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Effect of different cranio-cervical positions on abdominal and back muscles activities from different postures: A cross-section study

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ABSTRACT

The aim of this study was to investigate whether changing cranio-cervical postures is associated with changes in abdominal and back muscle activities during bridging and plank positions, and to present the importance of cranio-cervical posture control during trunk stabilization exercises. This was a cross-sectional study that included thirty patients (21 men and 9 women), aged between 18 and 30 years, with no history of previous spinal surgery, other severe musculoskeletal disorders, or neurological disorders, selected from Cairo University's Faculty of Physical Therapy. Every patient was requested to adopt a bridging and a plank position. Surface Electromyography (EMG) was used to assess muscular activation patterns by measuring muscle activity amplitudes. EMG signals of rectus abdominus and lumbar erector spinae in different cranio-cervical postures (extension 25°, neutral, and flexion 25°) were compared. The cranio-cervical posture was controlled utilizing a cervical range of motion device (CROM). Cranio-cervical posture was found to significantly influence trunk muscle activities (p=0.001), with cranio-cervical flexion yielding the highest activity in the rectus abdominus in both bridging (p=0.001) and plank positions (p=0.001), while cranio-cervical extension yielded the highest activity in the lumbar erector spinae in both bridging (p=0.001) and plank positions (p=0.017). Cranio-cervical flexion increased rectus abdominus muscle activity during the bridging and plank positions, while cranio-cervical extension improved lumbar erector spinae muscle activity during the bridging and plank positions. Consideration of cranio-cervical posture is suggested when carrying out trunk stabilization exercises.

KEYWORDS

Cranio-Cervical; Stabilization Exercise; Electromyography; Plank; Bridging

1. INTRODUCTION

Maintaining a vertical alignment of the body's segments is what we mean when we talk about "posture." Another aspect of posture is the dynamic relationship between various tissues that express a particular bodily position in reaction to stimuli (whether internal or external). The term "proper posture" refers to a state of musculoskeletal equilibrium in which the body experiences minimal stress as well as strain (Shaghayeghfard et al., 2016). A healthy posture is essential for good biomechanics and optimum function of the spine, so a very early rehabilitation of bad posture habits is mandatory to prevent premature degeneration of the spine's active and passive structures (Cădar et al., 2015).

The relationship between one joint and another during an upright posture is called a posture chain, which states that all spinal regions are connected through the vertebral system from the cranium to the coccyx. Consequently, changes in one region may affect another region through a chain reaction (Page et al., 2010). This relationship could be through myofascial chains, meaning that neck muscles are connected to trunk muscles with fascia (Wilke et al., 2016). Some studies have hypothesized that this connection is reflexive because many of our postural reflexes are situated in or originate from the head and neck. These include the vestibulocollic reflex, the cervicocollic reflex, the pelvo-ocular reflex, the vestibulo-ocular reflex, the cervico-ocular reflex, and cervical somatosensory input (Morningstar et al., 2005).

Abnormal posture in one place can influence the whole spine from head to pelvis (Page et al., 2010). Any changes in posture, especially in cervical spine biomechanics, reflected on the other spine curves and may be one of the causes of back pain (Cădar et al., 2015). Therefore, it may be essential to address abnormal head posture for effective whole-spine posture correction, in which the rest of the spine orients itself from the top down (Araújo et al., 2018; Diab, 2012).

All trunk muscles are key in adjusting and maintaining correct spine positions and movements, as well as reducing the risk of acute or chronic back problems (Comfort et al., 2011). The rectus abdominis and erector spinae are major contributors to trunk and spine stabilization. Weakness in these muscles can lead to decreased trunk stability and subsequent low back pain (Grenier & McGill, 2007). Patients with low back pain have found that strengthening the abdominal and back muscles helps decrease pain. To perform at one's highest potential and limit the risk of both acute and chronic damage, it is crucial to keep these muscles strong and balanced (Comfort et al., 2011).

Muscle activation in one part of the body can affect muscles in another part when the body is in motion. This relationship can be observed between the head and neck regions and the lumbopelvic region. The influence of trunk control based on head conditions has been observed in the crook-lying position (Su et al., 2016), during lifting (Hlavenka et al., 2017), abdominal hollowing (Parfrey et al., 2014), prone bridging (Yu et al., 2015), active straight leg raising (Takasaki & Okubo, 2020), and the Biering-Sørensen test (Dejanovic et al., 2014). It has been reported that different head and neck conditions alter abdominal and back muscle activities. Two head positions that potentially influence trunk control are head extension and upper cervical flexion (Su et al., 2016; Parfrey et al., 2014; Dejanovic et al., 2014).

There is a gap in the literature regarding the impact of changing head and neck positions on the activity of lower trunk muscles. Therefore, this study is designed to investigate whether changing cranio-cervical postures is associated with changes in abdominal and back muscle activities during bridging and plank positions. Additionally, this study aims to present the importance of cranio-cervical posture control during trunk stabilization exercises.

2. METHODS

2.1. Study design and participants

This was a cross-sectional study carried out from October 2021 to February 2022 in compliance with the guidelines of the ethics committee for human research at Cairo University's Faculty of Physical Therapy (Reference number P.T. REC/012/002349).

All thirty patients (21 men and 9 women), aged between 18 and 30 years, were selected from Cairo University's Faculty of Physical Therapy and completed a written consent form before participating, in accordance with the guidelines of the Helsinki Declaration. Participants were evaluated for eligibility to participate in the study. Participants were excluded if they met any of the following criteria: had a neurological disorder, had musculoskeletal disorders, had undergone previous abdominal or back surgery, had any psychiatric or cognitive disorders, were undergoing chemotherapy, were pregnant, or were receiving renal dialysis. Individuals who refused to sign the written consent form were also excluded.

2.2. Instruments

Two types of instruments were used in this study:

1. **Cervical Range of Motion Device (CROM):** The CROM (Performance Attainment Associates, St Paul, MN, USA) was utilized to evaluate cervical range of motion, including flexion, extension, lateral flexion, and rotation. This involved different inclinometers: the first located in the sagittal plane for flexion-extension, the second in the frontal plane for lateral flexion, and the third in the horizontal plane for rotation. Measurements were expressed in degrees and demonstrated high reliability and validity (Audette et al., 2010).
2. **Surface Electromyography (EMG):** Surface Electromyography was used to assess muscular activation patterns by measuring muscle activity amplitudes. The Neuromyoanalyzer NMA-4-01 (Neuromyan-Medicom MTD Ltd, Taganrog, Russia) offers efficient EMG, nerve conduction study (NCS), and evoked potentials (EP) evaluation with unique, time-saving technology. Available in both desktop and laptop variants as two-channel amplifiers, our compact amplifier ensured rapid waveform capture. The updated examination list facilitates easy integration of protocols, patient data, and reports, resulting in increased productivity and reduced test times. The remote controller (RC) combined with an electrostimulator simplifies repeated standard studies without the need for a mouse and keyboard.

2.3. Procedures

Step 1. Measuring maximum voluntary contraction of rectus abdominis and erector spinae

Surface EMG activities from the lumbar erector spinae and rectus abdominis muscles during Maximum Voluntary Contraction (MVC) were recorded for normalization of the study data (Hoseinpoor et al., 2014; Blasimann et al., 2014). Prior to electrode placement, the electrode locations were cleansed with alcohol and shaved using disposable shavers. The skin was then cleansed again with alcohol to minimize skin impedance (Schoenfeld et al., 2014). Electrodes were placed 2 cm lateral to the umbilicus for the rectus abdominis (Kim et al., 2011; Kang & Kim, 2014) and at the L5 level, 1 cm lateral to the spinous process for the lumbar erector spinae (Vera-Garcia et al., 2010).

Subjects performed exercises for the lumbar erector spinae by lying prone on a padded table with legs extended and hands at their sides. They were instructed to lift their upper torso into extension while gripping two straps that secured their legs. For maximal voluntary contractions (MVCs) of the rectus abdominis muscle, participants laid supine on a cushioned table with knees extended. They contracted their abdominals and bent at the waist until their upper body was elevated to approximately 45 degrees, with legs secured by straps. Each muscle group underwent three MVC trials, each lasting 8-10 seconds with a 30-second rest between trials (Hoseinpoor et al., 2014).

Step 2. EMG activities of the trunk muscles (lumber erector spinae and rectus abdominus) were recorded in both bridging and plank positions in three cranio-cervical postures neutral, flexed 25 ° degrees, and extended 25°degrees (Su et al., 2016; Takasaki & Okubo, 2020).

Step 2.1. Measuring rectus abdominis and lumbar erector spinae in the bridging position

The supine bridging position was used to assess the activation of abdominal as well as back muscles in relation to cranio-cervical postures. A towel was positioned below the occiput to help support the weight of the head as well as cervical spine, and the patient's knees were bent to 90 degrees while lying supine with their feet about shoulder-width apart. After that, they were told to raise their pelvises so that their greater trochanters were parallel to their acromion and lateral femoral epicondyles. Participants' rectus abdominus and erector spinae muscle activity were recorded while they maintained neutral, 25° flexion, with 25° extension cranio-cervical posture. A cervical range of motion instrument was used to regulate the cranio-cervical posture (CROM; Performance Attainment Associates, St Paul, MN, USA). An individual in a cranio-cervical neutral posture has their head and neck in a linear fashion with respect to the ground, their eyes level with that line, and their CROM set to zero degrees. According to the CCF posture description, the mid- and lower-cervical spines were kept in a neutral position whereas the upper-cervical spine was flexed by 25 degrees. A cranio-cervical extension (CCE) posture is one in which the upper cervical spine is extended by 25 degrees while the middle and lower cervical spines remain in a neutral position. Ten seconds were spent in each position while muscle activity was recorded. Three separate measurements of muscle activity were taken for each posture, and the sequence in which the postures appeared was chosen at random. Muscle activities recorded in the initial and end two seconds were discarded, and the data in the intermediate six seconds was evaluated. In this analysis, muscle activity levels were evaluated three times, with the mean value utilized.

Step 2.2. Measuring rectus abdominis and lumbar erector spinae in the plank position

According to the three cranio-cervical postures, abdominal and back muscle activities were measured from the plank position. Participants extended their bodies while maintaining a neutral spine and pelvis by resting on their forearms and feet. Participants assumed the plank position, in which they rested on their forearms and hands while keeping the rest of their body completely off the ground. When the lumbar spine is in a neutral posture, there is no inclination (angle) among the trunk and the hip joint, and there is no inclination (angle) among the shoulder joint as well as the trunk. The location of the elbows was such that they were below the shoulders on both sides. The individuals' lumbar erector spinae as well as rectus abdominus muscle activity were recorded while they maintained neutral, flexion, and extension positions of the cranio-cervical spine. Cranio-cervical neutral, flexion, and extension postures were achieved with the aid of CROM device. Participants were asked to hold each posture for 10 seconds while muscle activity was recorded. Muscle activity was assessed thrice for each posture, and the sequence in which the postures were assessed was shuffled. Only the middle six seconds of muscle activity data were evaluated, after the first two and the last two seconds of data were discarded. In this analysis, we averaged the results from all three measurements of muscle activity.

2.4. Statistical analysis

The statistical analysis commenced with the examination of participant characteristics using descriptive statistics, followed by testing the data for normality using the Shapiro-Wilk test. Subsequently, we employed multivariate analysis of variance (MANOVA) to analyze the collected data. All statistical analyses were performed using SPSS for Windows, version 20 (SPSS, Inc., Chicago, IL), with a significance level set at $\alpha = 0.05$.

3. RESULTS

3.1. Participant characteristics

Table 1 presents participant characteristics. They had a mean age of 26 years (SD = 2.6), an average weight of 77.5 kg (SD = 9.2), a mean height of 177 cm (SD = 9.2), and a BMI of 24.7 kg/m^2 (SD = 2.5). The sample predominantly consisted of males, comprising 70% (21 participants), with females accounting for 30% (9 participants) of the total.

Table 1. Participant characteristics

Study sample (n = 30)	**Mean±SD**	
Age (year)	26±2.6	
Weight (kg)	77.5±9.2	
Height (cm)	177±9.2	
BMI (kg/m^2)	24.7±2.5	
Gender	**No.**	**%**
Male	21	70%
Female	9	30%

3.2. Test of normality

Normality and homogeneity of variance were assessed for the collected data. Normality was tested using the Shapiro-Wilk procedure, confirming that the variables under study (EMG activity of the rectus abdominis and lumbar erector spinae) follow a normal distribution.

3.3. Differences between rectus abdominus activities at plank and bridging position at different cranio-cervical positions

Table 2 presents the mean values of rectus abdominis activities in plank and supine bridging positions. MANOVA was used to compare plank and supine bridging positions, revealing a statistical substantial difference between the mean values of rectus abdominus activities in both positions in all cranio-cervical positions (p = 0.001) in favor of the plank position. Also, there was a statistically significant difference between rectus abdominus activities at different cranio- cervical positions (flexion, neutral, and extension) in plank and bridging position (p = 0.001).

Table 2. Differences between rectus abdominus activities at plank and bridging position at different cranio-cervical positions

Rectus abdominus activity	**Starting position**		**Difference**	**f-value**	**p-value**
Cranio-cervical position	**Plank position** Mean ± SD	**Supine bridging position** Mean ± SD			
Flexion	40.3 ± 7	15.6 ± 2.7	24.7	520	0.001*
Neutral	36.2 ± 4.9	7.4 ± 1.8	28.8	709	0.001*
Extension	34.8 ± 4.4	5.1 ± 0.9	29.6	753	0.001*
f-value	13.89	52.16			
p-value	0.001	0.001			

3.4. Post hoc test for mean values of rectus abdominus

Table 3 displays the mean values of rectus abdominis activity at different cranio-cervical positions in the plank position. Post hoc tests revealed statistically significant differences between the flexion versus neutral positions and flexion versus extension positions (p = 0.001), favoring the flexion position. However, there was no statistically significant difference between the neutral versus extension positions (p = 0.177). In the bridging position, significant differences were found between the flexion versus neutral positions and flexion versus extension positions (p = 0.001), favoring the flexion position, as well as between the neutral versus extension positions (p = 0.031), favoring the neutral position.

Table 3. Post hoc test for the mean values of rectus abdominus in plank and bridging position at different cranio-cervical positions

Rectus abdominus	**Plank position**		**Bridging position**	
	Mean difference	**P-value**	**Mean difference**	**P-value**
Flexion vs. neutral	4	0.001*	8.2	0.001*
Flexion vs. extension	5.5	0.001*	10.5	0.001*
Neutral vs. Extension	1.4	0.177	2.3	0.031*

3.5. Differences between erector spinae activities at plank and bridging position at different cranio-cervical positions

Table 4 shows the mean values of erector spinae activities in plank and supine bridging positions. MANOVA was used to compare these positions, revealing a statistically significant difference in the mean values of erector spinae activities across all cranio-cervical positions (p = 0.001), favoring the bridging position. Additionally, there was a significant difference in erector spinae activities between different cranio-cervical positions (25° flexion, neutral, and 25° extension) within both the plank and bridging positions (p = 0.001).

Table 4. Differences between erector spinae activities at plank and bridging position at different cranio-cervical positions

Erector spinae activity	**Starting position**		**Difference**	**f-value**	**p-value**
Cranio-cervical position	**plank position** Mean ± SD	**supine bridging position** Mean ± SD			
Flexion	7.8 ± 0.9	35.4 ± 5.4	27.6	748	0.001*
Neutral	10 ± 1.3	40.3 ± 5.5	30.3	905	0.001*
Extension	12.4 ± 2.1	38.9 ± 5.1	26.5	688	0.001*

f-value	10.3	12.5
p-value	0.001*	0.001*

3.6. Post hoc test for mean values of erector spinae

As observed in Table 5, we conducted a post hoc test to find the statistical difference between the mean values of erector spinae activity at different cranio- cervical positions. In the plank position, there were statistically significant differences between flexion versus neutral position (p=0.034) in favor to neutral position and among flexion versus extension position (p=0.001) in favor to extension position. Also, there was a statistical substantial difference among neutral and extension positions (p=0.017) in favor of extension positions. At the bridging position, there were statistical substantial differences between the flexion versus neutral position (p=0.001) in favor to the neutral position and between the flexion versus extension position (p=0.001) in favor to the extension position, while there was no statistical difference between the neutral versus extension position (p=0.149).

Table 5. Post hoc test for the mean values of erector spinae in plank position at different cranio-cervical positions

Erector spinae	**Plank position**		**Bridging position**	
	Mean difference	**P-value**	**Mean difference**	**P-value**
Flexion vs. neutral	-2.2	0.034*	-4.9	0.001*
Flexion vs. extension	-4.6	0.001*	-3.5	0.001*
Neutral vs. Extension	-2.4	0.017*	1.5	0.149

4. DISCUSSION

The main results of this study revealed a statistical substantial difference between rectus abdominus activity at different cranio- cervical positions in the plank position; there were statistically significant differences between flexion versus neutral position and between flexion versus extension position (p=0.001), in favour of the flexion position. There was no statistical substantial difference between the neutral versus the extension position (p=0.177).

At the plank position, there was a statistical substantial difference in the lumbar erector spinae activity between the cranio-cervical flexion versus the cranio-cervical neutral position (p=0.034) in favour to the cranio-cervical neutral position and between the cranio-cervical flexion versus the cranio-cervical extension position (p=0.001) in favour to the cranio-cervical extension position. Also, there was a statistical substantial difference among the cranio-cervical neutral versus the cranio-cervical extension position (p=0.017) in favour to the cranio-cervical extension position.

At the bridging position, there were statistically significant differences in rectus abdominus activity between cranio-cervical flexion versus cranio-cervical neutral position and between cranio-cervical flexion versus cranio-cervical extension position (p=0.001), in favour to cranio-cervical flexion position. There were are significant differences between cranio-cervical neutral versus cranio-cervical extension (p=0.031), in favour to the cranio-cervical neutral position.

At the bridging position, there was a statistical substantial difference in lumbar erector spinae activity between cranio-cervical flexion versus neutral position (p=0.001) in favour to cranio-cervical neutral position and between flexion versus extension position (p=0.001) in favour to cranio-cervical extension position, while there was no statistically significant difference between cranio-cervical neutral versus cranio-cervical extension (p=0.149).

Our results agree with a study that has been performed to investigate the difference in abdominal muscle activities in relation to changes in the cranio-cervical posture in the crock-lying position, which showed that the rectus abdominus muscle had significantly greater muscle activity in cranio-cervical flexion than in cranio-cervical extension and cranio-cervical neutral postures (Su et al., 2016). Another study showed that during bridging exercise, the activity of the rectus abdominus was more significant in neck flexion positions than in the non-flexion position, as well as the activities of lumbar extensors were decreased in a more flexed position which may be due to reciprocal inhibition (Ishida et al., 2011).

While investigating the effect of different cranio-cervical positions on rectus abdominus and lumbar erector spinae during plank position, our results were in the same context with a study that was conducted on fifteen healthy persons to evaluate the impact of head posture on trunk muscle activation throughout prone bridging position The result showed that in the prone bridging exercise (plank position), there was a greater activity of rectus abdominus muscle throughout the flexion. It was substantially greater than that during the neutral and the extension, and the activity of the lumbar multifidus increased with cervical extension (Yu et al., 2015). While in the same study, it was reported that the change in the activity of lumbar erector spinae concerning the different cranio-cervical posture was not statically significant which disagree with the results of our study (Yu et al., 2015). Another study investigated low back extensors muscles endurance by changing head and neck posture. Head and cervical posture founded to substantially affect low back muscles endurance with the extension position showing the highest endurance scores than the neutral position, while cervical the flexion position showed the lowest scores (Dejanovic et al., 2014).

Our findings underscore the significance of cervical spine position in influencing trunk muscle activity, aligning with existing research. For instance, Parfrey et al. (2014) demonstrated that altering cervical spine position during abdominal hollowing exercises affects abdominal muscle activation. Similarly, Takasaki & Okubo (2020) found that cranio-cervical flexion influences abdominal muscle firing patterns during active straight leg raising exercises, contrasting with the minimal effect observed during head extension. Our study further supports these insights, consistent with Hlavenka et al. (2017), who reported increased trunk muscle activity, specifically in the lumbar erector spinae and external oblique muscles, when using a retracted neck posture during lifting tasks. Additionally, Salahzadeh et al. (2020) highlighted that cranio-cervical position impacts trunk muscle endurance, with individuals exhibiting forward head posture showing lower endurance compared to those without. These collective findings emphasize the interconnectedness between cervical spine posture and trunk muscle function across various exercises and activities.

All regions of the spine are connected from the cranium to the coccyx through the vertebral system (Page et al., 2010) as well as through myofascial chains (Wilke et al., 2016). Some studies supposed that this relation could be reflexive based on the fact that some of our postural reflexes, are situated, or happen, within the head and neck region (Morningstar et al.,2005), so, changes in one spinal region may impact the whole spine from head towards pelvis (Page et al., 2010). Any changes in posture, especially in cervical spine biomechanics, reflected on the other spine curves and may be one of the causes of back pain (Cădar et al., 2015), Therefore, it may be necessary to rectify abnormal head position in order to get favorable results in adjusting the spine as a whole (Araújo et al., 2018; Diab, 2012).

Cervical posture changes the mechanical characteristics of the spinal cord with the nerve roots that might influence the firing patterns of the neurons comprising these structures, which may in turn impact the activity of the trunk muscles (Dejanovic et al., 2014). However, the exact process by which this occurs is unclear (Harrison et al., 1999). Studies have shown that altering cervical position can impact upper limb movement accuracy (Knox & Hodges, 2005) and hand grip strength (Zafar et al., 2018). Additionally, head repositioning has been observed to affect upper limb strength, possibly through the modulation of the tonic neck reflex (Kumar et al., 2012).

5. LIMITATIONS

This study has several limitations that warrant consideration. Firstly, it focused exclusively on the rectus abdominis and lumbar erector spinae muscles. Future research should explore how altering cranio-cervical posture affects other abdominal and back muscles. Secondly, the study only examined the effects in bridging and plank positions. Further investigations should encompass various positions and exercises to comprehensively assess the impact of cranio-cervical posture on muscle activity. Thirdly, the study sample size was relatively small. Therefore, the findings should be validated in larger and more diverse populations to enhance generalizability. Additional research is needed to elucidate the underlying mechanisms through which cranio-cervical position influences abdominal and back muscle activity, addressing these limitations for a more comprehensive understanding.

6. CONCLUSIONS

Despite the study's limitations, the most notable conclusion is that cranio-cervical flexion was observed to efficiently increase rectus abdominis muscle activity during bridging and plank positions. In contrast, the cranio-cervical extension position was found to effectively increase erector spinae muscle activity during bridging and plank positions. Consideration of cranio-cervical posture is suggested when performing trunk stabilization exercises.

7. CLINICAL IMPLICATIONS

Practitioners should carefully consider cranio-cervical positioning when prescribing bridging exercises to optimize muscle activation. Similarly, when prescribing plank exercises, attention to cranio-cervical posture can maximize the effectiveness of the exercise regimen. These recommendations highlight the practical implications of our findings for enhancing the therapeutic outcomes of trunk stabilization exercises through targeted manipulation of cranio-cervical posture.

8. REFERENCES

1. Araújo, L. M., Antoniolli, A., Schmit, E. F. D., & Candotti, C. T. (2018). Relation between posture and spine and pelvis flexibility: a systematic review. *Fisioterapia em Movimento, 31,* 1-11.
2. Audette, I., Dumas, J. P., Côté, J. N., & De Serres, S. J. (2010). Validity and between-day reliability of the cervical range of motion (CROM) device. *Journal of Orthopaedic & Sports Physical Therapy, 40*(5), 318-323.

3. Blasimann, A., Fleuti, U., Rufener, M., Elfering, A., & Radlinger, L. (2014). Electromyographic activity of back muscles during stochastic whole body vibration. *Journal of Musculoskeletal and Neuronal Interactions*, *14*(3), 311-317.
4. Cădar, I. D., & Pop, L. V. (2015). Correlations between cervical spine posture and low back pain. *Human and Veterinary Medicine*, *7*(3), 178-181.
5. Comfort, P., Pearson, S. J., & Mather, D. (2011). An electromyographical comparison of trunk muscle activity during isometric trunk and dynamic strengthening exercises. *The Journal of Strength & Conditioning Research*, *25*(1), 149-154. https://doi.org/10.1519/JSC.0b013e3181fb412f
6. Dejanovic, A., Balkovec, C., & McGill, S. (2015). Head posture influences low back muscle endurance tests in 11-year-old children. *Journal of Motor Behavior*, *47*(3), 226-231. https://doi.org/10.1080/00222895.2014.974493
7. Diab, A. A. (2012). The role of forward head correction in management of adolescent idiopathic scoliotic patients: a randomized controlled trial. *Clinical Rehabilitation*, *26*(12), 1123-1132. https://doi.org/10.1177/0269215512447085
8. Grenier, S. G., & McGill, S. M. (2007). Quantification of lumbar stability by using 2 different abdominal activation strategies. *Archives of Physical Medicine and Rehabilitation*, *88*(1), 54–62. https://doi.org/10.1016/j.apmr.2006.10.014
9. Harrison, D. E., Cailliet, R., Harrison, D. D., Troyanovich, S. J., & Harrison, S. O. (1999). A review of biomechanics of the central nervous system—Part I: Spinal canal deformations resulting from changes in posture. *Journal of Manipulative and Physiological Therapeutics*, *22*(4), 227-234. https://doi.org/10.1016/s0161-4754(99)70049-7
10. Hlavenka, T. M., Christner, V. F., & Gregory, D. E. (2017). Neck posture during lifting and its effect on trunk muscle activation and lumbar spine posture. *Applied Ergonomics*, *62*, 28-33. https://doi.org/10.1016/j.apergo.2017.02.006
11. Hoseinpoor, T. S., Kahrizi, S., & Mobini, B. (2014). EMG Activity of Trunk Muscles in Patients with Chronic Low Back Pain after Fatigue. *Canadian Journal of Basic and Applied Sciences*, *2*(01), 01-09.
12. Ishida, H., Kobara, K., Osaka, H., Ito, T., & Watanabe, S. (2011). Influence of neck flexion on lumbar curvature during bridging exercises. *Journal of Physical Therapy Science*, *23*(6), 941-944.
13. Kang, M. H., & Kim, M. S. (2014). EMG activity in the abdominal muscles and the kinematics of the lumbar spine during unilateral upper-limb resistance exercises under stable and unstable

conditions. *Journal of Physical Therapy Science, 26*(6), 873-875. https://doi.org/10.1589/jpts.26.873

14. Kim, S. J., Kwon, O. Y., Yi, C. H., Jeon, H. S., Oh, J. S., Cynn, H. S., & Weon, J. H. (2011). Comparison of abdominal muscle activity during a single-legged hold in the hook-lying position on the floor and on a round foam roll. *Journal of Athletic Training, 46*(4), 403-408.
15. Knox, J. J., & Hodges, P. W. (2005). Changes in head and neck position affect elbow joint position sense. *Experimental Brain Research, 165*(1), 107-113. https://doi.org/10.1007/s00221-005-2293-y
16. Kumar, N. S. S., Daniel, C. R., Hilda, M., & Dharmarajan, R. (2012). Grip strength: influence of head-neck position in normal subjects. *Journal of Neurology Research, 2*(3), 93-98.
17. Morningstar, M. W., Pettibon, B. R., Schlappi, H., Schlappi, M., & Ireland, T. V. (2005). Reflex control of the spine and posture: a review of the literature from a chiropractic perspective. *Chiropractic & Osteopathy, 13*(1), 1-17.
18. Moustafa, I. M., & Diab, A. A. (2015). The effect of adding forward head posture corrective exercises in the management of lumbosacral radiculopathy: a randomized controlled study. *Journal of Manipulative and Physiological Therapeutics, 38*(3), 167-178. https://doi.org/10.1016/j.jmpt.2014.11.009
19. Page, P., Frank, C. C., & Landner, R. (2012). Assessment and Treatment of Muscle: The Janda Approach. Assessment and Treatment of Muscle: The Janda Approach. *The Journal of the Canadian Chiropractic Association, 56*(2), 158.
20. Parfrey, K., Gibbons, S. G., Drinkwater, E. J., & Behm, D. G. (2014). Effect of head and limb orientation on trunk muscle activation during abdominal hollowing in chronic low back pain. *BMC Musculoskeletal Disorders, 15*(1), 1-12.
21. Salahzadeh, Z., Rezaei, M., Adigozali, H., Sarbakhsh, P., Hemati, A., & Khalilian-Ekrami, N. (2020). The Evaluation of Trunk Muscle Endurance in People with and without forward Head Posture: a Cross-Sectional Study. *Muscles, Ligaments & Tendons Journal, 10*(4), 752-758.
22. Schoenfeld, B. J., Contreras, B., Tiryaki-Sonmez, G., Willardson, J. M., & Fontana, F. (2014). An electromyographic comparison of a modified version of the plank with a long lever and posterior tilt versus the traditional plank exercise. *Sports Biomechanics, 13*(3), 296-306.
23. Shaghayeghfard, B., Ahmadi, A., Maroufi, N., & Sarrafzadeh, J. (2016). Evaluation of forward head posture in sitting and standing positions. *European Spine Journal, 25*(11), 3577-3582.

24. Su, J. G., Won, S. J., & Gak, H. (2016). Effect of cranio-cervical posture on abdominal muscle activities. *Journal of Physical Therapy Science*, *28*(2), 654-657. https://doi.org/10.1589/jpts.28.654
25. Takasaki, H., & Okubo, Y. (2020). Deep neck flexors impact rectus abdominis muscle activity during active straight leg raising. *International Journal of Sports Physical Therapy*, *15*(6), 1044. https://doi.org/10.26603/ijspt20201044
26. Vera-Garcia, F. J., Moreside, J. M., & McGill, S. M. (2010). MVC techniques to normalize trunk muscle EMG in healthy women. *Journal of Electromyography and Kinesiology*, *20*(1), 10-16. https://doi.org/10.1016/j.jelekin.2009.03.010
27. Wilke, J., Krause, F., Vogt, L., & Banzer, W. (2016). What is evidence-based about myofascial chains: a systematic review. *Archives of Physical Medicine and Rehabilitation*, *97*(3), 454-461. https://doi.org/10.1016/j.apmr.2015.07.023
28. Yu, J., Hong, J., Kim, J., Kim, S. J., Sim, D. S., Lim, J. E., & Lee, D. Y. (2015). Influence of head posture on trunk muscle activation during prone bridging exercise. *Indian Journal of Science and Technology*, *8*(7), 423-7.
29. Zafar, H., Alghadir, A., & Anwer, S. (2018). Effects of head-neck positions on the hand grip strength in healthy young adults: a cross-sectional study. *BioMed Research International*, *2018*, 7384928. https://doi.org/10.1155/2018/7384928

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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