group	
VAS	**1st measurement**	5 (3 – 8)	5 (3 – 7)	5 (3 – 7)	5 (3 – 7)	0.346[c]
	2nd measurement	5.5(3 – 8)	4(3 – 7)	3(1 – 7)	4(1 – 6)	**0.006[c]**
	3rd measurement	5(3 – 7)	3(2 – 6)	2(1 – 8)	2(1 – 5)	**<0.001[c]**
	Δ (3rd–1st)(Median)	0	-2	-3	-3	
	^{2}p	0.056[d]	**<0.001[d]**	**0.002[d]**	**<0.001[d]**	
ODI	**1st measurement**	32.33 ± 8.51 33(20 – 44)	38.17 ± 15.87 31(32 – 76)	31.54±11.20 30(18 – 64)	31.69 ± 8.32 32(18 – 42)	0.689[c]
	2nd measurement	31.33 ±7.92 32(18 – 42)	32.83 ± 15.82 30(14 – 72)	25.23±10.44 24(0 – 28)	24.77 ± 9.88 24(12 – 48)	0.224[c]
	3rd measurement	27.83 ± 8.46 25(16 – 44)	36.67 ± 18.07 23(16 -44)	18.15±9.91 20(0 – 36)	16.31 ± 10.45 6(12 – 40)	**0.008[c]**
	Δ (3rd–1st)(Mean)	-4.50	-1.50	-13.39	-15.38	
	^{2}p	**0.016[d]**	**0.001[d]**	**0.001[d]**	**<0.001[d]**	
DNSHS	**1st measurement**	43.67± 25.04 35.35 (16.7 - 110)	39.05 ± 10.03 40.35(11.7– 50)	37.69±8.94 38.4 (15 - 50)	39.59 ± 11.89 35 (26.7 -74)	0.827[c]
	2nd measurement	33.95 ± 7.39 35.35 (20 – 47.8)	39.01±9.88 39.35(12 – 49.3)	24.52±9.51 26(10.7 – 36)	26.96 ± 12.77 25.5(12.7 – 64)	**0.001[c]**
	3rd measurement	33.57 ± 7.96 35.1(17.7 – 47.8)	37.45±9.75 38.80 (11.1 – 48)	15.7 ± 9.02 14(0 - 30)	19.18 ± 12.33 17.4(8.57 – 58)	<0.001[c]
	Δ (3rd–1st)(Mean)	-10.10	-1.60	-21.99	-20.41	
	^{2}p	0.815[d]	**<0.001[d]**	**<0.001[d]**	**<0.001[d]**	
RMDQ	**1st measurement**	7.67 ± 3.77 7(2 – 16)	8.08 ±2.46 8(4 – 13)	9.62 ± 3.95 9(3 – 19)	9.15 ± 4.07 8(5 – 18)	0.616[c]
	2nd measurement	8.67 ± 3.08 8(5 – 15)	7.08 ± 2.39 7(4 – 13)	6.54 ± 5.78 4(0 – 19)	6 ± 4.06 5(1 – 15)	0.141[c]
	3rd measurement	7.25 ± 3.72 6.5(3 – 16)	5.08 ± 1.56 4.5(3 – 8)	4.38 ± 5.05 3(0 – 17)	3.38 ± 2.78 3(0 – 8)	0.022[c]
	Δ (3rd–1st)(Mean)	-0.42	-3	-5.24	-5.77	
	^{2}p	0.159[d]	**<0.001[d]**	**<0.001[d]**	**<0.001[d]**	
ATT	**1st measurement**	2.84 ± 1.49 2.94(0.3 – 5.42)	2.31±0.97 2.14(1.09– 4.04)	2.75±1.60 2.07(1.34– 7.13)	3 ± 1. 14 2.77(0.55 - 4.69)	0.291[c]

	2nd measurement	2.80 ± 1.56 2.25(0.98 – 5.35)	2.80±1.26 2.42(1.13– 5.03)	2.73±1.37 2.44(0.55– 5.6)	2.97 ± 1.56 2.46(1.27 – 6.24)	0.976[c]
	3rd measurement	3.02 ± 1.23 2.79(1.49 – 5.35)	2.58±0.73 2.46(1.30– 3.74)	2.02±0.76 1.74(0.94– 3.49)	2.45 ± 1.25 1.83(1.20 – 4.80)	0.138[c]
	Δ (3rd–1st)(Mean)	0.18	0.27	-0.73	-0.55	
	^{2}p	0.567[d]	0.567[d]	0.199[d]	0.199[d]	
RLTT	**1st measurement**	11.60 ± 3.05 10.87(8.64– 7.62)	10.01±2.49 9.95(6.37 – 14.35)	12.36±4.49 12.63(6.579.96)	13.31±6.08 12.25(6.91–8.61)	0.470[c]
	2nd measurement	12.99±3.98 12.61(7.79– 0.04)	9.06±3.51 8.99(4.38 – 16.5)	10.71±3.82 9.91(6.28– 7.47)	11.07±4.48 9.96(4.39–19.70)	0.127[c]
	3rd measurement	12.25 ± 4.06 11.48(8.55-21.36)	8.67 ± 2.39 8.41(4.54 - 11.64)	7.71±3.04 7.68(2.35– 3.04)	8.57±4.34 7.11(3.89– 1.10)	**0.013[c]**
	Δ (3rd–1st)(Mean)	0.65	-1.34	-4.65	-4.74	
	^{2}p	0.218[d]	0.144[d]	**0.002[d]**	**0.032[d]**	
PTT	**1st measurement**	5.21 ± 1.87 4.74(2.22 – 9.32)	5.84 ± 2.38 5.7(2.52 – 10.22)	4.62±1.25 5.18(2.44– 6.22)	4.54 ± 1.41 4.71(2.24 – 6.02)	0.420[c]
	2nd measurement	5.14 ± 2.54 4.51(2.23 – 11.32)	5.83 ±1.5 6.04(3.06 – 8.36)	3.81±1.66 3.47(1.71– 7.14)	5.51 ± 1.29 5.2(4 – 8.75)	**0.009[c]**
	3rd measurement	4.77 ± 1.86 4.5(2.94 –9.84)	6.07 ± 2.39 5.9(3.46 – 12.19	4.19 ± 1.38 4.35(1.91– 6.19)	4.67± 2.01 3.98(1.45 – 8.37)	0.226[c]
	Δ (3rd–1st)(Mean)	-0.44	0.23	-0.43	0.13	
	^{2}p	0.407[d]	0.455[d]	**0.735[d]**	**0.292[d]**	
LLTT	**1st measurement**	10.29 ± 4.32 10.51(3.75 – 7.28)	10.08±2.72 10.38(4.32– 3.56)	9.98 ± 4.12 8.42(4.92 – 6.06)	10.67 ± 2.39 10.39(7.20-15.03)	0.959[c]
	2nd measurement	9.94±3.77 10.58(4.55– 5.11)	9.58 ± 3.15 9.84(4.06 – 13.53)	9.18±3.51 7.64(5.87-18.31)	10.24 ± 3.32 10.15(4.66– 5.03)	0.806[c]
	3rd measurement	10.24±3.28 10.39(5.29– 5.01)	10.05 ± 3.59 9.81(4.68 – 14.96)	6.49±2.51 6.49(2.5– 12.05)	8.18±1.96 8.37(5.30-12.16)	**0.018[c]**
	Δ (3rd–1st)(Mean)	-0.05	-0.03	-3.49	-2.49	
	^{2}p	0.303[d]	0.853[d]	**0.023[d]**	**0.023[d]**	

CG: Control Group; SM: Spinal Manipulation; DNS: Dynamic Neuromuscular Stabilization; SMDNS: Spinal Manipulation + Dynamic Neuromuscular Stabilization; VAS: Visual Analog Scale; ODI: Oswestry Disability Index; DNSHS: Dynamic Neuromuscular Stabilization Heel Slide Test; RMDQ: Roland–Morris Disability Questionnaire; ATT: Anterior Translations Total; RLTT: Right Lateral Translations Total; PTT: Posterior Translations Total; LLTT: Left Lateral Translations Total. Between-group comparisons were performed using the Kruskal–Wallis test (c). Within-group comparisons across time were performed using the Wilcoxon signed-rank test (d). Δ (3rd–1st) indicates change from baseline (1st measurement) to week 4 (3rd measurement).

Table 3. Comparison of differences between groups

Parameters	Control Group (CG)	SM Group	DNS Group	SMDNS Group	p	Hedges g [95% CI] (SMDNS vs CG)	Hedges g [95% CI] (SMDNS vs SM)	Hedges g [95% CI] (SMDNS vs DNS)
VAS D1	-0.08 ± 0.51 0 (-1.0 – 1.0)	-0.33 ± 0.65 0 (-2.0 – 0.0)	-1.15 ± 2.12 0 (-6.0– 2.0)	-1.62 ± 0.87 -2 (-3.0 – 0.0)	**0.002[C]**	2.09 [1.08, 3.10]	1.62 [0.69, 2.55]	0.28 [-.52,1.08]
VAS D2	-0.45 ± 0.52 0 (-1.0 – 0.0)	-1.33 ± 0.49 -1.0 (-2.0 – -1.0)	-1.92 ± 2.22 -2 (-6.0 – 3.0)	-2.62 ± 1.33 -3 (-4.0 – 0.0)	**<0.001[C]**	2.07 [1.07, 3.08]	1.24 [0.36, 2.12]	0.37 [-0.44, .18]
DNS-HS PC1	-9.76 ± 26.86 -1.05 (-60 – 20)	0.1 ± 2.2 0.9 (-3 – 3)	-34.2 ± 22.5 -36.6 (-65 – 0.0)	-32.3 ± 0.37 -36.7 (-64 – 3.0)	**<0.001[C]**	1.15 [0.28, 2.01]	19.83 [13.92, 25.74]	-0.12 [-.92,0.69]
DNS-HS PC2	-11.2 ± 26.5 -0.8 (-60 – 20)	-4.2 ± 0.2 -4.1 (-9 – -1)	-61.0 ± 19.7 -60.7 (-100.0 – -31)	-53.7 ± 14.4 -55.7 (-75 – -22)	**<0.001[C]**	1.92 [0.94, 2.91]	4.69 [3.09, 6.29]	-0.41 [-.22,0.40]
RMDQ PC1	42.8 ± 94.5 15.5 (-50 – 300)	-10.3 ± 23.2 -15.3 (-33 – 50)	-41 ± 41.1 -42.9 (-100 – 44)	-35.3 ± 32.4 -36.4 (-83 – 38)	**0.001[C]**	1.07 [0.21, 1.93]	0.86 [0.02, 1.70]	-0.15 [-.95,0.65]
RMDQ PC2	13.5 ± 71.7 0 (-57 – 200)	-35.0 ± 165.8 -37.5 (-56 – 0)	-63.5 ± 31.7 -71.4 (-100 – -8)	-63.1 ± 30.6 -71.4 (-100 – 0)	**<0.001[C]**	1.34 [0.45, 2.23]	0.23 [-0.58, 1.03]	-0.01 [-.81,0.79]
ODI PC1	1.1 ± 17.7 0 (-48 – 27)	-13.6 ± 19.8 -11.2 (-65 – 13)	-15.8 ± 46.9 -26.7 (-100 – 90)	-22.6 ± 18.9 -27.3 (-47 – 14)	0.058[C]	1.25 [0.37, 2.13]	0.45 [-0.36, 1.26]	0.18 [-0.62,0.99]
ODI PC2	-13.3 ± 14.3 -8.7 (-43 – 0)	-21.6 ± 26.8 -29.5 (-40 – 60)	-41.4 ± 33.5 -43.8 (-100 – 20)	-49.8 ± 25.0 -55.6 (-85 – 0)	**0.002[C]**	1.73 [0.78, 2.68]	1.05 [0.19, 1.91]	0.27 [-0.53,1.08]
ATT PC1	0(-48 – 430)	16(-34 – 40)	3 (-81 – 93)	-3(-71 – 347)	0.575[C]	-	-	-
ATT PC2	-45(-45 – 787)	5(-24 – 139)	-21(-72 – 52)	-33(-74 – 773)	0.159[C]	-	-	-
RLTT PC1	9(-12 – 58)	-8(-43 – 33)	-8(-34 – 9)	-18(-76 – 144)	0.054[C]	-	-	-
RLTT PC2	1(-22 – 34)	-16(-45 – 30)	-35(-81 – 12)	-32(-76 – 84)	**<0.006[C]**	-	-	-
PTT PC1	-3(-44 – 28)	3(-70 – 126)	-29(-61 – 26)	23(-29 – 120)	0.089[C]	-	-	-
PTT PC2	-3(-33 – 32)	10(-40 – 67)	7(-69 – 130)	-9(-76 – 208)	0.675[C]	-	-	-
LLTT PC1	0(-48 – 59)	0(-54 – 21)	6(-57 – 58)	0(-66 – 51)	0.969[C]	-	-	-
LLTT PC2	6(-36 – 43)	0(-37 – 21)	-46(-66 – 132)	-46(-66 – 132)	**<0.022[C]**	-	-	-

CG: Control Group; SM: Spinal Manipulation; DNS: Dynamic Neuromuscular Stabilization; SMDNS: Spinal Manipulation + Dynamic Neuromuscular Stabilization; VAS: Visual Analog Scale; ODI: Oswestry Disability Index; DNS-HS: Dynamic Neuromuscular Stabilization Heel Slide Test; RMDQ: Roland–Morris Disability Questionnaire; ATT: Anterior Translations Total; RLTT: Right Lateral Translations Total; PTT: Posterior Translations Total; LLTT: Left Lateral Translations Total; D1: Difference 1; D2: Difference 2; PC1: Percentage Change 1; PC2: Percentage Change 2. Between-group comparisons were performed using the Kruskal–Wallis test (c). Effect sizes (Hedges g) were computed and reported only for outcomes summarized as mean±SD. For outcomes summarized as median (min–max) (ATT, RLTT, PTT, LLTT), standardized effect sizes could not be derived from the available summary statistics; therefore, results are presented as median changes with corresponding p-values. 95% confidence intervals for Hedges g were calculated from group means/SDs assuming n=12 per group using a standard approximation for the standard error of Hedges g.

Within-group analyses showed that ODI changed significantly only in the Control group ($p = 0.016$) (Table 2). In the SM group, significant time effects were observed for VAS ($p < 0.001$), ODI ($p = 0.001$), DNSHS ($p < 0.001$), and RMDQ ($p < 0.001$) (Table 2). In the DNS group, VAS ($p = 0.002$), ODI ($p = 0.001$), DNSHS ($p < 0.001$), RMDQ ($p < 0.001$), RLTT ($p = 0.002$), and LLTT ($p = 0.023$) changed significantly over time (Table 2). In the SMDNS group, significant reductions were found for VAS ($p < 0.001$), ODI ($p < 0.001$), and RMDQ ($p < 0.001$), and postural variables also changed over time for RLTT ($p = 0.032$) and LLTT ($p = 0.023$) (Table 2). To facilitate interpretation of change over time, Table 2 also reports Δ (3rd–1st) values; for variables summarized non-parametrically, Δ is presented as the median (3rd–1st) (Table 2).

Difference1 is used to express the difference between the measurements at time 1 and 2, Difference2 is used to express the difference between the measurements at time 1 and 3. PC1 is used to express the difference between the measurements at time 1 and 2 as a percentage, PC2 is used to express the difference between the measurements at time 1 and 3 as a percentage (Table 3).

VAS-D1 decreased the most in the SMDNS group compared to the other groups ($p = 0.002$). VAS-D2 showed a similar reduction in the SMDNS and DNS groups, both significantly greater than in the Control group. For DNS-HS PC1 and PC2, the Control and SM groups were similar, and the DNS and SMDNS groups were similar, with both intervention groups showing significantly greater reductions than the Control group ($p < 0.001$) (Table 3).

For RMDQ PC1 and PC2, the Control and SM groups were similar, as were the DNS and SMDNS groups; both intervention groups showed significantly greater reductions than the Control group ($p < 0.001$). No significant difference was found between groups for ODI PC1 ($p = 0.058$). For ODI PC2, the Control and SM groups were similar, and the DNS and SMDNS groups were similar, with significantly greater decreases in the DNS and SMDNS groups compared to the Control group ($p = 0.002$) (Table 3).

For RLTT PC2, the DNS and SMDNS groups showed greater decreases than the Control group ($p < 0.006$), and for LLTT PC2, the DNS and SMDNS groups showed greater decreases than the Control group ($p < 0.022$) (Table 3).

To facilitate interpretation of the magnitude of change, standardized between-group effect sizes are reported as Hedges g with 95% confidence intervals (Hedges g [95% CI]) for outcomes summarized as mean±SD (Table 3). For outcomes summarized as medians (ATT, RLTT, PTT, LLTT), results are presented as median changes with corresponding p-values because standardized mean-difference effect sizes with 95% confidence intervals cannot be derived from summary median statistics alone (Table 3).

4. Discussion

The present study aimed to comparatively investigate the effects of HVLA lumbar spinal manipulation and Dynamic Neuromuscular Stabilization (DNS) exercises on pain, functional impairment, physical function, dynamic core-muscle adaptation, and postural deviations in individuals with chronic non-specific low back pain. Overall, our findings suggest parameter-specific benefits rather than universal superiority of any single intervention. Specifically, the combined SM+DNS (SMDNS) approach was associated with greater early pain reduction at the second assessment, whereas DNS-based interventions (DNS and SMDNS) demonstrated more consistent improvements in disability-related outcomes and core-stabilization performance across follow-up.

Özcan et al. compared spinal manipulation with Mulligan mobilization techniques in patients with chronic low back pain and reported improvements in all measured parameters, particularly pain and functionality, in the spinal manipulation group [19]. In another study comparing laser therapy with spinal manipulation in patients with chronic non-specific low back pain, lower VAS and RMDQ scores were observed in favor of the manipulation group after 1 year of follow-up [20]. Similarly, Carrasco et al. compared spinal manipulation with a modified flexion-distraction technique in patients with chronic low back pain and found reductions in VAS and ODI scores in all groups [21]. Consistent with this literature, the SM group in our study showed improvements in VAS, RMDQ, and ODI scores. Similar reductions in pain and disability were also observed in the group receiving combined SM and DNS.

In a study comparing conventional exercise with DNS exercises in obese women with postpartum low back pain, DNS exercises produced greater improvements in pain and related outcomes than conventional exercise [22]. Likewise, Hlaing et al. reported that core stabilization exercises resulted in greater reductions in functional impairment than strengthening exercises in individuals with subacute non-specific low back pain [7]. In our study, the DNS group showed improvements in VAS, ODI, and RMDQ scores between baseline and the final assessment. Comparable improvements were also observed in the combined SM+DNS group.

Schulz et al. evaluated the effectiveness of adding spinal manipulation or supervised exercise to home exercise in patients with subacute or chronic low back pain and found no clear superiority between groups in terms of pain at 1-year follow-up [23]. They also reported that the addition of spinal manipulation or supervised exercise did not provide clear medium- or long-term benefit, although participants tended to prefer these interventions over home exercise alone [23]. In our study, when percentage changes were compared between the SM and SM+DNS groups, the combined intervention produced greater improvements in VAS, RMDQ, and ODI than SM alone. These findings suggest that DNS may serve as a useful adjunct to spinal manipulation within multimodal treatment programs.

Similarly, Salık Şengül et al. reported that stabilization exercises were more effective than conventional exercises in reducing pain during activity and improving core stability and endurance in patients with chronic non-specific low back pain [24]. In our study, when percentage changes were compared between the DNS and SM+DNS groups, the combined intervention showed greater improvement in early pain reduction between the first and second assessments. Because the remaining parameters showed broadly similar patterns, it may be inferred that combining spinal manipulation with DNS could be advantageous when rapid pain reduction is a treatment priority.

Overall, our findings are consistent with guideline-based care, in which exercise is considered a core component of treatment for chronic low back pain and manual therapy may provide additional short-term symptom relief when delivered alongside exercise. Evidence syntheses similarly indicate that both exercise therapy and manual therapy can improve pain and disability, although their effects are often modest and influenced by context and duration of follow-up [37,38,39]. Accordingly, the mechanisms of manual therapy are better interpreted within contemporary neurophysiological and biopsychosocial frameworks rather than structural subluxation-based models.

Some authors have proposed neurophysiological explanations linking spinal joint dysfunction with altered sensorimotor control; however, these concepts remain debated and should be interpreted cautiously [25]. It has been suggested that chiropractic HVLA manipulation may influence the function of deep paraspinal muscles by altering abnormal sensory input [26]. Spinal manipulation has also been proposed to

stimulate mechanoreceptors, thereby modifying afferent input and potentially increasing motor neuron recruitment and muscle activation [27]. Several studies have reported increases in muscle strength after spinal manipulation [26,28,29,30], and Kendall et al. concluded in a systematic review that manual therapy may have short-term effects on stability [31]. In our study, DNS-HS scores changed over time in the SM group in favor of improved dynamic core-muscle adaptation, with the third assessment differing favorably from the first and second assessments. These explanations remain hypothetical in the context of our trial, because we did not directly measure neurophysiological variables. Therefore, the observed improvement in DNS-HS performance in the SM group should be interpreted cautiously and may reflect neurophysiological adaptation, motor learning, or other non-specific effects.

Haavik et al. suggested that altered afferent input from paraspinal tissues may contribute to longer-term cortical reorganization and changes in top-down sensorimotor control [26]. In our study, the absence of a clear difference between the first two DNS-HS assessments in the SM group may indicate that 4 sessions over 2 weeks were insufficient to produce measurable change in this outcome. Because the optimal frequency and duration of manipulation remain uncertain in the literature, our findings may suggest that a treatment period of at least 4 weeks could be more appropriate for observing potential changes in dynamic core-muscle adaptation in patients receiving twice-weekly care. Nevertheless, this interpretation should be considered exploratory, and further studies with larger samples, more frequent assessments, and longer follow-up are needed to clarify dose-response relationships for chiropractic manual therapy.

Few studies have specifically evaluated the effects of DNS exercises on dynamic core-muscle adaptation in individuals with chronic low back pain using the DNS-HS test. However, a positive relationship between core stability and functional performance is well recognized [32]. Mahdieh et al., for example, evaluated training effects using the Y-Balance Test and Functional Movement Screening and reported that DNS exercises improved basic functional skills [18]. In the present study, we used the DNS-HS test to assess lumbopelvic muscle adaptation in a more isolated manner. In the DNS group, DNS-HS scores improved between the first and third assessments, suggesting enhanced dynamic core adaptation over time.

Rapid gains following exercise interventions are often attributed, at least in part, to neurological adaptations such as increased motor unit recruitment and changes in neuromuscular control [33]. In our study, the improvement observed in DNS-HS performance after DNS may likewise reflect enhanced neuromuscular activation of the core musculature, although this mechanism was not directly measured. A similar favorable change between the first and last assessments was also observed in the combined SM+DNS group.

In the SM group, no significant change was observed in sagittal postural deviations across measurements. Postural patterns in chronic low back pain may reflect maladaptive or protective responses consistent with pain-adaptation models, in which individuals avoid painful positions and adopt compensatory postures. Although some models have described segmental dysfunction using the term "vertebral subluxation," this concept remains debated and should not be interpreted as a definitive structural cause of chronic low back pain [34]. Haavik et al. suggested that spinal joint dysfunction may be associated with broader sensorimotor alterations extending beyond the local segment [26]. Therefore, rather than focusing exclusively on segment-specific alignment, we assessed overall posture in an attempt to capture the global postural response in individuals with chronic low back pain.

It has been proposed that spinal manipulation may increase mechanoreceptive input to the central nervous system and thereby influence motor control [26]. Future studies incorporating objective neurophysiological measures are needed to evaluate these

proposed mechanisms directly. In our study, sagittal postural deviations in the SM group showed only slight improvement, although this change reached statistical significance. No significant difference was found in frontal-plane deviations, which may be related to the absence of participants with marked scoliosis or substantial frontal-plane postural asymmetry in the sample. Larger and longer-duration studies are therefore needed to better determine the effects of spinal manipulation on posture.

Exercise-related effects are frequently discussed in relation to postural control, including balance and static posture, and postural control has often been evaluated through postural sway or oscillation amplitude. Many studies have reported that core stabilization exercises are beneficial for postural control [35,36]. In our study, DNS exercises were associated with improvement in the total sagittal posture parameter, although the observed changes in anterior and posterior postural variables were small and not statistically significant. One possible explanation is that the sample did not include participants with pronounced frontal-plane deviations. Another possible interpretation is that DNS may have contributed to improved postural organization through better diaphragm activation, improved intra-abdominal pressure regulation, and more coordinated deep stabilizer co-activation. However, these mechanistic interpretations remain speculative and were not directly tested in this study. In the combined SM+DNS group, sagittal plane deviations decreased in a similar manner.

When percentage changes in sagittal posture measures were compared between groups, the SM+DNS group showed more favorable changes than SM or DNS alone, suggesting that DNS may be a useful adjunct for targeting postural outcomes in rehabilitation. However, when we examined the relationships between postural measures and VAS, DNS-HS, RMDQ, and ODI across groups and time points, these associations were not consistent. This inconsistency may reflect the limited number of participants with clinically meaningful postural deviations as well as the modest sample size.

Several additional limitations should be considered when interpreting our findings. Associations between postural measures and VAS, DNS-HS, RMDQ, and ODI were not consistently observed, and this may partly relate to the modest sample size. The small improvements observed in the Control group may reflect natural symptom fluctuation, regression to the mean, or retest effects in a usual-activity wait-list design. In addition, baseline disability levels were relatively low, particularly on the ODI, which may indicate a floor effect; given the heterogeneity of chronic non-specific low back pain, persistent pain may coexist with relatively preserved daily functioning. One participant in the SM+DNS group had extreme obesity (BMI 53.7), which may have influenced posture and exercise tolerance and may limit generalizability. Finally, this was a single-center study conducted in a private physiotherapy clinic, and participant or therapist blinding was not feasible because of the nature of the interventions. Accordingly, the findings should be interpreted cautiously and confirmed in larger multicenter trials with blinded outcome assessment and longer follow-up.

5. Conclusions

Spinal manipulation and DNS, when delivered as standalone interventions, were associated with improvements in several study outcomes. The combined SM+DNS intervention appeared to offer parameter-specific benefits, most notably greater early pain reduction, while DNS-based approaches yielded more consistent improvements in disability, functional status, and core stabilization. Nevertheless, these findings should be interpreted cautiously, and their clinical significance should be evaluated with reference to established minimal clinically important differences (MCIDs), where available. Larger trials with blinded outcome assessment and longer follow-up are needed to confirm these results.

Author Contributions: Conceptualization, IA, SHH and EBA; methodology, IA, SHH and EBA; validation, SHH, ICB and EBA; formal analysis, SHH, ICB and EBA; investigation, IA and SHH; data curation, IA; writing—original draft preparation, IA, SHH and ICB; writing—review and editing, IA, SHH and ICB; visualization, IA; supervision, SHH and ICB; project administration, SHH and EBA. All authors have read and agreed to the published version of the manuscript.

Funding: This research did not receive any spesific grant from funding agencies in the public, commercial, or non – for – profit sectors.

Institutional Review Board Statement: Ethical approval was obtained from the Gümüşhane University Rectorate Scientific Research and Publication Ethics Board (meeting no. 2022/6; 26 October 2022). The study was conducted in accordance with the principles of the Declaration of Helsinki, and written informed consent was obtained from all participants. Clinical Trials registration: NCT06277700.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author. The data are not publicly available due to ethical and privacy restrictions.

Acknowledgments: We are greateful to all the individuals who participated in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Sheng, Y.; Duan, Z.; Qu, Q.; Chen, W.; Yu, B. Kinesio taping in treatment of chronic non-specific low back pain: A systematic review and meta-analysis. J. Rehabil. Med. 2019, 51, 734–740. https://doi.org/10.2340/16501977-2605.
2. Lara-Palomo, I.C.; Gil-Martínez, E.; Antequera-Soler, E.; Castro-Sánchez, A.M.; Fernández-Sánchez, M.; García-López, H. Electrical dry needling versus conventional physiotherapy in the treatment of active and latent myofascial trigger points in patients with nonspecific chronic low back pain. Trials 2022, 23, 238. https://doi.org/10.1186/s13063-022-06179-y.
3. Becker, A.; Held, H.; Redaelli, M.; Strauch, K.; Chenot, J.F.; Leonhardt, C.; Keller, S.; Baum, E.; Pfingsten, M.; Hildebrandt, J.; Basler, H.D.; Kochen, M.M.; Donner-Banzhoff, N. Low back pain in primary care: Costs of care and prediction of future health care utilization. Spine (Phila Pa 1976) 2010, 35, 1714–1720. https://doi.org/10.1097/BRS.0b013e3181cd656f.
4. Paige, N.M.; Miake-Lye, I.M.; Booth, M.S.; Beroes, J.M.; Mardian, A.S.; Dougherty, P.; Branson, R.; Tang, B.; Morton, S.C.; Shekelle, P.G. Association of spinal manipulative therapy with clinical benefit and harm for acute low back pain: Systematic review and meta-analysis. JAMA 2017, 317, 1451–1460. https://doi.org/10.1001/jama.2017.3086.
5. Bronson, M.A.; Smith, D.L.; Tuchin, P. Spinal manipulation is beneficial for nonchronic low back pain. Am. J. Emerg. Med. 2017, 35, 1576–1577. https://doi.org/10.1016/j.ajem.2017.04.048.
6. Thomas, J.S.; Clark, B.C.; Russ, D.W.; France, C.R.; Ploutz-Snyder, R.; Corcos, D.M.; RELIEF Study Investigators. Effect of spinal manipulative and mobilization therapies in young adults with mild to moderate chronic low back pain: A randomized clinical trial. JAMA Netw. Open 2020, 3, e2012589. https://doi.org/10.1001/jamanetworkopen.2020.12589.
7. Hlaing, S.S.; Puntumetakul, R.; Khine, E.E.; Boucaut, R. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: A randomized controlled trial. BMC Musculoskelet. Disord. 2021, 22, 998. https://doi.org/10.1186/s12891-021-04858-6.
8. Mousavi, S.M.S.; Mirsafaei Rizi, R. Effect of Central Stability and Dynamic Neuromuscular Stabilization Exercises on Pain, Flexibility, Balance, Muscle Endurance and Quality of Life in Men With Nonspecific Chronic Low Back Pain. J. Guilan Univ. Med. Sci. 2022, 31, 136–149. https://doi.org/10.32598/JGUMS.31.2.1789.1.
9. Ross, H. A comparison of dynamic neuromuscular stabilization and abdominal bracing on pain in adults with chronic low back pain: A case report. Dissertation, Azusa Pacific University, Azusa, CA, USA, 2017.
10. Frank, C.; Kobesova, A.; Kolar, P. Dynamic neuromuscular stabilization & sports rehabilitation. Int. J. Sports Phys. Ther. 2013, 8, 62–73.
11. Gorji, S.M.; Mohammadi Nia Samakosh, H.; Watt, P.; Marchetti, P.H.; Oliveira, R. Pain Neuroscience Education and Motor Control Exercises versus Core Stability Exercises on Pain, Disability, and Balance in Women with Chronic Low Back Pain. Int. J. Environ. Res. Public Health 2022, 19, 2694. https://doi.org/10.3390/ijerph19052694.
12. Abdel-Aziem, A.A.; Abdelraouf, O.R.; El-Basatiny, H.M.Y.; Draz, A.H. The effects of stabilization exercises combined with pelvic floor exercise in women with nonspecific low back pain: A randomized clinical study. J. Chiropr. Med. 2021, 20, 229–238. https://doi.org/10.1016/j.jcm.2021.12.008.
13. Cha, Y.J.; Lee, J.J.; Kim, D.H.; You, J.S.H. The validity and reliability of a dynamic neuromuscular stabilization-heel sliding test for core stability. Technol. Health Care 2017, 25, 981–988. https://doi.org/10.3233/THC-170929.

14. Hopkins, B.C. Validity of PostureScreen Mobile® in the measurement of standing posture. Master's Thesis, Brigham Young University, Provo, UT, USA, 2014.
15. Cosma, G.; Ilinca, I.; Rusu, L.; Nanu, C.; Burileanu, A. Physical exercise and its role in a correct postural alignment. Discobolul Phys. Educ. Sport Kinetother. J. 2015, 11, 58–64.
16. Szucs, K.A.; Brown, E.V.D. Rater reliability and construct validity of a mobile application for posture analysis. J. Phys. Ther. Sci. 2018, 30, 31–36. https://doi.org/10.1589/jpts.30.31.
17. Gyer, G.; Michael, J.; Davis, R. Advanced Osteopathic and Chiropractic Techniques for Manual Therapists: Adaptive Clinical Skills for Peripheral and Extremity Manipulation; Singing Dragon: Philadelphia, PA, USA, 2020.
18. Mahdieh, L.; Zolaktaf, V.; Karimi, M.T. Effects of dynamic neuromuscular stabilization (DNS) training on functional movements. Hum. Mov. Sci. 2020, 70, 102568. https://doi.org/10.1016/j.humov.2019.102568.
19. Özcan, E.; Hatık, S.H.; Tekin, D. Kronik Bel Ağrılı Bireylerde Kayropraktik Manipülasyonu İle Mulligan Mobilizasyonu Tekniğinin Ağrı ve Fonksiyonellik Üzerine Etkisinin Karşılaştırılması. Ahi Evran Med. J. 2022, 6, 55–63. https://doi.org/10.46332/aemj.841282.
20. Nambi, G.; Kamal, W.; Es, S.; Joshi, S.; Trivedi, P. Spinal manipulation plus laser therapy versus laser therapy alone in the treatment of chronic nonspecific low back pain: A randomized controlled study. Eur. J. Phys. Rehabil. Med. 2018, 54, 880–889. https://doi.org/10.23736/S1973-9087.18.05005-0.
21. Carrasco-Martínez, F.; Ibáñez-Vera, A.J.; Martínez-Amat, A.; Hita-Contreras, F.; Lomas-Vega, R. Short-term effectiveness of the flexion-distraction technique in comparison with high-velocity vertebral manipulation in patients suffering from low-back pain. Complement. Ther. Med. 2019, 44, 61–67. https://doi.org/10.1016/j.ctim.2019.02.012.
22. Ghavipanje, V.; Rahimi, N.M.; Akhlaghi, F. Six weeks effects of dynamic neuromuscular stabilization (DNS) training in obese postpartum women with low back pain: A randomized controlled trial. Biol. Res. Nurs. 2022, 24, 106–114. https://doi.org/10.1177/10998004211044828.
23. Schulz, C.; Evans, R.; Maiers, M.; Schulz, K.; Leininger, B.; Bronfort, G. Spinal manipulative therapy and exercise for older adults with chronic low back pain: A randomized clinical trial. Chiropr. Man. Ther. 2019, 27, 21. https://doi.org/10.1186/s12998-019-0243-1.
24. Salik Sengul, Y.; Yilmaz, A.; Kirmizi, M.; Kahraman, T.; Kalemci, O. Effects of stabilization exercises on disability, pain, and core stability in patients with non-specific low back pain: A randomized controlled trial. Work 2021, 70, 99–107. https://doi.org/10.3233/WOR-213557.
25. Cooperstein, R.; Young, M.; Haneline, M. Interexaminer reliability of cervical motion palpation using continuous measures and rater confidence levels. J. Can. Chiropr. Assoc. 2013, 57, 156–164.
26. Haavik, H.; Kumari, N.; Holt, K.; Niazi, I.K.; Amjad, I.; Pujari, A.N.; Türker, K.S.; Murphy, B. The contemporary model of vertebral column joint dysfunction and impact of high-velocity, low-amplitude controlled vertebral thrusts on neuromuscular function. Eur. J. Appl. Physiol. 2021, 121, 2675–2720. https://doi.org/10.1007/s00421-021-04727-z.
27. Pickar, J.G. Neurophysiological effects of spinal manipulation. Spine J. 2002, 2, 357–371. https://doi.org/10.1016/S1529-9430(02)00400-X.
28. Grindstaff, T.L.; Hertel, J.; Beazell, J.R.; Magrum, E.M.; Ingersoll, C.D. Effects of lumbopelvic joint manipulation on quadriceps activation and strength in healthy individuals. Man. Ther. 2009, 14, 415–420. https://doi.org/10.1016/j.math.2008.06.005.
29. Lo, C.N.; Ng, J.; Au, C.K.; Lim, E.C.W. The effectiveness of spinal manipulation in increasing muscle strength in healthy individuals: A systematic review and meta-analysis. J. Manipulative Physiol. Ther. 2019, 42, 148–158. https://doi.org/10.1016/j.jmpt.2018.10.003.
30. Niazi, I.K.; Kamavuako, E.N.; Holt, K.; Janjua, T.A.M.; Kumari, N.; Amjad, I.; Haavik, H. The effect of spinal manipulation on the electrophysiological and metabolic properties of the tibialis anterior muscle. Healthcare (Basel) 2020, 8, 548. https://doi.org/10.3390/healthcare8040548.
31. Kendall, J.C.; Vindigni, D.; Polus, B.I.; Azari, M.F.; Harman, S.C. Effects of manual therapies on stability in people with musculoskeletal pain: A systematic review. Chiropr. Man. Therap. 2020, 28, 13. https://doi.org/10.1186/s12998-020-0300-9
32. Sediek, R.H.; El-Tohamy, A.M.; Nassar, I. Relation between core-stability and functional abilities in children with spastic cerebral palsy. Trends Appl. Sci. Res. 2016, 11, 19–25. https://doi.org/10.3923/tasr.2016.19.25.
33. Del Vecchio, A.; Casolo, A.; Dideriksen, J.L.; Aagaard, P.; Felici, F.; Falla, D.; Farina, D. Lack of increased rate of force development after strength training is explained by specific neural, not muscular, motor unit adaptations. J. Appl. Physiol. (1985) 2022, 132, 84–94. https://doi.org/10.1152/japplphysiol.00218.2021.
34. Meier, M.L.; Vrana, A.; Schweinhardt, P. Low back pain: The potential contribution of supraspinal motor control and proprioception. Neuroscientist 2019, 25, 583–596. https://doi.org/10.1177/1073858418809074.
35. Szafraniec, R.; Barańska, J.; Kuczyński, M. Acute effects of core stability exercises on balance control. Acta Bioeng. Biomech. 2018, 20, 145–151. https://doi.org/10.5277/ABB-01178-2018-02.
36. Cabrera-Martos, I.; Ortiz-Rubio, A.; Torres-Sánchez, I.; López-López, L.; Jarrar, M.; Valenza, M.C. The effectiveness of core exercising for postural control in patients with stroke: A systematic review and meta-analysis. PM R 2020, 12, 1157–1168. https://doi.org/10.1002/pmrj.12330.

37. Briggs, A.M.; Sumi, Y.; Banerjee, A. The World Health Organization guideline for non-surgical management of chronic primary low back pain in adults: Implications for equitable care and strengthening health systems globally. Glob. Health Res. Policy 2025, 10, 26. https://doi.org/10.1186/s41256-025-00426-w.
38. Bernstein, I.A.; Malik, Q.; Carville, S.; Ward, S. Low back pain and sciatica: Summary of NICE guidance. BMJ 2017, 356, i6748. https://doi.org/10.1136/bmj.i6748.
39. Qaseem, A.; Wilt, T.J.; McLean, R.M.; Forciea, M.A. Noninvasive treatments for acute, subacute, and chronic low back pain: A clinical practice guideline from the American College of Physicians. Ann. Intern. Med. 2017, 166(7), 514–530. https://doi.org/10.7326/M16-2367.
40. Chicu, M.; Matran-Dan, M.I.; Esanu, I.; Mihailov, L.; Onofrei, B.A. Low back pain- Algorithm of diagnosis and management. Balneo and PRM Research Journal 2024, 15, 657. https://doi.org/10.12680/balneo.2024.657.
41. Cha, Y.J.; Lee, J.J.; Kim, D.H.; You, J.S.H. The validity and reliability of a dynamic neuromuscular stabilization–heel sliding test for core stability. Technol Health Care 2017, 25(5), 981–988. https://doi.org/10.3233/THC-170929.