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Cervical stability training with and without core stability training for patients with cervical disc herniation: A randomized, single-blind study

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Abstract

Background: This study aims at evaluating and comparing the effects of cervical stability training to combined cervical and core stability training in patients with neck pain and cervical disc herniation.
Methods: Fifty patients with neck pain and cervical disc herniation were included in the study, randomly divided into two groups as cervical stability and cervical-core stability. Training was applied three times a week in three phases, and lasted for a total duration of 8 weeks. Pain, activation and static endurance of deep cervical flexor muscles, static endurance of neck muscles, cross-sectional diameter of M. Longus Colli, static endurance of trunk muscles, disability and kinesiophobia were assessed.
Results: Pain, activation and static endurance of deep cervical flexors, static endurance of neck muscles, cross-sectional diameter of M. Longus Colli, static endurance of trunk muscles, disability and kinesiophobia improved in both groups following the training sessions ($p < 0.05$). Comparison of the effectiveness of these two training methods revealed that the cervical stability group produced a greater increase in the right transverse diameter of M. Longus Colli ($p < 0.05$). However, static endurance of trunk muscles and kinesiophobia displayed better improvement in the cervical-core stability group ($p < 0.05$).
Conclusions: Cervical stability training provided benefit to patients with cervical disc herniation. The addition of core stability training did not provide any additional significant benefit. Further research is required to investigate the efficacy of combining other techniques with cervical stability training in patients with cervical disc herniation.
Significance: Both cervical stability training and its combination with core stability training were significantly and similarly effective on neck pain and neck muscle endurance in patients with cervical disc herniation.

1. Introduction

Cervical stability training is applied as an exercise programme in order to improve the stability of the cervical spine, reduce pain and enhance functionality (Hides et al., 2001). For individuals suffering from neck pain, stability training starts with low-load exercises so that while deep cervical flexor (DCF) muscles are activated, superficial muscle

activity is reduced (Jull et al., 2009). In order to compensate for the deep flexor muscles, the superficial muscles are overactivated. This overactivity of the superficial muscles results in fatigue and muscles spasms. Therefore, physiotherapy focuses primarily on reducing the excessive activation of these muscles and decreasing fatigue (Falla et al., 2005; Brotzman and Manske, 2011). The treatment procedure, which starts with pain management and muscular coordination restoration, is followed by increasing muscular strength and endurance (Falla et al., 2005).

Cervical stability training is based on the knowledge that the strength and endurance of DCF muscles are reduced in individuals suffering from neck pain (Jull et al., 2004, 2009; Falla et al., 2005; Domenech et al., 2011). Studies investigating the coordination between deep and superficial cervical flexor muscles have demonstrated that during cranio-cervical flexion, electromyography (EMG) amplitude of DCF muscles decreases (Jull et al., 2004). Conversely, EMG amplitude of superficial cervical flexor muscles increase in patients with neck pain (Falla, 2004a), when compared to healthy subjects. Several studies have shown that the significant factor in neck pain is the inadequacy of DCF muscles in maintaining stabilization of the cervical spine (Falla et al., 2004b; Borisut et al., 2013). Moreover, it is reported that reactivating DCF muscles aid the reorganization of motor control and normalization of superficial muscle activation levels in neck pain, resulting in improved clinical outcomes (Falla, 2004a; Falla et al., 2007; Borisut et al., 2013).

Physiotherapy programmes for individuals suffering from neck pain generally focus on the cervical region, while other parts of the spine are often overlooked. Black et al. reported that different sitting positions involving thoracic or lumbar spine activity cause changes in the position of the cervical spine (Black et al., 1996). In spite of numerous studies indicating interaction between different segments of the spine (Manchikanti et al., 2004; Lau et al., 2010), there have been no studies investigating the effectiveness of approaches that involve the whole spine in patients suffering from neck pain.

Therefore, this study was based on the hypothesis that instead of exercises focusing only on the cervical spine, more comprehensive programmes including stability and mobility of all segments of the spine would be more effective on clinical outcomes in patients with neck pain. The aim of this study was to compare the effects of cervical stability training with cervical plus core stability training on pain, muscle activation and endurance, muscle cross-sectional diameter, level of functionality and kinesiophobia in patients with cervical disc herniation.

2. Methods

2.1 Study design

This study was designed as a single-blind randomized controlled trial. Individuals who agreed to participate in the study were divided into two groups on the basis of gender and age using the matched randomization method: cervical stability group (CS) and cervical-core stability group (CCS). Approval for the study was given by Gazi University's Ethics Committee (permission number: 223). Written informed consent was obtained from all participants.

2.2 Participants

Patients with cervical disc herniation whose condition was documented by magnetic resonance imaging at the Department of Physical Medicine and Rehabilitation and referred to the physiotherapy unit were included in the study. Inclusion criteria were as follows: ongoing neck pain for a minimum of 3 months, Neck Disability Index Score below 15, having no rheumatologic, neurologic or musculoskeletal problems which prevent exercise. Exclusion criteria were: any history of cervical spine surgery, having received physiotherapy because of neck pain during the past 6 months, Body Mass Index of 30 and over and vertebrobasilar arterial insufficiency. A total of 114 patients were referred for physiotherapy, of whom 57 did not meet the inclusion criteria. The remaining 57 patients were eligible for inclusion in the study and were divided into two groups, with 27 patients in the CS group and 30 in the CCS group. However, two patients from the CS group and five from in the CCS group refused to take part in the training programme because of personal reasons. As a result, the training programme was completed with 50 participants, with 25 patients in each group.

2.3 Study interventions

Cervical stability training was applied to the CS group. The same training programme along with additional core stability training was applied to the CCS group. For both groups, trainings were applied 3 days a week, and conducted in three phases, for a total of 8 weeks. While the first two phases each lasted for 2 weeks each, the third phase was for 4 weeks. Based on the exercise tolerance of the

patients, all exercises were repeated 7–10 times during the first week and 10–15 times during the second week of each phase. Before the stability trainings started, lectures were given to the participants about spine health and how to improve it. The lectures involved simple descriptions of the anatomical and biomechanical features of the spine and how to maintain the neutral position of the spine during activities in daily life. The stability trainings were applied by experienced physiotherapists (BB).

Pressure biofeedback was used to teach cranio-cervical flexion in the CS group and centering in the CCS group. Additionally, verbal and tactile stimuli were used to maintain correct posture and to modify erroneous movements during the exercise sessions. Difficulty level of the exercises was increased by working in different positions, the use of Thera-Bands, Pilates exercise balls, and body weight and by adding movements to the extremities. In addition, same posture and thoracic mobility exercises were given to both groups (Fig. 1 o,p,r). Training programmes are detailed in Table 1 and some example exercises are shown in Fig. 1.

2.3.1 Cervical stability training

The CS training consisted of three application phases. The aim of the first phase was to improve muscular coordination and proprioception. Primary target muscles were M. Longus Capitis, M. Longus Colli and deep cervical extensors. In the first session, activation of DCF muscles with cranio-cervical flexion exercise was carried out. Exercises were applied gently and in a controlled manner during the first phase. The second phase aimed at improving muscular endurance and strength, and the final phase aimed at improving muscular strength as well. The intensity of exercise in the third phase was higher than in the second phase.

2.3.2 Cervical and core stability training

This programme included core stability training in addition to the core stabilization exercises. Core stability training paralleled the CS group's training and exercises that could overload the cervical spine were avoided. The aim of the core stability training was to improve core stability and mobility. The training consisted of three phases similar to the CS training. During the first session, activation of DCF muscles using cranio-cervical flexion exercise and activation of M. Transversus Abdominis using the abdominal draw-in manoeuvre were conducted. The patients were asked to perform this manoeuvre and the cranio-cervical flexion during all stability exercises. The main aim of the first phase was to teach how to activate both cervical and core muscles at the same time and to improve muscular coordination and proprioception in both spinal areas. Exercises were made more intense in the second and third phases in order to improve muscular endurance and stability.

2.4 Assessment

The demographic data of all patients (age, body mass index, duration of diagnosis) were recorded. Pain, activation and static endurance of DCF muscles, neck flexors-extensors' endurance, static endurance of trunk muscles and questionnaires were handled by a physiotherapist (OB), and the cross-sectional area and diameter of M. Longus Colli were evaluated by a radiologist (YD). The researcher performing the evaluations was not informed about the patients' group allocation in order to mitigate bias. All assessments were performed both prior to and after stability trainings took place.

2.4.1 Visual analog scale

The average severity of pain for the past 4 weeks both at rest and during an activity was evaluated using the visual analog scale (VAS; Cagnie et al., 2009).

2.4.2 Cranio-cervical flexion test

This test was applied in order to evaluate the activation and static endurance of DCF muscles. The evaluation was conducted using a biofeedback pressure unit (Stabilizer Pressure Biofeedback-Chattanooga Stabilizer). The test was performed at five different pressure levels with 10 repetitions (Jull et al., 2008a). The patients were asked to lie down on an examination table in the hook lying position, with the neck held in a neutral position (Falla et al., 2003). The biofeedback pressure unit was inflated to 20 mmHg without causing any increase in the cervical lordosis. The patients were asked to close their mouths, with just a slight opening between the jaws, place their tongue against the upper palate and nod their head (as if saying "yes"; Fernandez-de-las-Peñas et al., 2007). Measurement results covered both the activation score and performance index (Jull et al., 2008a).

Table 1 Cervical and cervical-core stability training.

	Phase: 1		Phase: 2		Phase: 3	
	CS	CCS	CS	CCS	CS	CCS
Supine	*Cranio-cervical Flexion (CSF) (Fig. 1a) *CCF+UEE(shoulder flexion-extension) (Fig. 1b)	*CSF+Abdominal draw-in (AD) (Fig. 1j) *CCF+AD+ UEE/LEE	*CCF+ neck isometric flexion/extension/lateral flexion	*CCF+ AD+ neck isometric flexion/ extension/lateral flexion *CCF+ AD+bridging *CCF+AD+bridging+UEE/ LEE (Fig. 1k)	–	*CCF+AD+bridging *CCF+AD+bridging+UEE/LEE *Sit-ups (7–8 weeks)
Forearms	*CCF+deep cervical extensors exercise (Fig. 1c)	*CCF+ AD+deep cervical extensors exercise	–	–	–	*Modify lateral bridging (7–8 weeks) (Fig. 1n)
Side Lying	*CCF	*CCF+AD *CCF+AD+LEE	–	*CCF+AD+LEE with yellow Thera-Band (Fig. 1 m–l)	–	CCF+AD+LEE with red Thera-Band
Four-Point Kneeling	*CCF *CCF+UEE/LEE *CCF+deep cervical extensors exercise	*CCF+AD *CCF+AD+UEE/ LEE *CCF+AD+deep cervical extensors exercises *Spinal mobility and flexibility exercises	*CCF+with book on the head *CCF+ with book on the head+ UEE (Fig. 1d) *CCF +deep cervical extensors exercise	*CCF+ AD+ with book on the head *CCF+ AD+ with book on the head+ UEE *CCF+ AD+ deep cervical extensors exercise *Spinal mobility and flexibility exercises	*CCF+with book on the head+ UEE+LEE *CCF+with book on the head+deep cervical extensors exercise	*CCF+AD+with book on the head *CCF+ AD+with book on the head+UEE *CCF+ AD+deep cervical extensors exercise *Spinal mobility and flexibility exercises
Sitting	*CCF *CCF+with upper extremity PNF patterns	*CCF+AD *CCF+AD+with upper extremity PNF patterns	*CCF+upper extremity PNF patterns with yellow Thera-Band (Fig. 1e)	*CCF+ AD *CCF+ AD+ with upper extremity PNF patterns with yellow Thera-Band	*CCF+ neck isometric flexion/extension/lateral flexion/rotation with yellow Thera-Band (Fig. 1h)	*CCF+ AD+ neck isometric flexion/extension/lateral flexion/rotation with yellow Thera-Band
Standing	*CCF *CCF+with upper extremity PNF patterns	*CCF+AD *CCF+AD+with upper extremity PNF patterns	*CCF+ neck isometric flexion/extension/lateral flexion (ball between head and wall) (Fig. 1f) *Same exercises with UE movements *CCF+UEE with yellow Thera-Band (ball between back of the head and wall) *Neck flexion/extension/ lateral flexion/rotation with yellow Thera-Band (Fig. 1g) *CCF with upper extremity PNF patterns with yellow Thera-Band *CCF+deep cervical extensors exercise with yellow Thera-Band	*CCF+AD+neck isometric flexion/extension/lateral flexion (ball between head and wall) *Same exercise with UE movements *CCF+ AD+UEE with yellow Thera-Band (ball between back of the head and wall) *CCF+ AD+neck flexion/ extension/lateral flexion/ rotation with yellow Thera-Band *CCF+AD+CCF with PNF patterns with yellow Thera-Band *CCF+AD+deep cervical extensors exercise with yellow Thera-Band	*Same exercises in the second phase with red Thera-Band (example; deep cervical extensors exercise, Fig. 1i)	*Same exercises in the second phase with red Thera-Band

CS, Cervical Stability Training; CCS, Cervical-Core Stability Training; AD, Abdominal Draw-in; CSF, Cranio-cervical Flexion; PNF, Proprioceptive Neuromuscular Facilitation; UEE, Upper Extremity Exercises; LEE, Lower Extremity Exercises.

Figure 1 Cervical and core stability exercise examples.

2.4.3 Neck flexors endurance test

Patients were lying down in the hook lying position with the therapist's hand placed under their head. The patients were then asked to bring their chin closer to their chest in the Chin Tuck position lifting their head about 2.5 cm and to then hold that position (Edmondston et al., 2008). The test was terminated if the patient experienced any pain or fatigue, or if their head touched the therapist's hand. Two measurements were taken and the longest duration was recorded.

2.4.4 Neck extensors endurance test

The patients were lying with their heads bent downwards and their arms resting at their sides. They were asked to approach the edge of the bed so that their head and chest would be hanging from the bed. A sandbag weighing of 2 kg was placed at the back of the neck (between the ears) and the patients were asked to lift their head to the neutral position and then hold it there (Edmondston et al., 2008). The test was terminated in case of any pain or fatigue experienced by the patients, or a 5° deterioration in the position of the head. Two measurements were taken and the highest score was recorded.

2.4.5 Examining the cross-sectional diameter of M. Longus Colli

The patients were placed in a relaxed position with their arms at their sides and knees and hips in

flexion. A small pillow was placed at the posterior of the neck. The cross-sectional area and the diameter of M. Longus Colli were evaluated by an experienced radiologist (YD) using high resolution ultrasound (Toshiba Aplio 500, Tokyo, Japan) (Cagnie et al., 2009). B-mode images were taken using a 12–18 MHz linear transducer. Ultrasound examination of the neck was carried out while the transducer was placed perpendicular to the long axis of the neck in axial plane. In order to gain the clearest images, M. Longus Colli images were taken at the level of C5–C6. The area of the muscle was calculated using anterio-posterior and transverse diameters of M. Longus Colli (Fig. 2).

2.4.6 Evaluating static endurance of trunk muscles

Sorensen Test and Trunk Flexors Endurance Test were applied to evaluate the static endurance of the trunk muscles. The measurements were taken using a stopwatch and the timed results recorded in numbers of seconds. Each measurement was repeated twice and the best scores recorded. In case of any deterioration in the position or the patient's inability to hold that position, the tests were terminated (McGill et al., 1999).

2.4.7 Sorensen test

The test consists of measuring the amount of time a person can hold their upper body unsupported in a horizontal prone position with the lower body lying on the examination table (McGill et al., 1999; Roponen et al., 2005).

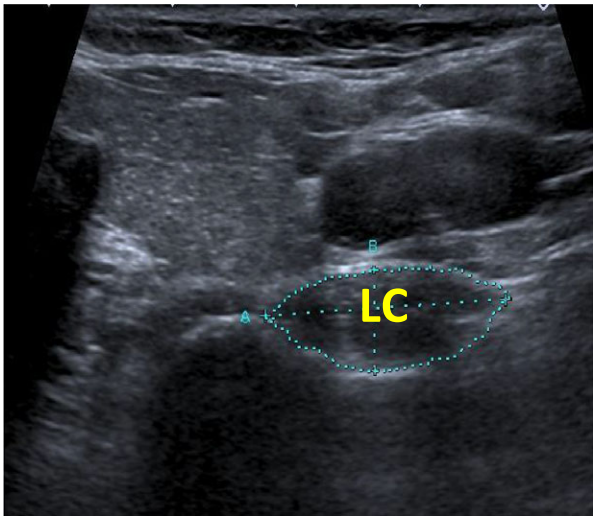

Figure 2 Ultrasound image of the M. Longus Colli (LC: M. Longus Colli).

2.4.8 Trunk flexors endurance test

To perform this test, the subjects were placed in a modified sit-up position with their knees and hips in 90° flexion, their feet flat on the floor held down by the physiotherapist and their trunk at a 60° angle to the floor (McGill et al., 1999; Ropponen et al., 2005).

2.4.9 Neck disability scale

The Neck Disability Index was applied in order to evaluate how the patient's neck pain affects their daily life (Bicer et al., 2004; Vernon, 2008). Total point changes between 0 and 35, with a high score indicating a higher level of disability.

2.4.10 Tampa scale of kinesiophobia

The scale was used to assess fear of pain or re-injury that may occur because of any movement. Consisting of 17 items, the scale assesses the parameters of injury/re-injury and fear/avoidance in various activities (Tunca Yılmaz et al., 2011). Total points may vary between 17 and 68, with a high score indicating a higher level of kinesiophobia.

2.5 Statistical analysis

Statistical analysis was conducted using "Statistical Package for Social Sciences" (SPSS) software Version 18.0 (SPSS Inc., Chicago, IL, USA). Normal distribution of the data was tested with the "Shapiro–Wilk Test", while "Wilcoxon Signed Rank Test" was used to compare pre- and post-treatment changes within each group, and "Mann–Whitney *U* test" was performed to compare and analyse the differences between the groups. It was determined that a sample size of 25 patients in each group was needed to achieve 91% power with alpha set at 0.05 (The sample size calculation is based on a change of five points in the Neck Disability Index at 9 weeks (Falla et al., 2013; MacDermid et al., 2009)).

Table 2 Examining demographic information of individuals.

	SS group median (IQR)	SCS group median (IQR)	*p*
Age (years)	36 (28.5–49)	38 (33–46.5)	0.961
BMI (kg/m^2)	25.78 (22.725–27.775)	26.34 (24.245–27.34)	0.816
Duration of diagnosis (years)	4 (2–5)	4 (3–6)	0.361

$p > 0.05$.

3. Results

Demographic data (age, body mass index and duration of diagnosis) of the patients in both the CS and CCS groups was found to be similar ($p > 0.05$; Table 2).

Patients reported significantly decreased levels of pain after both stability trainings. These trainings improved activation and static endurance of DCF muscles, static endurance of neck muscles, thickness of M. Longus Colli and static endurance of trunk muscles. Disability and kinesiophobia also decreased after both trainings ($p < 0.05$) (Table 3).

Comparison of the clinical outcomes of the treatments showed that patients in both groups experienced similar improvements in terms of pain, activation and static endurance of DCF muscles, static endurance of neck muscles, area and diameter of M. Longus Colli (anterior–posterior diameter) and Neck Disability Index ($p > 0.05$; Table 4).

While the right transverse diameter of M. Longus Colli was found to increase more in the CS group when compared to the CCS group, the static endurance of trunk muscles and Tampa Kinesiophobia Scale scores were found to be higher in the CCS group ($p < 0.05$; Table 4).

4. Discussion and conclusion

Results of this study showed that following the stability trainings, neck pain, disability and kinesiophobia decreased, while M. Longus Colli thickness and endurance of neck and trunk muscles increased in both the CS and CCS groups. Additionally, there were similar improvements in pain, activation and static endurance of DCF muscles, static endurance of neck muscles, anterio-posterior thickness of M. Longus Colli and disability in both the CS and CCS groups. While the static endurance of trunk muscles and kinesiophobia was further improved after the CCS training, the right transverse thickness of M. Longus Colli increased more in the CS group.

When the literature is reviewed, it is seen that cervical stability training improves the clinical outcomes in patients with neck pain. However, the studies only focus on cervical stability training effects in patients with neck pain (Jull et al., 2009; Borisut et al., 2013; Falla et al., 2013), although all structures of the spine are related. Therefore, it is necessary to develop a proper posture not only in the cervical region, but throughout the spine in patients with neck pain. However, to date there have been no studies investigating the effects of spinal stability

Table 3 Results of the assessments before and after the stability trainings in both group.

		CS Group			CCS Group		
		Before median (IQR)	After median (IQR)	*p*	Before median (IQR)	After median (IQR)	*p*
VAS (0–10)							
Rest		5 (3.5–6)	0	<0.001	5 (2–6)	0	<0.001
Activity		7 (5.5–8)	1 (0–2)	<0.001	7 (5–8)	0 (0–2)	<0.001
Cranio-Cervical Flexion Test							
Activation Score (mmHg)		2 (0–2)	10 (10–10)	<0.001	0 (0–2)	10 (8–10)	<0.001
Performance Index (point)		10 (6–18)	100 (100–100)	<0.001	12 (8–18)	100 (80–100)	<0.001
Neck Muscles Endurance (sn)							
Flexor		11.6 (8.47–18.85)	36.24 (25.66–43.89)	<0.001	11.9 (7.92–16.85)	40.25 (27.63–45.36)	<0.001
Extensor		39.35 (22.215–69.905)	211.24 (136.55–412.26)	<0.001	53.09 (25.43–81.88)	362.76 (226.57–468.04)	<0.001
Ultrasound (diameter, mm)							
Transverse	Right	13 (12–14)	15.5 (14.5–17)	<0.001	12 (10–15)	15 (12–17.75)	<0.001
	Left	13 (11.9–14.25)	15 (14–16.2)	<0.001	13.4 (10.25–14.25)	15 (14–17)	<0.001
Anterior–Posterior	Right	7 (6.25–8)	8 (7.25–9)	<0.001	6.5 (6–7)	8 (7.5–8.2)	<0.001
	Left	6.5 (6–8.75)	8 (7.47–9)	<0.001	6.5 (6–7.25)	8 (7.5–8.55)	<0.001
Total		10 (9.55–10.39)	11.63 (11.125–12.69)	<0.001	9.6 (8.25–10.815)	11.38 (10.34–12.375)	<0.001
Sorensen Test (s)		16.5 (4.41–29.075)	35.64 (23.625–53.47)	<0.001	11.32 (5.32–29.225)	41.3 (30.895–61.99)	<0.001
Trunk Flexor Endurance Test (s)		10.4 (4.855–21.4)	24.15 (16.54–35.865)	<0.001	8.32 (5.135–18.6)	30.54 (20.15–43.09)	<0.001
Neck Disability Index (0–35 point)		13 (9–15)	2 (1–2)	<0.001	13 (9.5–14.5)	2 (1–3)	<0.001
Tampa Scale of Kinesiophobia (17–68 point)		42 (41–45)	39 (36–40)	<0.001	39 (37–41.5)	33 (30.5–35)	<0.001

VAS, Visual Analog Scale, $p < 0.05$.

Table 4 Comparison of pre and post-treatment differences between groups.

		CS group Δ Median (IQR)	CCS group Δ Median (IQR)	*p*
VAS (0–10)				
Rest		−4 (−6 to −3)	−5 (−6 to −2)	0.738
Activity		−6 (−6 to −3.5)	−6 (−7 to −4)	0.258
Cranio-Cervical Flexion Test				
Activation Score (mmHg)		8 (6 to 10)	8 (6 to 10)	0.820
Performance Index		86 (73 to 91)	88 (62 to 92)	0.815
Neck Muscles Endurance				
Flexor		22.24 (12.62 to 31.245)	28.09 (15.405 to 35.19)	0.299
Extensor		192.07 (110.71 to 365.16)	296.69 (179.19 to 385.79)	0.056
Ultrasound (diameter, mm)				
Transverse	Right	3 (2 to 4)	2 (0.55 to 3)	0.038*
	Left	2 (1 to 3.75)	2 (1 to 4)	0.915
Anterior–Posterior	Right	1 (0.4 to 1.8)	1.5 (0.5 to 1.9)	0.323
	Left	10 (5 to 15)	5 (5 to 14.5)	0.728
Total		1.87 (1.295 to 2.37)	1.65 (1.24 to 2.44)	0.641
Sorensen Test (s)		−18.13 (−26.665 to −10.395)	−25.39 (−42.42 to −20.28)	0.037*
Trunk Flexor Endurance Test (s)		−13.21 (−17.72 to −7.085)	−19.78 (−30.235 to −8.695)	0.004*
Neck Disability Index (0–35 point)		−10 (−13 to −7)	−10 (−12 to −7)	0.493
Tampa Scale of Kinesiophobia (17–68 point)		4 (3 to 5.5)	6 (5 to 7.5)	0.004*

VAS, Visual Analog Scale, *$p < 0.05$.

trainings that include the whole spine in patients with neck pain and cervical disc herniation, hence this current study. Thus, we aimed at investigating and comparing the effects of cervical stability training versus a combination of cervical and core stability trainings.

Recent clinical data indicate that cranio-cervical flexion exercises decrease neck pain (Falla et al., 2013; Lluch et al., 2013). Falla et al., conducted a progressive exercise programme which began with the strengthening of DCF and deep extensor muscles and progressed towards superficial cervical muscles in patients with neck pain (Falla et al., 2013). Similarly, Lluch et al. (2013) showed the effects of DCF muscles training in patients with neck pain. These studies both reported that cervical stability trainings decrease neck pain and reduces disability. While similar results were observed when comparing the current and previous reports, the cervical stability training applied in this study was more comprehensive.

The main problem is the decrease in endurance and strength of DCF muscles in patients with neck pain (Jull et al., 2004, 2009; Falla et al., 2005). Jull et al. (2008b) investigated the effects of cranio-cervical flexion training and cervical muscles training on the activation level of DCF muscles, M. Sternomastoideus and M. Scalenius Anterior by EMG. The researchers reported that DCF muscles' EMG activity level increased after the cranio-cervical flexion training, while M. Sternomastoideus and M. Scalenius Anterior's EMG activity level decreased. The researchers suggested that this result was the primary target in neck pain treatment; therefore any exercise programme should start with cranio-cervical exercises. In this current study, the researchers evaluated the activity of DCF muscles using cranio-cervical flexion test by means of a pressure biofeedback device and improvement was observed in both DCF muscles' activity level and endurance. Significant improvement in DCF muscles' activity level was also noted in both the CS and CCS stability training groups. On the other hand, there was no significant difference detected between the two groups in terms of DCF muscles' activity level or endurance. Additionally, while cervical flexor and extensor muscles' endurance improved after both groups' training, no difference was found between the groups in terms of gain.

In this study, a statistically significant increase was reported in the cross-sectional diameter of M. Longus Colli in both groups. The effect of cranio-cervical flexion trainings on M. Longus Colli thickness has previously been investigated (Chung et al., 2012) by the researchers. Chung et al. reported that the cross-sectional area of M. Longus Colli increased after cranio-cervical flexion exercises. These findings are similar to our findings. Additionally, when

comparing the CS and CCS groups, results showed that the right transverse diameter of M. Longus Colli increased more in the CS group than the CCS group.

This study found that both the CS and CCS training increased the static endurance of trunk muscles in patients with cervical disc herniation. The increase was more significant in the CCS group which was an expected result. On the other hand, as core stability exercises were not included in the CS training programme, it was surprising to also see an increase in the CS group. It has been reported in the literature that M. Transversus Abdominus is activated 15 ms prior to the start of movement in the upper limbs (Hodges and Richardson, 1997). However, no studies were found in the literature indicating whether or not M. Transversus Abdominus or M. Lumbar Multifidus are activated during neck muscles' activity. The findings of this study suggest that trunk muscles are also activated during cervical stabilization trainings.

Parallel with the results reported in studies (Falla et al., 2007; Jull et al., 2009), the disability level decreased after CS training. Additionally, this improvement was also observed in the CCS group. On the other hand, the improvement level was not found to be significantly different between the groups.

In this current study, we reported that kinesiophobia decreased after both trainings; however, this effect was seen greater in the CCS group. It is suggested that the reason for this result could be that the whole body is involved in CCS training and thus may be more effective in overcoming the fear of movement. As no studies have examined the effects of CS or CCS trainings on kinesiophobia, future research could be considered to address this gap.

In summary, the data presented suggest that cervical stability training and the combination of cervical and core stability training are effective on clinical outcomes. On the other hand, the addition of core stabilization training did not provide a significant additional benefit. The reason for this could be that only a limited number of core stability exercises were applied in order not to increase neck pain of the patients. Further research is suggested to investigate the efficacy of combining other techniques with cervical stabilization training for patients with cervical disc herniation.

Although no significant difference was found between the groups, we recommend that clinicians employ evaluations and treatments which include all segments of the spine, rather than exercises that focus only on the cervical spine. It is suggested that in the long term, stability training given for the entire spine may be more effective in preventing musculoskeletal pain in the cervical, lumbar and thoracic regions. Further studies performed with a greater number of patients would be necessary in order to scientifically validate this hypothesis.

Author contributions

All authors contributed to the conception and design of the study as well as making intellectual contributions to its content. B.B. applied the cervical and core stability training. A.G.-G. and S.B. formulated the plan for this study. B.B. and A.G.-G. drafted the manuscript. O.B. assessed the physical performance tests. Y.D. performed the ultrasonographic assessments. E.E.K. initially diagnosed and referred the patients. All authors discussed the results, commented on and approved the final manuscript.

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