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Comparative Immediate Effects of Isometric Chin-tuck and Dynamic Neuromuscular Stabilization on Neck Flexor Muscle Thickness and Upright Sitting Height Posture

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Abstract

Background: Cervical dysfunction is a common pathomechanical marker in individuals with forward head posture (FHP). To overcome the limitations of the isometric chin-tuck (ICT) exercise, dynamic neuromuscular stabilization (DNS), which emphasizes an entire spinal chain exercise, has recently shown promising clinical results.

Objects: Purpose of this study was to compare the immediate effects between ICT and DNS techniques.

Methods: 43 young subjects (mean age, 24.0±5.0 years) were recruited. Group of subjects with FHP were measured under baseline, ICT, and DNS conditions. Outcome measures included sitting height, longus colli (LC) and sternocleidomastoid (SCM) muscle thickness and LC/SCM thickness ratio. One-way repeated measures ANOVA was used to compare the continuous dependent variables among FHP, ICT, and DNS conditions at $p<.016$.

Results: Both ICT and DNS exercise conditions yielded significantly increased LC muscle thickness, LC/SCM thickness ratio and sitting height than did FHP condition ($p<.0001$, respectively). Sitting height was significantly greater in DNS exercise than in the ICT exercise ($p<.0001$).

Conclusion: The present results demonstrated that sitting height was greater in the DNS exercise than in the ICT exercise, as well as both corrective postural training exercises were effective on LC/SCM muscle balance ratio when compared with the baseline FHP condition. Therefore, it is considered that DNS exercise can be the recommended exercise for people with FHP.

Key Words: Cervical flexor muscle thickness; Cervical instability; Dynamic neuromuscular stabilization; Isometric chin-tuck; Sitting height; Thoracic-lumbopelvic chain.

Introduction

Cervical chain dysfunction is a common pathomechanical marker in individuals with forward head posture (FHP), which is often implicated with other global thoracolumbopelvic core chain instabilities (Frank et al, 2013). A cervical local core chain is interconnected with the thoracolumbopelvic chain, which provides a stable basis for cervical spinal stability and superimposed movement. If one local thoracic or lumbopelvic chain is insufficient and/or weak, the other muscles in the cervical kinetic chain are compromised to compensate for the loss of core stability (Frank et al, 2013). In fact, Jull and her colleagues reported that lumbopelvic chain instability deactivated the deep “uprighting” stabilizers, includ-

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ing the longus colli (LC) and longus capitis muscles, but overactivated the superficial sternocleidomastoid (SCM) and anterior scalene muscles (Jull et al, 2009). Recently, the effect of dynamic neuromuscular stabilization (DNS) on increased activation of the underactive deep neck flexor muscles and deactivation of the overactive superficial SCM muscle in individuals with cervical instability was reported to be superior to those of the abdominal drawing-in maneuver (ADIM) and preferred stabilization (PS) (Cha et al, 2018). Lumbopelvic chain instability often results in FHP with increased thoracic kyphosis and craniocervical lordosis (inability to maintain a corrected upright posture), which contribute to musculoskeletal injuries in the other global-chain cervical-thoracic spine, ribs, and shoulder complex (Clark and Lucett, 2010). If FHP is not corrected properly, the repetitive cervical movement with FHP will affect other global-chains over time by increasing thoracic kyphosis and craniocervical lordosis, which could result in movement impairments and associated discogenic or arthrogenic pain (Page et al, 2010).

To mitigate FHP with thoracic kyphosis and craniocervical lordosis, the isometric chin-tuck (ICT) exercise, a form of craniocervical flexion exercise, which stabilizes a local chain emphasizing only cervical chain has been widely used (Falla et al, 2007), but it poses a potential limitation of a localized chain effect. The ICT exercise is designed to improve the strength and endurance of the local deep neck flexor muscles by actively contracting the LC and longus capitis muscles via chin-tuck movement and isometrically maintaining the correct activation. However, ICT exercises emphasize a selective activation of the deep or local neck flexor muscles of the cervical spinal segment rather than focusing on the neutral upright posture and associated movement coordination of the entire cervical-thoracic-lumbopelvic segmental chain. Selective deep neck flexor muscle exercises may be insufficient to connect the lumbopelvic link, which provides a stable basis for upright cervical spinal posture and stability (Caneiro et al, 2010; Kobesova and Kolar, 2014; Frank et al, 2013).

To overcome the limitations of such unlinked or localized selective chain exercise in the conventional ICT exercise, DNS, which emphasizes a coordinated global cervical-thoracic-lumbopelvic segmental chain exercise, has recently gained attention and shown promising clinical results (Cha et al, 2018). The DNS treatment approach is designed to activate the integrated spinal stabilizing system (ISSS) based on the theoretical concepts of developmental neurophysiology and kinesiology to provide an optimal core stabilization link or basis for the entire cervical-thoracic-lumbopelvic segmental chain movement (Frank et al, 2013). The ISSS encompasses balanced core muscle chain co-activation between the deep cervical-lumbosacral flexors and extensor muscles, as well as the diaphragm and pelvic floor in the entire spinal region. It also activates the intra-abdominal pressure (IAP), which promotes anterior stabilization of the lumbopelvic chain, spinal stability, and dynamic core stability via the sensorimotor control mechanism. For example, proper stabilization of the entire cervical-thoracic-lumbopelvic segmental chain serves to provide a fundamental basis for dynamic stability (or “punctum fixum”) of the LC and capitis muscles in the cervical spine and psoas major in the lumbar spine by providing accurate and enriched proprioceptive inputs (joint position and kinesthetic sense) to the local stabilizers as an integral part of the sensorimotor control process (Borghuis et al, 2008; Frank et al, 2013; Liebenson, 2007). Anatomically, the LC muscle originates from anterior portion of the T3-T4 vertebral bodies and functions as an important lower cervical spinal stabilizer. However, the thoracic-lumbo-pelvic spine chain below the cervical spine chain level is weak or broken; the proper stabilization regulation of the ISSS is interrupted, which cannot provide a stable basis (or punctum fixum) for the LC muscle. Consequently, a compensatory overactivation of the superficial SCM, scalene, and upper trapezius muscles may occur and create excessive FHP (craniocervical hyperextension with lower cervical flexion); it may also be accompanied with associated cervical movement impairment (Singla and Veqar, 2017). Therefore, proper regulation of the ISSS is paramount for the successful management of the cervical or lumbar spinal pathology associated with either the entire cervical-thoracic-lumbopelvic segmental chain instability or one segmental chain instability (Frank et al, 2013). The purpose of the present study was to compare the two stabilization exercises to activate or facilitate the deep neck flexor muscles effectively, while providing an optimal upright spinal stabilization, by comparing between the local cervical chain-based ICT and integrated entire segmental chain-based DNS techniques. We hypothesized that integrated entire segmental chain-based DNS would produce superior effects on the LC/SCM muscle thickness balance ratio and spinal upright height as compared with the local cervical chain-based ICT in participants with FHP.

Methods

Subjects

Convenience samples of 43 young subjects (mean age, 24.0±5.0 years) were recruited from a major university setting (Table 1). All subjects provided informed consent prior to their participation in the study. The inclusion criteria entailed subjects with functional FHP, with and without a history of non-mechanical neck pain within 6 months. All the subjects had a functional FHP, which is operationally defined as existing when the external auditory meatus is positioned anterior more than 1 ㎝ to the vertical postural line (Kendall et al, 1993; Lee et al, 2018; Sawyer 2006). The exclusion criteria were as follows: serious congenital or acquired spinal pathology and deformities (e.g., kyphosis and scoliosis), neurological deficit, and surgical history or participation in a neck exercise program in the past 12 months (Cha et al, 2018; Falla et al, 2007). The present experimental protocol was approved by the Yonsei Institutional Review Board and Ethics Committee (IRB No. 1041849-201810-BM-099-03).

Experimental procedures

The present study involves a single-factor independent-measures design in which a group of subjects with FHP was measured under the following three conditions: baseline, ICT, and DNS. The outcome measures included sitting height measurement, and the LC and SCM muscle thickness and the associated LC/SCM muscle thickness balance ratio to determine better exercise condition among the two conditions.

(1) Upright sitting height measurement

Since the correct upright sitting posture and alignment of spine affect the sitting height. upright sitting height was measured as a variable (Jones et al, 1961; Schmidt et al, 2013). For the sitting height measurement, the subjects were instructed to sit comfortably on a chair with triple 90° flexion of the hip, knee, and ankle joints. The sitting height was then determined by measuring the distance between the most superior midline of the head and the ischial tuberosity using the extensometer. The sitting height was repeatedly measured under the baseline and two exercise conditions, normalized by the total height, and expressed as percentages (Bogin and Varela-Silva, 2010). An extensometer (HM-002, Cozyma Co., Ltd.,

Table 1. Subjects' demographic characteristics (N=43; 16 women, 27 men)

Parameters	Subjects
Age (years)	24.0±5.0[a]
Weight (㎏)	66.9±13.0
Height (㎝)	169.9±7.6
Sitting height (㎝)	127.8±3.8

[a]mean±standard deviation.

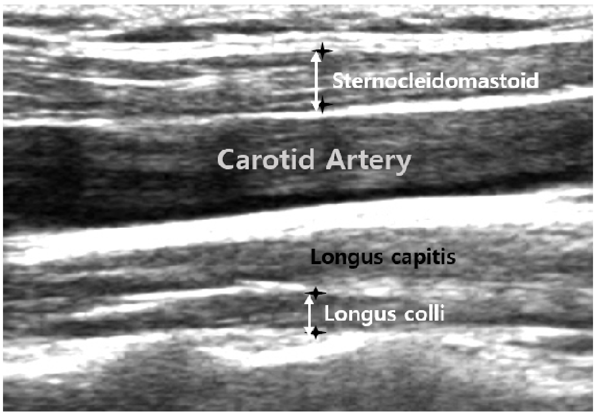

Figure 1. Ultrasonographic image of the sternocleidomastoid and longus colli muscles.

Korea) with 200 ㎝ measuring range was used to measure the sitting height.

(2) Ultrasonography measurement

The ultrasonography data of the SCM and LC muscles were recorded unilaterally (non-dominant side). The ultrasonography device in B-mode with a 10-㎒ linear transducer was used to measure muscle thickness. By placing the probe perpendicular to the vertical axis of the neck, an axial cross-sectional image was obtained. To measure the size of the SCM muscle, the probe was placed longitudinally on the anterior neck, parallel to the orientation of the trachea and approximately 5 ㎝ from its midline (Jesus et al, 2008). To measure the size of the LC muscle, the area 2 ㎝ below SCM level was marked using a marker, and the image was obtained at this level in the sitting position (Javanshir et al, 2011). B-mode ultrasonographic images were captured, and the muscle dimensions of the cross sectional area (CSA) were measured online using on-screen calipers (Figure 1). The muscle balance ratio was then determined by computing the ratio of the SCM muscle thickness to the LC muscle thickness. The examiner was a well-trained Ph.D. candidate in physical therapy. The SonoAce (X8, Medison Co., Ltd., Korea) in B-mode with a 10-㎒ linear transducer (L5-12EC) was used to measure the cross-sectional area of the LC and SCM muscles.

(3) Testing and exercise conditions

All the subjects who were initially assumed to have FHP underwent corrective postural exercises, including ICT and DNS. First, the baseline FHP testing condition was determined as follows: each subject was asked to demonstrate his or her typical sitting posture of FHP (upper cervical extension and

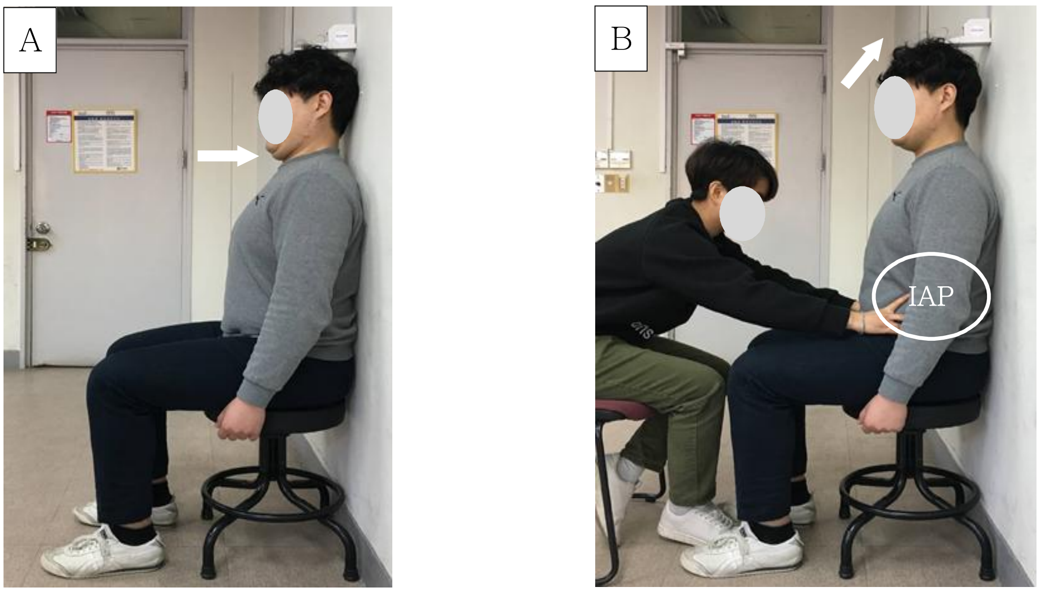

Figure 2. Lateral view of the exercise condition (A-ICT: isometric chin-tuck, B-DNS: dynamic neuromuscular stabilization, IAP: Intra-abdominal pressure).

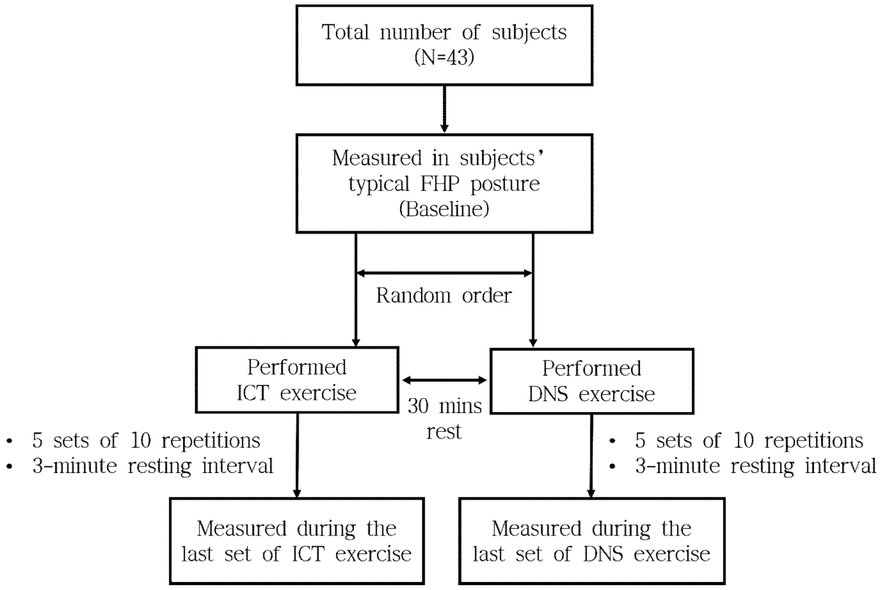

Figure 3. Flow chart of the experimental procedure.

mid-lower cervical flexion) and upper thoracic kyphosis, which resembled a smartphone-viewing posture (Singla and Veqar, 2017). Second, for the ICT exercise condition in the sitting position, which focuses on local chain stabilization, the subjects practiced the chin-tuck exercise to activate the deep neck flexor muscles selectively, while deactivating the SCM muscle and maintaining the upright posture (Figure 2-A) (Singla and Veqar, 2017). During the exercise, the therapist closely monitored whether the correct procedure was performed to ensure the quality of movements, including slight upper cervical spinal flexion and lower cervical extension. The thoracic and lumbar spine were fixed in triple 90° flexion of the hip, knee, and ankle joints with the feeling of attaching the back to the wall. Lastly, for the DNS exercise condition, (1) the cervical-thoracic region and rib cage were centralized (or neutralized), and the diaphragm-transverse abdominals and pelvic floor were activated; (2) the therapist palpated 10–12 ribs laterally and the angelus costae to ensure the correct procedure (caudal movement and widening of the intercostal spaces) and a relatively stable rib motion (no cranial motion) in the transverse plane. The upright posture was then maintained via the axial elongation of cervical-thoracic-lumbar spine, including the movement of the neck, with the feeling that the jaw is pulled toward the crown of the head (Figure 2-B) (Liebenson, 2007). The height of the chair was determined individually where triple 90° flexion of the hip, knee, and ankle joints occurred for each subject considering the height of the subject. Each subject implemented the two training conditions five sets of ten repetitions, which lasted for 20 minutes, with a 3-minute resting interval. The two exercises were performed in a random order with a 30-minute resting interval. The muscle thickness of LC and SCM and upright sitting height were measured during the last set of two exercises (Figure 3).

Statistical analysis

Statistical analyses included descriptive means, standard deviations, and parametric analysis of variance. One-way repeated measures ANOVA was used to compare the dependent variables in LC muscle thickness, SCM muscle thickness, muscle thickness imbalance ratio, and sitting height across the FHP, ICT, and DNS conditions. The post-hoc analyses were performed. The SPSS version 21.0 software (IBM corp., Armonk, NY, USA) was used for the analysis at $p<.016$ by Bonferroni adjustment.

Results

The demographic characteristics of 43 subjects are presented in Table 1. The post-hoc comparison revealed that both the ICT and DNS exercise conditions yielded a more significantly increased LC muscle thickness than did the FHP condition (p<.0001) (Table 2). However, no significant difference was observed in the LC muscle thickness between the ICT and DNS conditions (p=1.000).

No significant difference was observed in the SCM muscle thickness between the FHP and ICT conditions (p=.698), the FHP and DNS conditions (p=.033) as well as between the ICT and DNS conditions (p=.272) (Table 2).

The post-hoc comparison revealed that the ICT and DNS exercise conditions yielded significantly greater LC/SCM balance ratio than did the FHP condition (p<.0001) (Table 2). The LC/SCM balance ratio was greater in the DNS condition than in the ICT condition. However, no significant difference was observed in the LC/SCM balance ratio between the ICT and DNS conditions (p=.148).

A significant effect was observed in the ratio of sitting height across the FHP, ICT, and DNS conditions (p<.0001) (Table 2). The post-hoc comparison showed that the ratio of sitting height in the DNS condition increased more significantly compared with those in the FHP and ICT conditions (p<.0001).

Discussion

The present study highlights important immediate therapeutic effects of two different exercises approaches on muscle thickness and upright posture height in the sitting position in adults with FHP. The results of present study demonstrated that DNS exercise showed more significant differences between the baseline and exercise on the sitting height ratio than in ICT exercise for individuals with FHP. This study also revealed that ICT and DNS exercises showed more significant differences between the FHP (baseline) and exercise on the LC thickness, LC/SCM ratio and sitting height ratio.

This findings were in line with our hypothesis that integrated entire segmental chain-based DNS would produce a greater effect on spinal upright height than the local cervical chain-based ICT in participants with FHP. The present ultrasonography data analysis demonstrated that the muscle balance

Table 2. Muscle thickness and sitting height outcome data among FHP, ICT and DNS conditions (N=43)

	FHP[a] (Baseline)	ICT[b]	DNS[c]	*F*	*p*
LC[d] thickness (㎠)	0.69±0.16[e]	0.79±0.15			0.0001*
	0.69±0.16		0.80±0.16	21.541	0.0001*
		0.79±0.15	0.80±0.16		1.000
SCM[f] thickness (㎠)	0.72±0.13	0.70±0.14			0.698
	0.72±0.13		0.68±0.13	3.994	0.033
		0.70±0.14	0.68±0.13		0.272
LC/SCM ratio	0.98±0.29	1.16±0.27			0.0001*
	0.98±0.29		1.23±0.39	19.081	0.0001*
		1.16±0.27	1.23±0.39		0.148
Sitting height ratio	73.08±2.42	75.67±2.25			0.0001*
	73.08±2.42		76.84±1.91	147.328	0.0001*
		75.67±2.25	76.84±1.91		0.0001*

[a]forward head posture, [b]isometric chin-tuck, [c]dynamic neuromuscular stabilization, [d]longus colli, [e]mean±standard deviation, [f]sternocleidomastoid muscle, *significance level at p<.016.

more substantially improved after DNS and ICT exercises than FHP condition. These findings are consistent with previous studies in DNS (Cha et al, 2018; Frank et al, 2013; Kolar et al, 2012) and ICT (Amiri Arimi et al, 2017; Falla et al, 2007; Jull et al, 2009). Cha et al (2018) observed an effect of the DNS condition on increased activation of the underactive deep neck flexor muscle and deactivation of the overactive SCM muscle in individuals with cervical instability that is superior to those of the abdominal drawing-in maneuver (ADIM) and preferred stabilization (PS) conditions. The DNS contains a feedforward mechanism by which the postural stabilization cylinder belt the diaphragm, pelvic floor muscles, abdominal muscles, and spinal extensors-becomes synergistically orchestrated to create optimal IAP (Frank et al, 2013). Similarly, our results support that DNS, emphasizing the global-chain exercise, increases cervico-thoracic-lumbopelvic core stabilization, which consequently has greater effect on deep neck flexor (i.e., LC muscle)/superficial neck flexor (i.e., SCM muscle) muscle balance ratio, resulting in a better upright sitting posture.

A previous randomized controlled trials (RCT) evidence suggests that a low-load ICT had a better effect on the management of deep neck flexor muscle strength and endurance than other conventional deep neck flexion exercises (Amiri Arimi et al, 2017). Specifically, Falla et al (2007) found that the subjects in the craniocervical flexor training group who performed ICT exercise in the upright sitting position showed improved ability to maintain an upright position of the cervical spine as compared with the control group (progressive resistance exercise program in the supine position). Moreover, ICT exercise directly activates the deep cervical flexor musculature, which has a relatively high density of muscle spindles (Falla et al, 2003). The improved cervical kinesthetic sense after craniocervical flexor training may also explain the improved ability to maintain an upright position of the cervical spine (Jull et al, 2009).

Such immediately greater effect of DNS exercise over the conventional ICT exercise may have resulted from the fact that ICT exercises emphasize a selective activation of the deep or local neck flexor muscles of the cervical spinal segment and it may be insufficient to connect the lumbopelvic link, which provides a stable basis for upright cervical spinal posture and stability (Caneiro et al, 2010; Kobesova and Kolar, 2014; Frank et al, 2013). On the other hand, DNS exercises which emphasize a proper stabilization of the entire cervical-thoracic-lumbopelvic segmental chain may provide a punctum fixum or a stable foundation for the deep neck flexor muscles and psoas major in the lumbar spine (Borghuis et al, 2008; Frank et al, 2013; Liebenson, 2007).

The present data of sitting height was greater in the DNS exercise than in the ICT exercise, as well as both corrective postural training exercises were effective on LC/SCM muscle balance ratio when compared with the baseline FHP condition. In addition, the proprioceptive inputs from the joint centration during the DNS training could be augmented the deep neck flexor muscles. However, this notion should be further investigated. On the basis of the present and previous findings, the DNS approach may be more effective in restoring muscle balance in global-chain core stability, thereby resulting in a better upright sitting posture in individuals with FHP. DNS can be incorporated to the current core stabilization exercise programs for effective intervention for individuals with neck instability and FHP.

Limitations of the study

Some limitations should be considered in future studies. One limitation is that proprioceptive sensation was not measured in the present study. Proprioceptive sensation has been reported to play an important role in core muscle activation (Romero-Franco et al, 2012). Another limitation is that the present study examined the immediate effect of local and global core stabilization techniques; hence, whether such effects may have a long-term change in terms of deep neck flexor muscle motor control and postural changes in individuals with FHP is unknown. This study invites future research to ascertain this assumption so that we may comfortably generalize our novel findings when providing effective clinical management associated with core instability and FHP.

Conclusion

The purpose of this study was to compare the immediate effects between two different exercises approaches on LC, SCM muscle thickness, LC/SCM thickness ratio and upright posture height in the sitting position in adults with FHP. Group of 43 young subjects with FHP were measured under baseline, during ICT, and DNS conditions. Two training conditions were randomly implemented in five sets, which lasted for 30-40 minutes, with a 5-minute resting interval. The present results demonstrated an effect of the DNS exercise (i.e., better upright sitting posture and increased sitting height of individuals with cervical instability assumed to have FHP) that is greater than that of the ICT exercise, as well as both corrective postural training exercises were effective on LC/SCM muscle balance ratio when compared with the baseline FHP condition. These findings suggest that such increased neck flexor muscle thickness balance is closely linked with balanced core stabilization of the global cervical-thoracic-lumbopelvic chains. This study provides important conceptual and therapeutic evidence for clinicians when designing and implementing effective deep neck flexor muscle stabilization techniques for individuals with FHP. Therefore, it is considered that DNS exercise can be the recommended exercise for people with FHP.

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