Activation of the semispinalis cervicis and splenius capitis with cervical pulley exercises

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ACTIVATION OF THE SEMISPINALIS CERVICIS AND SPLENIUS CAPITIS WITH CERVICAL PULLEY EXERCISES

ABSTRACT

Study Design: Quasi-Experimental

Objective: To assess the activation of semispinalis cervicis (d-SSC) and splenius capitis (s-SC) muscles, and the activation between the two during neck pulley and free weight exercises.

Background: Altered activation of cervical extensors may occur with neck pain, suggesting exercises should be designed to target these muscles.

Methods: d-SSC and s-SC activity was recorded unilaterally with intramuscular electromyography from healthy volunteers during cervical isometric exercises: 1) extension with a pulley rope angled from incline to vertical, 2) extension with right, left and central forehead hanging weight, and 3) rotation with pulley rope angled from incline to decline.

Results: Extension against a vertical force led to greater activation of d-SSC ($P<0.001$) and s-SC ($P<0.001$) compared to the inclined, declined and horizontal pulley. With each of these conditions, amplitude of muscle activity was higher for the d-SSC compared to the s-SC muscle ($P<0.0001$). Extension with free weight hanging on right, left or central forehead, showed no differences across conditions, although in each condition, the d-SSC amplitude was higher than the s-SC. For cervical rotation, the declined pulley led to the greatest activation of both muscles ($P<0.05$). Higher levels of activity were observed for the s-SC compared to the d-SSC ($P<0.01$) for all rotation conditions.

Conclusion: A vertical resistance during an extension exercise, or a declined resistance during cervical rotation, increased neck extensor activation. The results from this preliminary study provide guidance for future work on the exploration and development of low-load exercise design for patients with neck pain disorders.

Key Words: *Neck extensors, EMG, exercise, neck pain*

INTRODUCTION

People with chronic neck pain display changes in the behavior and structure of their neck muscles (Cagnie et al. , 2008, Elliott et al. , 2006, Elliott et al. , 2011, Elliott et al. , 2008, O'Leary et al. , 2003, Schomacher et al. , 2013, Schomacher and Falla, 2013, Schomacher et al. , 2012a). Our recent work has revealed reduced activation of the deep cervical extensor muscle, semispinalis cervicis (d-SSC) in people with chronic neck pain disorders (Schomacher, Boudreau, 2013, Schomacher and Falla, 2013, Schomacher, Farina, 2012a). Moreover, atrophy (Elliott, Jull, 2008, Elliott et al. , 2014) and fatty infiltration (Abbott et al. , 2015, Elliott, Jull, 2006, Elliott, Pedler, 2011, Elliott et al. , 2015, Karlsson et al. , 2016) of the deep cervical extensors have been observed in both non-traumatic and traumatic neck disorders, respectively. Thus, exercise which targets and facilitates the activation of the deep cervical extensors may be relevant for people with neck pain to improve the activation of their neck muscles with the aim of gaining long term pain relief and improved function (O'Leary, Falla, 2003). A recent clinical trial revealed that participation in a neck-specific exercise program was the only significant factor associated with both neck pain and neck disability reduction at 3 and 12 months in a cohort of patients with whiplash associated disorders (Ludvigsson et al. , 2016). Patients who performed a neck-specific exercise program had up to 5.3 times higher odds of disability reduction, and 3.9 times higher odds of pain reduction compared to those in a physical activity group. These findings provide the incentive to identify selective and specific exercises to address neuromuscular impairments in people with neck pain.

Few studies have investigated whether specific exercise can facilitate activation of the deep cervical extensor muscles. One magnetic resonance imaging study showed differing muscle activation when the head was in craniocervical extension compared to a neutral head position (Elliott et al. , 2010). An electromyography (EMG) study showed that the activation of d-SSC increased relative to the superficial splenius capitis (s-SC) when manual resistance was applied over the vertebral arch versus the occiput (Schomacher et al. , 2012b). However, these exercises are limited in their application, as it is difficult to grade the exercise and apply additional resistance as training progresses.

A pulley apparatus or hanging weights allow for the design of exercises with resistance applied at any angle/direction (Faugli, 1996, Grimsby, 2008). It is theorized that specific muscles can be activated during exercises to allow for more targeted muscle activation without the patient having to cognitively participate (Grimsby, 2008). This approach may provide a more effective way to facilitate activation of the deeper extensor muscles, especially since the load and direction of resistance can be adjusted. Peolsson et al (2013) compared cervical extension exercises between a guild board and a pulley using ultrasound measurements of muscle deformation and deformation rate, but did not include varying angles of the pulley or the guild board. Performing the exercise on the guild board produced higher levels of deformation and deformation rates of the cervical extensors, however, differences between superficial and deep muscle deformation were not investigated.

This quasi-experimental study aimed to assess changes in activation of the d-SSC and s-SC, as well as relative activation between the two muscles during neck exercises using a pulley resistance and a free hanging weight. The following hypotheses were tested. 1: as the line of action from the pulley changed from an inclined to a more vertical position during cervical extension, a more declined line of action would increase the relative flexion torque, increasing activation of the d-SSC and s-SC. 2: a non-centrally placed vertical resistance during cervical extension, which would add a lateral flexion torque, and would enhance activation of the contralateral d-SSC and s-SC. 3: activity of the d-SSC and s-SC would be enhanced during a rotation exercise using a more declined line of action from a pulley, creating a flexion torque on the cranium. Finally, these specific approaches would induce a relatively greater activation of the d-SSC given the low load and specific nature of the exercises.

METHODS

Participants

Nine healthy volunteers (age: mean ± SD: 32.5 ± 8.9 years; height: 170.1 ± 8.4 cm; weight: 67.1 ± 23.7 kg) were recruited from staff and students of the University of Goettingen, Germany via e-mail and announcement on the university's notice board.

Subjects were included if they were 18-50 years old and without neck pain, and excluded if they had any neurological complaints, history of cervical spine surgery, known risk of infection following needle insertion, a history of coagulation disorders or were taking medications which could affect coagulation, such as aspirin.

Informed consent was obtained and the rights of the subjects were protected. The study was conducted at the University of Goettingen, Germany between May and June, 2014. Ethical approval for the study was granted by the University Ethics Committee (21/2/14). All procedures were conducted according to the Declaration of Helsinki.

Electromyography (EMG)

The primary outcome measure was normalized amplitude of muscle activity recorded from intramuscular EMG, which was acquired unilaterally from the right d-SSC and s-SC muscles at the level of the 2nd and 5th spinous processes (C2, C5). Teflon-coated stainless steel fine wire electrodes (diameter: 0.1 mm) were inserted in each muscle using a prefabricated 27-gauge hypodermic needle with a single wire inside (SEI EMG s.r.l., Cittadella, Italy). Approximately 3-4 mm of insulation was removed from the tip of the wire to obtain an interference EMG signal, which was acquired in referenced monopolar mode. Needle insertion was guided by ultrasound (Lee et al. , 2007) in B-mode (LS 128, Telemed, Vilnius, Lithuania) with a linear transducer (HL9.0/40) set to 8 and 9 MHz.

Subjects were prone with their head and neck in a slightly flexed position. The ultrasound transducer was placed transversely, lateral to the spinous processes of C2 and C5 to image the extensor muscles. Identification of the echogenic (bright, reflective) laminae and the spinous process were the main bony landmarks for locating the cervical extensors, which are separated by echogenic fascia layers (Stokes et al. , 2007). Doppler sonography displayed the deep cervical artery and the fascia separating semispinalis capitis from d-SSC muscle in which this artery lies. Following an exploratory scan of the muscles and artery, the spinous process of C2 and C5 were located by palpation (Lee, Tseng, 2007). Surgical pen marks were placed on the side of the C2 and C5 spinous processes, and 1.5 cm right of midline at the level of the occiput and C7. Crossing the imaginary extension of these lines indicated needle insertion points. Needles were inserted 1.5 cm lateral to the mid-line at C2 and C5 vertically into the d-SSC muscle as previously described (Kramer et al. , 2003) and for the s-SC, 2-3 mm caudal to the former site, obliquely at a ~45° angle. Once the needle tip was in the target muscle belly (confirmed on ultrasound), it was removed, leaving the wire in the muscle for the duration of the experiment. Needle insertion was performed under sterile procedures and the ultrasound transducer was enclosed in a sterile plastic envelope (Figure 1).

A reference surface electrode was placed adjacently (mastoid process, spinous process C7 for levels C2 and C5 respectively), and a common reference electrode was placed around the wrist. EMG signals were amplified (EMG-USB2, 256-channel EMG amplifier, OT Bioelettronica, Torino, Italy; band pass filtered: 10

Hz–450 kHz), sampled at 2048 Hz, and converted to digital form by a 12-bit analog-to-digital converter.

Procedure

Following electrode placement, the subjects were seated in a device to measure maximal voluntary contractions (MVC) of the neck extensor muscles (Cervical-Multi Unit, BTE Technologies). Supported by the backrest, the trunk was upright, hands resting on thighs and pelvis strapped to the seat with a firm belt. The occiput was positioned against the device's frame. Following a period of familiarization with the device, three isometric MVCs of neck extension were performed, each lasting 5s, separated by 30s rest. Instruction was given to extend the neck back into the device rather than retracting thereby encouraging extension of both the upper and lower neck. Verbal encouragement was provided.

Following 10 minutes of rest, seated subjects performed a series of isometric exercises in a standardized order. For each exercise, subjects were seated on a standard stool in an upright position with hands resting on thighs. A Velcro neoprene strap was fastened around the subject's head. Using a hook on the head strap for rope, a weight of 0.9 Kg (2 lb) was attached, either via a pulley fixed to a door or directly to the rope. The rope or pulley was placed in varying directions and vectors in order to determine how these variables would affect activation of the d-SSC and s-SC muscles. Rope angles were measured using an iPhone (Apple Inc) level application (iHandy Level Free) shown to be reliable and valid for goniometric measurements (Jones et al. , 2014, Kolber et al. , 2013, Mitchell et al. , 2014, Wellmon et al. , 2015), including the application used in this study (Kolber, Pizzini, 2013). During each exercise, subjects were asked to keep their head still against the resistance applied via the pulley device or rope. Head, neck and trunk posture was monitored and corrected by an investigator, as necessary, throughout the session to ensure consistency of the starting posture. Each exercise was repeated twice and sustained for 10s. Exercises are presented in detail in Figures 2-4 and summarized in Table 1.

Signal Analysis

EMG amplitude for each muscle at both spinal levels was estimated as the root mean square (RMS) of the signal in non-overlapping intervals of 250ms across the entire 10s contraction, which was then averaged. The average RMS computed during each exercise was obtained as an average across the two repetitions of each exercise and was normalized with respect to the peak RMS obtained during the MVC and expressed as a percentage. Since the relative load on the neck muscles may have differed with the various exercises, the ratio between the normalized RMS of the d-SSC and s-SC muscle was calculated and compared across conditions, an approach performed previously (Schomacher et al. , 2015, Schomacher, Petzke, 2012b) to evaluate the relative activation of different neck muscles. Ratios above one indicate enhanced activation of the d-SSC relative to the s-SC.

Statistical Analysis

The dependent variable was the EMG data (either normalized RMS or ratio data). Before comparisons, all data were tested for normality using the Shapiro-Wilk test and normal distribution of the data was confirmed. Since initial analysis confirmed no major influence of spinal level, the data from C2 and C5 were pooled.

To identify whether differences in the amplitude of muscle activity occurred during the different extension pulley exercises, a two-way repeated measures analysis of variance (ANOVA) was used with condition (incline, horizontal, decline, vertical) and muscle (d-SSC, s-SC) as factors. In addition, to compare the relative activation between muscles across the different extension pulley exercises, a one-way repeated measures ANOVA was used with condition (incline, horizontal, decline, vertical) as the factor.

A two-way repeated measures ANOVA was also used to compare the amplitude of muscle activity for the cervical extension exercise with a hanging free weight, with condition (central, right, left) and muscle (d-SSC, s-SC) as factors. The relative activation between muscles was evaluated with a one-way repeated measures ANOVA with condition (central, right, left) as the factor.

Finally, to evaluate whether differences in the amplitude of muscle activity occurred during the different exercises in cervical left rotation, a two-way repeated measures ANOVA was conducted on the amplitude of muscle activity with condition (incline, horizontal, decline) and muscle (d-SSC, s-SC) as factors. The relative activation between muscles was evaluated with a one-way repeated measures ANOVA with condition (incline, horizontal, decline) as the factor.

Significant differences revealed by ANOVA were followed by post-hoc Student–Newman–Keuls (SNK) pair-wise comparisons. Statistical significance was set at $P<0.05$.

RESULTS

Cervical Extension with Pulley and Central Hanging Free Weight

For the amplitude of muscle activity, a main effect was observed for condition ($F=6.9$, $P<0.001$) and muscle ($F=11.2$, $P<0.001$), but not for the interaction between condition and muscle ($F=1.6$, $P=0.192$) (Figure 5A). The activity of both muscles was greatest when the central hanging free weight was applied compared to all other conditions (all SNK: $P<0.05$) but no other differences between conditions were observed. Across all exercises, the amplitude of muscle activity was higher for the d-SSC compared to the s-SC muscle (SNK: $P<0.001$). However, the relative activation between muscles did not change across conditions ($F=1.8$, $P=0.157$; Figure 5B).

Cervical Extension with Central and Non-Central Hanging Free Weight

For the amplitude of muscle activity, a main effect was not observed for condition (F=2.8, P=0.061) but there was a main effect for muscle (F=14.9, P<0.001) (Figure 6A). No interaction between condition and muscle was observed (F=1.6, P=0.206) thus across all conditions, the amplitude of muscle activity was higher for the d-SSC compared to the s-SC (SNK: P<0.001). The relative activation between muscles did not change across conditions (F=1.5, P=0.227) (Figure 6B).

Cervical Left Rotation with Pulley Inclined, Horizontal or Declined

A main effect of both condition (F=3.6, P=0.031) and muscle (F=7.3, P<0.007) was observed for the amplitude of muscle activity (Figure 7A). Higher levels of activity were observed for both d-SSC and s-SC muscles when the pulley was positioned on a decline compared to inclined (SNK: P=0.032) position but not the horizontal condition (SNK=0.051). No difference was observed between the horizontal and inclined position (SNK=0.562). Overall, higher levels of activity were observed for the s-SC muscle compared to the d-SSC (SNK: P=0.008) for all conditions. There was no interaction between condition and muscle (F=1.2, P=0.281). Moreover, the relative activation between muscles did not change across conditions (F=2.2, P=0.116) (Figure 7B).

DISCUSSION

This study assessed changes in activation of healthy cervical extensor muscles with alterations in the line of action during resisted pulley exercises. In the first two exercises, the amplitude of muscle activity was higher for the d-SSC compared to the s-SC muscle. The activity of both muscles was greatest when the central-hanging weight was vertical compared to all other conditions in the first exercise, whereas no significant effects were found in the second exercise comparing center, right and left hanging weights. In contrast, in the third exercise, there was higher activity of the s-SC muscle compared to the d-SSC. However, both muscles had higher levels of activity when the pulley rope was in a declined position, compared to horizontal and inclined positions.

Cervical Extension with Pulley and Central Hanging Free Weight

The first hypothesis stated that as the line of action from the pulley changes from an incline to a more vertical position during an extension exercise, a more declined line of action would increase the relative flexion torque, increasing activation of the d-SSC and s-SC since their primary action is extension. Increased activation of both d-SSC and s-SC was confirmed in the vertical position compared to the other positions. These findings suggest that the greater the decline, from an inclined to a fully vertical position, the greater the activation of both muscles. However, the relative activation between the muscles did not change. Previous studies have evaluated cervical extensor muscle activation during isometric exercise, but contrary to the current study, no differentiation between superficial and deep cervical muscle activation was reported (Blouin et al. , 2007). On the contrary, the current results show that cervical extension exercises with a pulley or with a free hanging weight result in greater activation of the d-SSC compared to the s-SC, although one exercise is not superior to another at increasing the activation of the d-SSC relative to the s-SC. The study by Blouin et al (2007) involved heavier isometric work utilizing a dynamometer with the trunk fixed. The resistance of 25N and 50N (5.6 and 11.24 pounds respectively) used, far exceeds the resistance used in the current study, which may account for failure to demonstrate increased deep extensor activation compared to a superficial extensor, as noted in the current study.

Cervical Extension with Central and Non-Central Hanging Free Weight

The second hypothesis stated that a non-centrally placed vertical resistance during a cervical extension exercise, which would add a lateral flexion torque, would enhance activation of the contralateral d-SSC and s-SC. Moving the load to the left of the axis of motion for lateral flexion was expected to increase the counteracting activation of muscles for right lateral flexion. Although we observed that the activity of the d-SSC was higher compared to the s-SC muscle for each condition, contrary to our hypothesis, the activation of the extensor muscles did not vary significantly when the position of the hanging weight was changed.

The increased activation of the d-SSC compared to the s-SC for all three conditions might be explained by the flexion moment of the free hanging weight that may have to be specifically counteracted by activation of the deeper muscle layer, or by the fact that this was a low-load exercise which targeted the deep postural muscles. It is unclear if this pattern would be maintained at higher loads. However, there was no difference between conditions in the activation of the d-SSC relative to the s-SC.

Previous studies have not evaluated this type of variation in exercise design, targeting unilateral muscle groups. However, earlier work has shown greater changes in muscle activation ipsilateral to the side of pain in people with chronic neck pain (Falla, 2004, Falla et al. , 2004), suggesting the benefits of designing side-specific exercises.

Cervical Left Rotation with Pulley Inclined, Horizontal or Declined

The third hypothesis stated that activity of the cervical extensors would be enhanced during a rotation exercise using a more declined line of action from a pulley rope, creating a flexion torque on the cranium. Higher EMG amplitude of both the d-SSC and s-SC was observed when the pulley rope was declined, versus a horizontal or inclined position confirming our hypothesis, although no difference in the relative activation between muscles was observed across conditions. Increased activation of the d-SSC and s-SC may be anticipated due to the flexion torque created by the decline pulley rope requiring additional postural and/or proprioceptive support.

A relevant observation is that, in contrast to the other two exercises, the activity of the s-SC muscle was higher compared to the d-SSC for these rotation exercises as reflected in the ratio scores which are ~1 or less. This implies that the rotation exercises are less specific at targeting the d-SSC compared to the extension exercises or exercises with a hanging weight.

It should also be noted that activation of the right s-SC increased during a left rotation exercise with a decline pulley rope, even though this s-SC is a right rotator. The combined rotation and flexion torque in this low load condition created by the decline pulley rope likely required additional postural support, resulting in increased extensor action of the s-SC.

Clinical Considerations

This study evaluated the change in activation of neck extensor muscles with a pulley system or with hanging weights when altering the relative line of action applied to the cranium with controlled resistance. The results favour a more declined or vertical line of action when designing and performing cervical extension exercises. Unilateral neck pain has been associated with greater alterations in muscle function ipsilateral to the side of pain (Falla, Jull, 2004) and the current results suggest that the neck extensors can be targeted unilaterally by designing exercises with more vertical resistance, as well as providing a decline moment during rotational training.

Historically, the use of pulley training has applied basic physics when describing changes in the rope angle from a pulley system on the relative torque applied to the head. To achieve specificity in exercise design, emphasized in the Nordic training programs (Faugli, 1996) and the STEP concepts (Grimsby, 2008), a more declined or vertical line of resistance could be used with the aim of increasing the activation of the deep extensor muscles relative to the superficial extensors. As previously noted, people with chronic neck pain may present with reduced activation (Schomacher, Boudreau, 2013, Schomacher, Farina, 2012a), atrophy (Fernandez-de-las-Penas et al. , 2008, Kristjansson, 2004), and increased fatty infiltration (Elliott, Jull, 2006, Elliott et al. , 2009, Elliott, Jull, 2008) of their deep neck extensors. Targeted training may be able to reverse such changes in muscle structure and function. While preliminary, evidence exists to suggest specific resistance exercise can alter the structure and function of the neck extensors and flexors in chronic whiplash (O'Leary et al. , 2015), although this remains to be confirmed with larger-scaled studies involving patients with varying levels of pain and disability.

Methodological Considerations

The invasive nature of the experiment limited the sample size and although small, it is in line with similar invasive EMG studies, including studies comparing the activation of different cervical muscles during exercise (Blouin, Siegmund, 2007, Falla et al. , 2003, Falla et al. , 2006, Mayoux-Benhamou et al. , 1997, Schomacher, Boudreau, 2013). Additionally, it is acknowledged that this study was conducted on healthy volunteers. Further assessment in symptomatic subjects with atrophy and/or changes in muscle behavior as evidenced by ultrasound or MRI may be warranted. Moreover, it is not known whether the relation in activation between muscles holds true for the same exercises at higher forces/load since all exercise were performed at relatively low loads. Although we observed differences across conditions and muscles, it should also be noted that the differences were relatively small in most cases (e.g. 10 % MVC) and thus the actual clinical significance of these differences is unknown.

The EMG data were normalized relative to the maximal EMG amplitude of each muscle measured during maximal isometric neck extension, which activates the target muscles in healthy subjects (Blouin, Siegmund, 2007, Schomacher, Petzke, 2012b). However, this task in itself may not have been maximal for both muscles equally, which would introduce bias when comparing normalized EMG amplitude between muscles. A different force direction may have induced even greater activation of either muscle (e.g. posterolateral extension(Schomacher, Petzke, 2012b)). Alternatively, a submaximal task could have been used to normalize the EMG data such as lifting the head in prone. However, the method applied in this study was consistent for all exercises, thus would not affect the comparisons of the normalized EMG between the various exercises.

CONCLUSION

This study found that activation of d-SSC and s-SC was affected in stereotypical ways by altering the line of resistance during cervical extension and rotation exercises in a sample of people with no history of neck pain. Further investigation is necessary to assess the clinical benefit from more specialized exercise design for people with neck pain who might benefit from exercise that selectively facilitates the cervical extensors.

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FIGURE AND TABLE LEGENDS

TABLE 1: Estimation of the various external torques produced by the weight and pulley setup and the internal torques generated by the muscles of interest, the semispinalis cervicis (d-SSC) and splenius capitis (s-SC). R: Right, L: Left, E: Extension, F: Flexion.

		Direction of torque generated		
	Torque Generator (Muscles or Exercise)	Flexion / extension F or E	Lateral flexion R or L	Rotation R or L
Muscle action	Semispinalis Cervicis (d-SSC)	E	R	L
	Splenius capitis (s-SC)	E	R	R
Figure 1	Cervical extension pulley HORIZONTAL	F	—	—
	Cervical extension pulley DECLINED	F	—	—
	Cervical extension pulley INCLINCED	F	—	—
	Cervical extension pulley HANGING WEIGHT	F	—	—
Figure 2	Cervical extension CENTRAL hanging weight	F	—	—
	Cervical extension RIGHT hanging weight	F	R	—
	Cervical extension LEFT hanging weight	F	L	—
Figure 3	Cervical rotation INCLINED	E	R	R
	Cervical rotation HORIZONTAL	—	R	R
	Cervical rotation DECLINED	F	R	R

FIGURE 1. A. Needle insertion was performed under sterile procedures and the ultrasound transducer was enclosed in a sterile plastic envelope. Once the needle tip was in the target muscle belly of the (B) semispinalis cervics or (C) splenius capitis, the needle was removed leaving the wire in the muscle for the duration of the experiment.

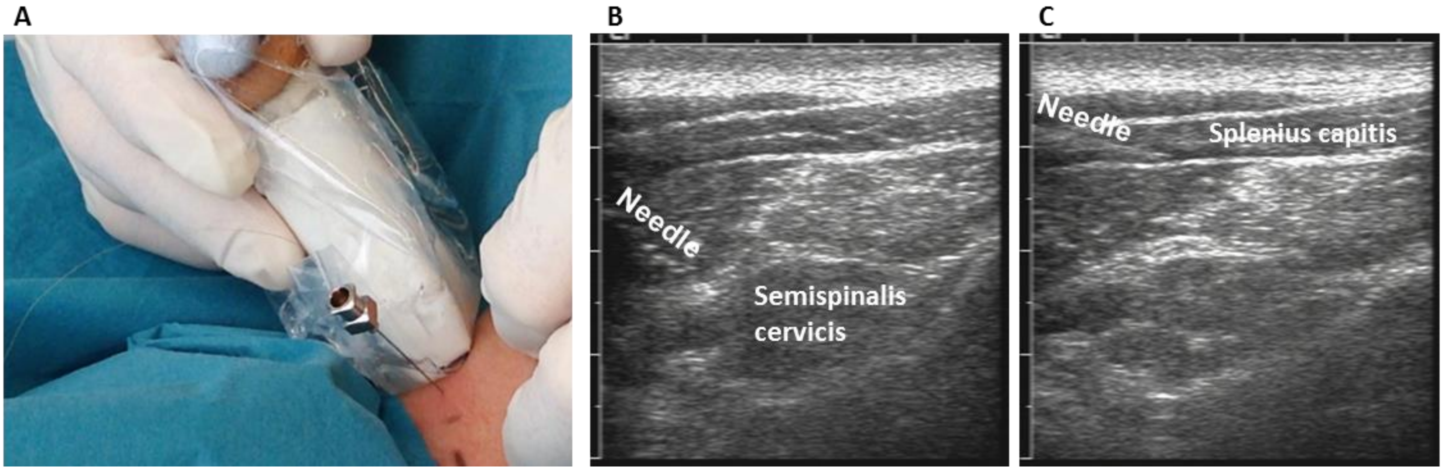

FIGURE 2. Cervical extension with pulley and central hanging free weight.

Rationale: Anatomically, the cervical extensor muscles attach directly to the cranium and vertebrae, thus are best suited to extend the head and neck backwards. As the resistance from the pulley is changing from incline, horizontal, decline to vertical, the amount of flexion torque is increased on the cranium. It is expected that the cervical extensors would be more active the more vertical the resistance.

Procedure: A pulley was attached to the subject's head in a neutral position, horizontally in the sagittal plane, perpendicular to the trunk. Exercise was performed with the rope inclined by 15° (A), horizontal (B) and declined by 15° (C). Data obtained were compared with findings from the free weight attached centrally at the forehead with the weight hanging vertically (D).

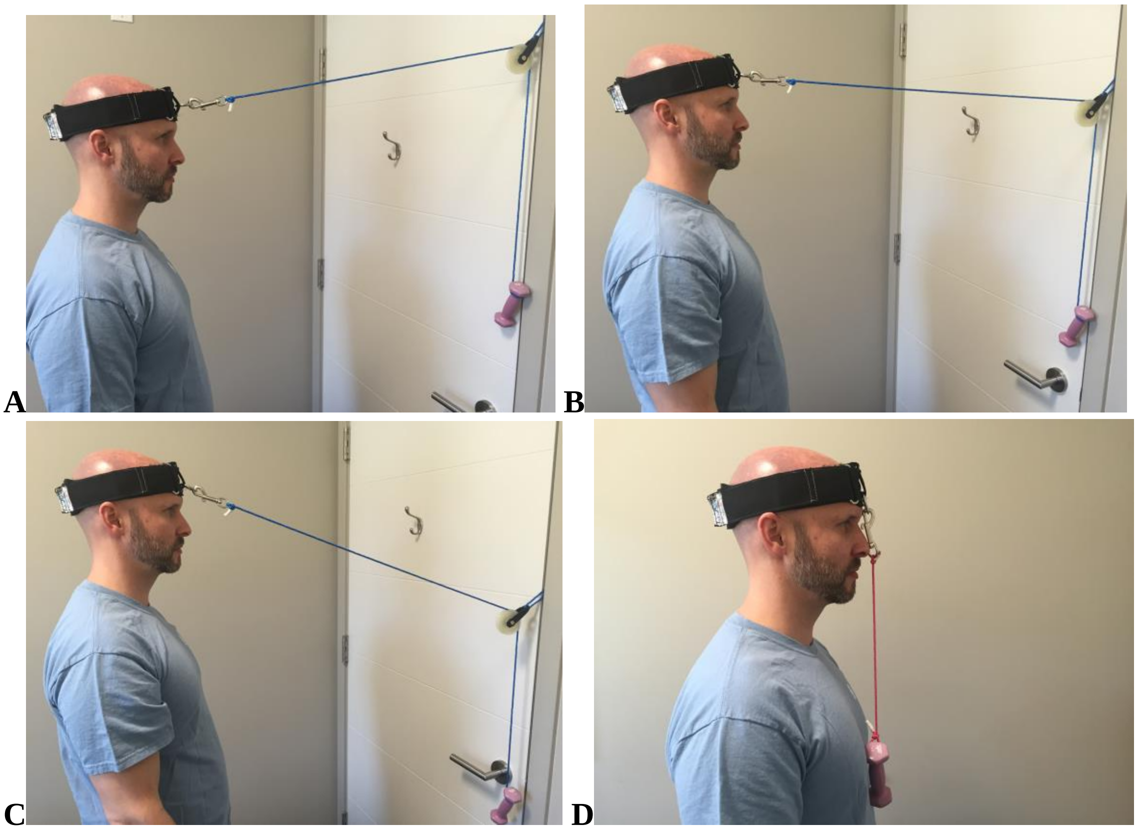

FIGURE 3. Cervical Extension with central and non-central hanging free weight.

Rationale: Anatomically, the d-SSC and s-SC have attachments directly to the vertebrae and cranium making them primary extensors, with a secondary action of ipsilateral lateral flexion. They are both suited to extend and laterally flex the head and neck. A central hanging weight produces a flexion torque on the cranium. Moving the weight to the right or left of center would impart a lateral flexion torque. It is expected that the right cervical extensors would have enhanced activation during extension with a resistance placed on the opposite side producing a contralateral side bending torque.

Procedure: With a free weight (0.9kg) hanging vertically from a rope and the head in neutral, measurements were taken with the weight attached *centrally* at the forehead (A), to the outside edge of the *right* orbit of the eye (B) and to the outside edge of the *left* orbit of the eye (C).

A B C

FIGURE 4. Cervical left rotation with pulley inclined, horizontal or declined.

Rationale: The pulley positioned to the right of the patient will produce a right rotation torque. Anatomically, the right d-SSC is a primary extensor, but has secondary actions, which include left rotation and right lateral flexion. The s-SC is also a primary extensor, with a secondary action of right lateral flexion, but its rotation action is to the right. It is expected that the right rotation torque from the pulley would not substantially change in the three positions tested. But, the decline pulley rope would increase the flexion torque, compared to horizontal and inclined positions, increasing the activation of both the d-SSC and s-SC during a left rotation exercise.

Procedure: The subject was sitting upright with the head in neutral. A horizontal (B) resistance (0.9kg) for left rotation, parallel to the plane of the trunk, was attached to the head strap from a door pulley, perpendicular (90°) to the lever arm for rotation. This exercise was then repeated with the pulley either inclined (A) or declined (C) in the frontal plane by 15°.

A

B

C


FIGURE 5. Cervical extension with pulley and central hanging free weight.

A. Mean and SE of normalised EMG amplitude (%) recorded from the semispinalis cervicis (d-SSC) and splenius capitis (s-SC). B. Mean and SE of the ratio between the normalised EMG amplitude (%) of the d-SSC and s-SC. Note: All four exercise conditions displayed a ratio above one indicating higher activation of d-SSC compared to s-SC. * indicates significant difference (P<0.05).

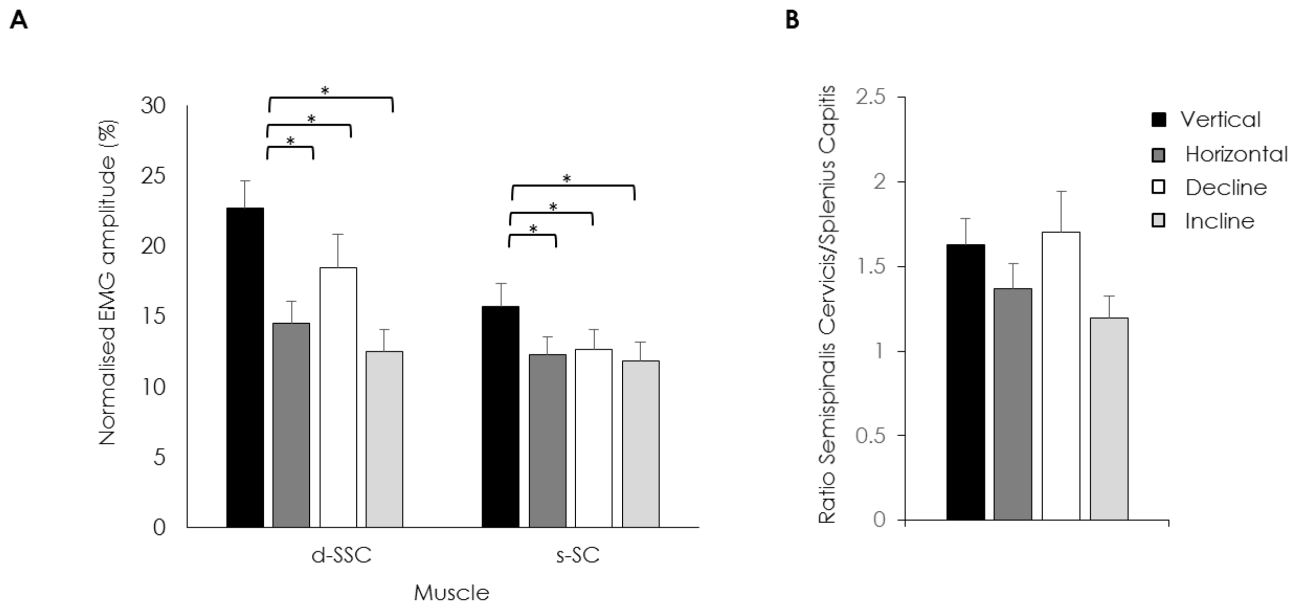

FIGURE 6. Cervical Extension with central and non-central hanging free weight.

A. Mean and SE of normalised EMG amplitude (%) recorded from the semispinalis cervicis (d-SSC) and splenius capitis (s-SC). B. Mean and SE of the ratio between the normalised EMG amplitude (%) of the d-SSC and s-SC. Note: All three variations of the exercise obtained a ratio above one, indicating higher activity of d-SSC compared to s-SC.

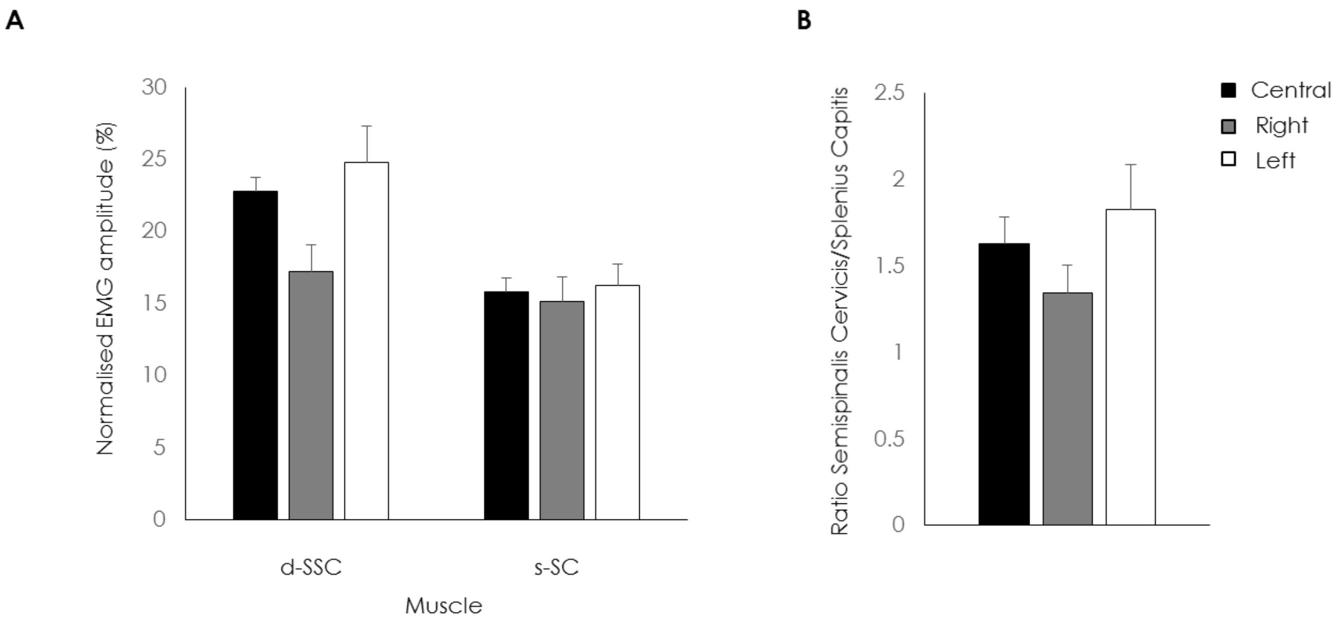

FIGURE 7. Cervical left rotation with pulley inclined, horizontal or declined. A. Mean and SE of normalised EMG amplitude (%) recorded from the semispinalis cervicis (d-SSC) and splenius capitis (s-SC). B. Mean and SE of the ratio between the normalised EMG amplitude (%) of the d-SSC and s-SC. Note: All three variations of the exercise obtained a ratio of approximately one or less, indicating higher activity of s-SC compared to d-SSC. * indicates significant difference (P<0.05).