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RESEARCH REPORT

Effect of dorsal neck muscle fatigue on cervicocephalic kinaesthetic sensibility

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Abstract It has been hypothesized that proprioceptive information plays an important role in cervical spine stabilization and that muscle fatigue may alter proprioceptive ability. Therefore, we investigated the effects of specific dorsal neck muscle fatigue on cervicocephalic kinaesthetic sensibility. Twenty-five asymptomatic young adults (age range 18-30 years) were recruited for the study. The subjects were measured for dorsal neck muscle strength (kg) with a digital dynamo-meter. The repositioning errors (degrees) were measured by two cervicocephalic kinaesthetic sensibility tests: the head-to-neutral head position repositioning and head-to-target repositioning tests. The repositioning tests were performed in the sagittal, transverse and frontal planes. The subjects were then exposed to a dorsal neck muscles fatiguing exercise protocol, after which the dorsal neck muscle strength and repositioning errors were again measured. Dorsal neck muscle strength was significantly reduced and repositioning errors in the sagittal plane were significantly increased after the fatiguing protocol ($p < 0.001$). However, in terms of frontal and transverse plane movements, no difference in repositioning errors was found following the fatiguing protocol. Dorsal neck muscle fatigue alters cervical position sense in sagittal plane movements. Improving the strength of these muscles might play a vital role in maintaining cervical position sense.

Introduction

Proprioceptive afferent input from neck muscles plays a significant role in the control of human posture [1]. Muscle fatigue is known to modify the discharge of sensory receptors such as muscle spindles or Golgi tendon organs in animals [2—5]. Muscle fatigue has been shown to influence joint position sense. Body sway increases significantly after strenuous physical exercise, possibly owing to an alteration in proprioception. Little is known, however, about how neck muscle fatigue affects postural equilibrium and orientation [3,6—10].

The location of the dorsal neck muscles suggests that they may play an important role in stabilizing the cervical spine [11—13]. In upper quadrant postural dysfunction, the dorsal neck muscles are often overused because of the forward-head position adapted by the subject resulting in

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a loss of strength and endurance [14—17]. It is apparent that the afferent input originating from the dorsal neck muscles may have an influence on activation of the muscles that control cervical motion and may thus contribute to the dynamic stability of the cervical spine [11—14]. The deep cervical flexors and dorsal neck muscles form a sleeve that stabilizes the cervical spine in all positions against the effects of gravity. In the presence of neck pain and headache, weakness is often found in the dorsal neck muscles. These patients also show increased activity in their superficial flexors, presumably as a compensation strategy [18,19].

The influence of fatigue on the sense of position has been previously studied in the peripheral joints and lumbar spine. It was shown that a subject's ability to reproduce a given joint angle deteriorated after exercise-induced fatigue, producing a significant proprioceptive error [7,20—25]. It is theorized that when muscle performance is impaired, the balance between the stabilizers on the posterior aspect of the neck and the deep cervical flexors might be disrupted, resulting in a loss of proper alignment and posture. This may in turn contribute to cervical impairment such as increased pain, decreased muscle strength and altered position sense. The purpose of this study was to determine whether dorsal neck muscle fatiguing exercise alters proprioception and neuromuscular control of the cervical spine.

Methods

Subjects

A convenience sample of 25 asymptomatic young adults (age range 18—30 years) was recruited through advertisements in a physical therapy department. All subjects reported that they had no neck pain at the time of the study. For inclusion, subjects had to have no previous treatment for neck pain and no current neck pain. Exclusion criteria were traumatic spinal injury, whiplash-associated disorders, central nervous system impairment (e.g. paraesthesia), vestibular impairment (e.g. vertigo), dizziness, or motor imbalance and neck pain induced by cervical motion in the range tested for the study.

Subjects were required to attend two sessions. In the first session, the subjects were familiarized with the equipment and the repositioning tasks. In the second session, the subjects underwent the actual testing using the repositioning tasks and dorsal neck fatiguing protocol. All participants signed written consent form before participating in the study. Ethical approval was obtained from the University ethical committee before commencement of the study.

Cervical range of motion device

The cervical range of motion (CROM) device is goniometer designed specifically for the cervical spine and was used to measure CROM. The CROM device, which has three inclinometers (one for each plane), is strapped to the head. One gravity dial meter measures flexion and extension, another gravity dial meter measures lateral flexion, and a compass meter measures rotation. Its accuracy was reinforced by two magnets placed over the subject's shoulders. The advantage of the CROM over a single inclinometer method is that it does not need to be moved to measure movement in separate planes. Studies have found that it is superior to the universal goniometer, visual estimation and a single inclinometer [26—29]. CROM devices are commonly used in clinical settings, easy to apply and cost-effective. They also have good criterion validity ($r = 0.89—0.99$) and reliability (intraclass correlation coefficient (ICC) = 0.92—0.96) [26—29].

Isometric dorsal neck muscle strength measurement

A dynamometer was used to test isometric dorsal neck muscle strength in extension. A physiotherapist with good experience in neck muscle strength testing recorded all the measurements. The methodology followed a standardized testing method [30]. Briefly, to measure cervical extension strength, the cell load was placed against the occipital bone with the subjects in a sitting position, their hands on their thighs with their arms close to their body, both hips in adduction and 90° flexion, both knees in 90° flexion and both feet on the floor. The sternal notch, chin and tip of the nose were kept in a vertical line, and the line between the base of the nose and occiput was kept horizontal. The seat surface was also horizontal. The thorax and pelvis were tightly held by two straps at the level of the scapula and the iliac spine. To warm up, subjects performed three submaximal cervical muscle contractions before each set of maximal voluntary contractions (MVCs). The subjects were instructed to relax their trunk, upper limbs and lower limbs. Next, each subject was instructed to do three MVCs in extension. The MVCs each lasted for 3—4 seconds and were separated by 5-minute intervals. The means of the three measures were used for subsequent analysis.

Measurement of cervicocephalic kinaesthetic sensibility

The subjects were asked to sit upright in a comfortable position and look straight ahead (i.e., in neutral head position) and advised not to move their shoulders for the rest of the test. The CROM unit was placed on top of the head and attached posteriorly using the Velcro strap. The magnetic part of the unit was then placed so that it sat squarely over the shoulders. The investigator calibrated the CROM device to a neutral head position.

For the cervicocephalic kinaesthetic sensibility tests, subjects were required to keep their head in the neutral position and were told to close their eyes throughout the subsequent tests. The first test was the head-to-neutral head position repositioning test [31]. The subjects were instructed to turn their head fully to the left and back to what they believed to be the starting point in a controlled fashion without opening their eyes. When the subjects reached the reference position, the subject's relocation accuracy was measured in degrees using the CROM device.

The second repositioning test was a head-to-target repositioning test [32]. The investigator moved the subject's head slowly to the predetermined target position, 65% of the maximum range of motion. The speed of passive neck motion was slow because higher speeds have been associated with significant differences in vestibular function according to age [31,32]. The head was maintained in the target position for 3 seconds, and the subject was asked to remember that position. The head was then brought to the neutral position. Next, the subjects were asked to reposition their head by moving it actively to the target position.

The two repositioning tests were done in the sagittal, transverse and frontal planes. When the subjects reached the reference position, their relocation accuracy was measured in degrees using the CROM device. Each test trial position was carried out three times, and the average of the three trials was used for analysis.

Fatiguing exercise protocol

Once the cervical reposition ranges had been measured using CROM device, the dorsal neck muscle fatiguing protocol was administered with the "extended neck lift'' technique [33]. The subject lay in a prone position with their legs straight, their arms positioned at their sides and a load (2 kg for women and 4 kg for men) applied around the head above the ears. The subjects then extended and raised their head just above the examination table (the tip of the chin pointing against the floor). The subjects were instructed to maintain the test position for as long as possible, stopping at exhaustion point or when pain was felt in the neck or radiating into the arms. During measurements, the physiotherapist reminded the subjects of the correct testing position. Following the fatiguing protocol, the isometric dorsal neck muscle strength testing and cervical repositioning tests were repeated to form a comparison with the prefatigue levels.

Statistical analysis

A paired *t* test was used to assess the pre—post difference in dorsal neck muscle strength and joint repositioning errors within the group. The statistical analysis was done using the SPSS 11.0 for Windows software. The statistical significance value was set at 0.05 with 95% confidence interval and p value less than or equal to 0.05 would be considered as significant. A paired t-test was used to assess pre-post difference in dorsal neck muscle strength and joint reposition errors within the group.

Results

The results showed that dorsal neck muscle strength decreased significantly following the dorsal neck muscle fatiguing protocol ($p = 0.001$) (Table 1).

Head—to-neutral head position errors were significantly greater following the dorsal neck muscle fatiguing protocol in a sagittal plane (i.e. flexion and extension) ($p = 0.001$) (Table 2). However, there was no significant difference in the same variable in frontal (side flexion-right and side flexion-left) and transverse plane (rotation-left and rotation-right) movements.

Head-to-target repositioning errors were also significantly larger following the dorsal neck muscle fatiguing protocol in the sagittal plane ($p = 0.001$) (Table 3). There was no significant difference in head-to-target repositioning errors in frontal (side flexion-right and side flexion-left) and transverse plane (rotation-left and rotation-right) movements.

Discussion

The results of the present study indicate that cervical kinaesthetic errors were significantly greater after subjects had undergone fatiguing of the dorsal neck muscles. Interestingly, a significant difference was seen in sagittal movements but not in frontal and transverse plane movements. The possible reason for increased repositioning errors in the sagittal plane may be that the dorsal neck muscles are more responsible for cervical spine stabilization in the sagittal plane, and fatiguing these muscles may have modified the discharge of sensory receptors such as muscle spindles and Golgi tendon organs, thus leading to an alteration in kinaesthetic sense [2,4]. The isometric dorsal neck muscle fatiguing protocol used in this study was able to fatigue the dorsal neck muscles, as revealed by a significant decrease in dorsal neck muscle strength was demonstrated following the fatiguing protocol.

The results of the present study lead us to postulate that localized muscle fatigue of the dorsal neck muscles may modify sensory inputs, affecting central mechanisms of postural control. This may be attributable to ionic or metabolic changes in free nerve endings, such as elevated interstitial potassium concentration, or reduced oxygen input attributable to reduced blood flow [5,34,35]. The errors were seen only in the sagittal plane, probably because of the anatomical orientation of the dorsal neck muscles. The dorsal neck muscles contract concentrically during extension and eccentrically during flexion, and provide a constant proprioceptive input, thereby maintaining a stable spine [1,2]. When the dorsal neck muscles were fatigued, proprioceptive repositioning errors were more apparent in the sagittal plane only.

A recent study has investigated the effects of localized neck muscle fatigue on postural control. After a 5-minute

Table 1 Change in dorsal neck muscle strength following the fatiguing protocol

Measure	Pre-fatigue protocol, mean ± SD	Post-fatigue protocol, mean ± SD	95% confidence interval		*p*
			Lower	Upper	
Strength (kg)	7.9 ± 1.4	4.1 ± 1.3	3.3	4.4	0.001

Table 2 Repositioning errors (degree) of head-to-neutral head position repositioning tests ($n = 25$)

Movement	Head-to-neutral head position (degrees)		95% confidence interval		p
	Pre-fatigue protocol	Post-fatigue protocol	Lower	Upper	
	Mean ± SD	Mean ± SD			
Flexion	3.6 ± 1.0	10.0 ± 2.1	−7.5	−5.3	0.001
Extension	3.2 ± 3.0	11.0 ± 1.2	−9.0	−6.6	0.001
Left-rotated	3.5 ± 4.0	3.6 ± 3.0	−0.1	−0.1	0.342
Right-rotated	3.7 ± 3.8	3.8 ± 3.2	−0.2	0.1	0.356
Left-side flexed	2.0 ± 1.1	2.0 ± 1.1	−0.01	0.1	0.466
Right-side flexed	2.2 ± 3.4	2.8 ± 3.6	−0.8	−0.2	0.227

period of sustained isometric dorsal neck muscle contractions using a load corresponding to 35% of an MVC, neck muscle fatigue was accompanied by significant increase in body sway (measured using a stabilometric platform, with the eyes closed) compared with control conditions [36].

In the present study, significant differences in proprioceptive errors were not found in the frontal and transverse planes. This may be because the dorsal neck muscles may not have significantly influenced side flexion and rotation movements, as the surrounding muscles may have provided feedback on position and movement information. Most of the subjects in the present study who showed repositioning errors in the sagittal plane following dorsal neck muscle fatigue showed the phenomenon of overshooting. This may be due to overcompensation by the surrounding muscles and an increased effort to reach the target.

Clinical implications

We believe that the results from this study have clinical relevance. The subjects' ability to recognize joint position was hindered after a bout of dorsal neck muscle fatiguing exercise. The implications of the decreased proprioception are twofold. First, afferent proprioceptive feedback integrated in the central nervous system elicits efferent neuromuscular responses that are vital to the functional stability of the cervical joints. Because fatigue hinders proprioceptive feedback from the cervical to the central nervous system, the neuromuscular responses responsible for joint stability may be hindered, leading to joint instability and eventually cervical impairment.

Second, if a person's ability to recognize joint position, particularly at the extremes of its range, is hindered, he or she may be prone to injury due to increased mechanical stress placed on both the static and the dynamic structures responsible for maintaining stability of the cervical spine. In the assessment of neck pain, it may be important to evaluate cervical muscle strength and cervical proprioception along with neck range of motion, segmental mobility, soft tissue mobility and flexibility, etc. Strengthening the dorsal neck muscles may reduce the negative effect of muscle fatigue on cervical proprioception, but this will require further investigations.

Limitations

This study has several limitations that need to be acknowledged. First, the study used a pre-test/post-test design without a control group. Factors other than the fatiguing protocol may have influenced the outcome. A randomized controlled trial is required to determine the changes in muscle strength and proprioceptive deficits following the dorsal neck muscle fatiguing protocol. Second, only asymptomatic young subjects were used. The results cannot be generalized to older adults and individuals with pathology in the cervical region. The influence of dorsal neck muscle fatigue on cervical spine proprioception in these client groups awaits further research.

Table 3 Repositioning errors (degree) of head-to-target repositioning tests ($n = 25$)

Movement	Head-to-target (degrees)		95% confidence interval		p
	Pre-fatigue protocol	Post-fatigue protocol	Lower	Upper	
	Mean ± SD	Mean ± SD			
Flexion	2.1 ± 1.0	7.2 ± 2.0	−6.0	−4.1	0.001
Extension	3.8 ± 1.8	9.2 ± 1.2	−6.2	−4.5	0.001
Left-rotated	3.2 ± 3.7	3.6 ± 4.3	−0.7	0.0	0.226
Right-rotated	3.0 ± 3.8	3.9 ± 2.0	−1.5	−0.2	0.468
Left-side flexed	2.9 ± 3.8	2.8 ± 3.6	−0.5	0.7	0.356
Right-side flexed	4.2 ± 2.2	4.4 ± 3.3	−0.4	0.1	0.456

Conclusion

The results of the present study show that dorsal neck muscle fatiguing exercise may alter cervical position sense during sagittal plane movements. Improved functional capacity of these muscles may play a vital role in maintaining cervical position sense, particularly following fatiguing activity.

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