Published in final edited form as:

J Electromyogr Kinesiol. 2013 October ; 23(5): 1082–1089. doi:10.1016/j.jelekin.2013.05.009.

Differential effects of mental concentration and acute psychosocial stress on cervical muscle activity and posture

Bahar Shahidi, Ashley Haight, and Katrina Maluf*

Physical Therapy Program, University of Colorado, Anschutz Medical Campus, Aurora, CO, USA

Bahar Shahidi: Bahar.Shahidi@ucdenver.edu; Ashley Haight: Ashley.Haight@ucdenver.edu; Katrina Maluf: Katrina.Maluf@ucdenver.edu

Abstract

Physical and psychosocial stressors in the workplace have been independently associated with the development of neck pain, yet interactions among these risk factors remain unclear. The purpose of this study was to compare the effects of mentally challenging computer work performed with and without exposure to a psychosocial stressor on cervical muscle activity and posture. Changes in cervical posture and electromyography of upper trapezius, cervical extensor, and sternocleidomastoid muscles were compared between a resting seated posture at baseline, a low stress condition with mental concentration, and a high stress condition with mental concentration and psychosocial stress in sixty healthy office workers. Forward head posture significantly increased with mental concentration compared to baseline, but did not change with further introduction of the stressor. Muscle activity significantly increased from the low stress to high stress condition for both the dominant and non-dominant upper trapezius, with no corresponding change in activity of the cervical extensors or flexors between stress conditions. These findings suggest that upper trapezius muscles are selectively activated by psychosocial stress independent of changes in concentration or posture, which may have implications for the prevention of stress-related trapezius myalgia in the workplace.

Keywords

Psychosocial stress; Neck; Electromyography; Posture; Mental concentration

1. Introduction

The annual prevalence of neck pain in the general population is between 30% and 50%, with nearly 12% of affected individuals reporting significant activity limitations due to pain (Hogg-Johnson et al., 2008). Compared to the general population, the annual prevalence of neck pain is notably higher (65%) among office workers (De Loose et al., 2008). Work-related exposures such as accumulated computer usage, sitting for long periods, sitting with a forward head posture, and poor workstation ergonomics have been linked to an increased

*Corresponding author. Address: University of Colorado Anschutz Medical Campus, Department of Physical Medicine & Rehabilitation, Physical Therapy Program, MS C244, Education 2 South, Bldg #L28, 13121 E, 17th Ave., Room 3108, Aurora, CO 80045, USA. Tel.: +1 303 724 9139; fax: +1 303 724 9016.

Conflict of interest: None declare.

risk of neck pain among office workers (Larsson et al., 2007; Johnston et al., 2009; Eltayeb et al., 2009). These observations support the role of prolonged, low intensity physical loads in the etiology of non-specific neck pain for this high-risk population (U.S. Department of Health & Human Services, 1997).

In addition to physical risk factors, evidence suggests that psychosocial stressors such as time demands, low social support, and monotonous work may also contribute to the development of neck pain (Larsson et al., 2007; U.S. Department of Health & Human Services, 1997; Ariens et al., 2001; Bongers et al., 1993; Hales and Bernard, 1996; Larsman et al., 2006). A hypothesized mechanism for this effect is an increase in sustained muscle activity during exposure to occupational stressors that over time may lead to muscle overuse, damage, and subsequent musculoskeletal pain (Lundberg et al., 1999, 2002). Several studies have investigated the effect of psychosocial stress on cervical muscle activity during actual and simulated office work in individuals with and without neck pain (Johnston et al., 2008; Lundberg et al., 1994, 2002; Larsman et al., 2009; Rissen et al., 2000; Sogaard et al., 2001; Stephenson et al., 2011). These studies observed increased electromyographic (EMG) activity of cervical muscles such as the upper trapezius and sternocleidomastoid muscles under stressful work conditions, sometimes even in the absence of physical task demands, thereby supporting a psychomotor mechanism for cumulative trauma injury of the cervical muscles.

Importantly, previous studies investigating the effects of psychosocial stress on muscle activation have rarely considered the potential confounding effects of changes in mental concentration or cervical posture with introduction of the stressor. Psychosocial stress is typically elicited using some form of mental concentration presented concurrently with social evaluative threat to increase physiologic arousal. Mental concentration in the absence of stress has been shown to increase muscle activity (Johnston et al., 2008), making it difficult to attribute such changes solely to a stress response for tasks that involve different cognitive demands. Similarly, evidence also suggests a relationship between forward head posture and increased EMG activity of the cervical musculature. For example, some studies have demonstrated increased cervical muscle activity with increased forward head postures (Edmondston et al., 2011; Westgaard et al., 2006), as well as increased forward head postures in individuals with neck pain compared to healthy controls (Falla et al., 2007; Szeto et al., 2005). In contrast, a study by Straker et al. (2009) comparing EMG recordings across different cervical flexion moments suggested that the overall change in cervical posture previously reported with office work may not be sufficient to significantly increase muscle activity. Additionally, cervical muscle activity and biomechanical loads do not always demonstrate linear responses, with some muscles becoming active only after a certain load threshold is exceeded (Sommerich et al., 2000). Given evidence that both mental concentration and neck posture may have some influence on cervical muscle activity, previous studies that failed to systematically evaluate the effects of these confounding variables may have overestimated the independent effects of psychosocial stress on muscle activation.

Due to the cognitive demands associated with prolonged computer use and the high prevalence of perceived job stress among office workers (Bongers et al., 1993), it is

important to understand the unique roles of neck posture, mental concentration, and psychosocial stress on changes in cervical muscle activity that may contribute to the development of neck pain in this high-risk population. Therefore, the purpose of this study was to quantify differences in cervical muscle activity and posture during a mental concentration task performed with and without exposure to an acute psychosocial stressor. We expected to observe increases in both cervical muscle activity and forward head posture with the introduction of mental concentration that would be even more pronounced with the further introduction of psychosocial stress.

2. Methods

2.1. Participants

A convenience sample of sixty asymptomatic office workers (45 women) with a mean (SD) age of 29.8 (7.7) years were recruited from a university medical campus and surrounding community. Due to the higher reported incidence of female office workers developing pain (Cote et al., 2008), a higher proportion of women was recruited. Participants had no history of neck pain in the previous year, and were excluded if they had any injury to the neck or shoulder region within the past 12 weeks, had a history of surgery involving the neck or shoulder region, experienced any neurological symptoms affecting the upper limb, or had been diagnosed with any other major neurologic, musculoskeletal, or psychiatric disorder. Participants were enrolled if they were at increased risk of developing neck pain due to working at least 30 h per week, and spending at least 75% of their workday at the computer (Eltayeb et al., 2009). A separate group of 19 individuals (12 women) with a mean (SD) age of 28.4 (4.6) years was recruited for a control experiment performed without the stress manipulation to identify any changes in muscle activity over time in the absence of stress. There were no differences in demographic characteristics of individuals who participated in the experimental session compared to those who participated in the control session (Table 1). All participants provided written informed consent prior to enrollment, and all study procedures were approved by the local Institutional Review Board.

2.2. Experimental protocol

Participants were positioned at a computer workstation without forearm support in a standardized seated posture based on guidelines developed by the Occupational Safety and Health Administration (OSHA). All measurements were first obtained at baseline with the participant sitting at the computer workstation and maintaining his or her gaze at a fixed location on the computer screen. This baseline position was considered the participant's resting seated posture. Following the baseline condition, participants completed a standardized psychomotor task with the dominant hand as described previously (Bruflat et al., 2012). The psychomotor task was a computerized version of the Operation Span (OpSpan) test (Conway et al., 2005) that required participants to solve complex arithmetic problems while memorizing and selecting lists of 2–8 words in sequential order using a computer mouse with their dominant hand. No physical demands were required of the non-dominant arm, which remained supported in the lap throughout the task. The OpSpan task was repeated under low (LS) and high (HS) stress conditions separated by a 15 min rest break. Task performance was scored on a scale ranging from 0 to 40 points, with higher

scores indicating greater accuracy. Task duration was measured as the amount of time required for participants to complete the task in each stress condition.

Prior to the LS condition, participants were told that they were “just practicing” and their performance would be unmonitored and without accuracy or speed constraints. Participants were also given positive encouragement by a familiar tester throughout the task. The same psychomotor task was subsequently repeated in a HS condition, in which participants were told that speed and accuracy were extremely important and that they would receive a monetary reward for high scores. The test was administered by an authoritative and unfamiliar tester who did not provide any positive feedback. This protocol was designed to simulate common stressors encountered in the workplace, including time and accuracy demands, evaluation by supervisors and peers, and productivity-based monetary incentives. Immediately after the HS condition, the methods and purpose of the stress manipulation were fully disclosed. Participants were assured that they did not perform poorly on the test and that they would receive full monetary compensation regardless of their performance.

To identify any evidence of muscle fatigue, maximum voluntary contractions (MVCs) of the upper trapezius muscle were performed at the beginning and end of each experimental session. MVCs were performed with the arms abducted approximately 45° and positioned in line with the trunk with the elbows flexed and the forearms resting on arm rests parallel with the floor. Restraints were placed over each acromion to prevent movement of the shoulders during isometric contraction of the upper trapezius muscle bilaterally. Participants were instructed to maximally shrug their shoulders upwards against the restraints while receiving strong verbal encouragement and viewing feedback of vertical shoulder forces on a computer monitor. MVCs were repeated with at least 60 s rest between trials until peak forces from the highest two trials agreed within 5%. This method was selected to verify consistency of maximal exertions and reduce variability due to unpracticed task novelty (Bao et al., 1997; Burden, 2010). No more than 5 MVCs were required to achieve consistency. Approximately 5 min rest was provided before the first experimental condition was presented following the assessment of MVCs.

2.3. Control experiment

Due to potential residual effects of the psychosocial stressor on measures of arousal collected in the same experimental session, the three test conditions (baseline, low stress, high stress) were presented in sequential order with the HS condition always presented last. Therefore, a separate control experiment was performed in which a matched group of 19 healthy office workers completed the same experimental protocol with the HS condition replaced by a second LS condition. This was done to identify any potential effects of task order or muscle fatigue on changes in muscle activity and cervical posture across test conditions.

2.4. Measurements

2.4.1. Cervical angle—Forward head posture was operationally defined as the angle of the cervical spine relative to the horizontal (cervical angle), with smaller cervical angles corresponding to increased forward head posture. Cervical angle was quantified as the angle

measured from the horizontal plane to a reflective marker located on the tragus of the ear, with the origin at a marker located over the spinous process of the seventh cervical (C7) vertebrae (Fig. 1). Cervical angles were calculated from digital photographs taken at baseline and when 75% of the OpSpan task had been completed during each stress condition. The photographs were taken with a digital camera (Canon Powershot, 16MP A4000IS, New York City, NY USA) mounted on a tripod distanced 0.8 m to the right of the participant, and aligned parallel to the level of the C7 spinous process. A recent systematic review on the reliability of angular posture measurements using digital photography in healthy individuals indicated that seated cervical angles assessed multiple times within the same session demonstrate good reliability, with intraclass correlations coefficients ranging from ICC = 0.78 to 0.98 (Silva et al., 2011).

2.5. Electromyography

Activation of bilateral upper trapezius (UT), cervical extensor (CE), and sternocleidomastoid (SCM) muscles was recorded at 2 kHz using 8-mm diameter bipolar Ag/AgCl surface electrodes with an inter-electrode distance of 2 cm. The electrodes were placed bilaterally 2 cm lateral to the midpoint of the line between the C7 spinous process and the acromion for the UT (Hermens et al., 2000), 2 cm lateral to the C4 spinous process for the CE (Sommerich et al., 2000), and one-third of the distance from the sternal notch to the mastoid process for the SCM muscle groups (Falla et al., 2002). Reference electrodes were placed on the clavicle. Prior to digitization and storage, surface EMG signals were amplified (1000 $\times$) and bandpass filtered at 13–1000Hz (Coulbourn V-series modules, Allentown, PA, USA). Each signal was then inspected for heart rate artifact, which was subsequently removed using an automated custom software algorithm (Marker and Maluf, 2012). The root mean squared (RMS) amplitude of the EMG signal was calculated for a 5s window surrounding the time at which digital photographs of cervical posture were obtained in each stress condition (Fig. 2). These values were then normalized to the RMS amplitude of muscle activity recorded for each cervical muscle in a resting seated posture during the baseline condition (Sommerich et al., 2000). The RMS amplitude of UT muscle activity was also calculated for non-overlapping 0.5 s epochs for each MVC trial. The maximum RMS values recorded from pre- and post-session MVC trials were compared to identify any changes in maximal activation resulting from fatigue of the UT muscle during the experimental session.

2.6. Physiologic arousal and perceived anxiety

To verify that the stress protocol elicited a sympathetic arousal response, blood pressure and heart rate were assessed immediately after each test condition using an automated oscillometric blood pressure cuff (Coulbourn V-series module, Allentown, PA, USA) placed around the non-dominant arm. The Rate Pressure Product (RPP) was calculated as the product of heart rate (beats/min) and systolic blood pressure (mmHg) to provide an index of changes in cardiac demand across test conditions (Wasmund et al., 2002). Perceived anxiety was also assessed following baseline, LS, and HS conditions using the state version of the Spielberger State-Trait Anxiety Inventory (STAI-State), a 21 item questionnaire ranging from 20 to 80 points with higher scores indicating greater perceived anxiety (Metzger, 1976).

3. Analysis

Demographic characteristics of participants in the experimental and control sessions were compared using independent *t*-tests for continuous variables and chi-squared tests for categorical variables. Cervical angle, RPP, and STAI-State scores were analyzed using a one-way repeated measures analysis of variance (ANOVA) to compare baseline, LS, and HS conditions. Post hoc comparisons using Tukey's HSD procedure were performed for outcomes with significant main effects. Normalized activity of UT, CE, and SCM muscles was compared across the two stress conditions using paired *t*-tests. These analyses were performed separately for the experimental and control sessions. Associations between changes in muscle activity, cervical angle, and task duration between test conditions were assessed using Pearson's correlation coefficients. All statistical tests were performed using statistical software package SAS version 9.3 (SAS Institute Inc., Cary, NC USA). Values were considered significant if they were below an alpha level of 0.05.

4. Results

4.1. Experimental session

There was a significant increase in both RPP ($F = 39.73$, $p < 0.001$) and STAI-State ($F = 116.11$, $p < 0.001$) scores across experimental conditions, indicating an increase in both physiologic arousal and perceived anxiety with the introduction of mental concentration as well as the further introduction of stress (Fig. 3). Post hoc tests revealed that the HS condition elicited significantly greater increases in arousal and anxiety compared to both the baseline condition (RPP: $p < 0.0001$; STAI-State: $p < 0.0001$) and the LS condition (RPP: $p = 0.026$; STAI-State: $p < 0.0001$). There was also a significant overall decrease in cervical angle across experimental conditions ($F = 30.29$, $p < 0.001$), reflecting an increase in forward head posture during both the LS and HS conditions compared to baseline ($p < 0.001$), with no difference in cervical angle between the two stress conditions ($p = 1.00$) (Fig. 4).

Changes in muscle activity from the LS to HS condition are illustrated for a representative participant in Fig. 2. Analysis of group means revealed a significant increase in normalized EMG for both the dominant ($p = 0.007$) and non-dominant ($p = 0.020$) UT muscles from the LS to HS condition, with no corresponding change in EMG activity of the CE ($p = 0.051$) or SCM ($p = 0.586$) muscle groups between stress conditions (Fig. 5). Although trapezius muscle activity increased across stress conditions, this increase could not be attributed to muscle fatigue based on a lack of significant change in peak EMG values measured during maximal contractions performed before and after the experimental session (0.378(0.216) mV vs. 0.378(0.227) mV, $p = 0.989$ for dominant trapezius; 0.368(0.229) mV vs. 0.362(0.219) mV for non-dominant trapezius, $p = 0.623$). Accuracy scores did not differ between the LS and HS conditions (14.7(6.4) vs. 15.0(8.3) points; $p = 0.652$), however participants performed the psychomotor task faster in the HS condition, with the average task duration decreasing from 277.4(67.5) to 258.4(51.4) s; $p = 0.004$). This difference was not significantly correlated with increases in muscle activity across stress conditions, and explained less than 1% of the variance in EMG for both the dominant ($r = 0.02$, $p = 0.869$) and non-dominant upper trapezius muscles ($r = 0.08$, $p = 0.526$). A significant association

between changes in cervical muscle activity and posture from baseline to the LS condition was found only for CE on the non-dominant side ($r = 0.37$, $p = 0.007$), with a similar trend on the dominant side ($r = 0.22$, $p = 0.139$). No significant associations between changes in muscle activity and posture were observed for any muscle group from the LS to HS condition, likely due to the lack of a significant change in cervical posture across stress conditions.

4.2. Control session

STAI-State scores increased with the introduction of mental concentration from baseline to LS ($p = 0.019$), with no subsequent change between the first and second LS trials ($p = 0.875$) in the control session. RPP did not change across baseline, first LS, or second LS conditions ($F = 1.51$, $p = 0.231$). Furthermore, the control session revealed no significant change in EMG activity from the first to the second LS trial for the UT ($p = 0.369$), CE ($p = 0.711$), or SCM ($p = 0.091$) muscle groups, indicating that muscle activity did not increase as a result of time, test order, or muscle fatigue for the experimental protocol used in this study.

5. Discussion

Our results demonstrate that mentally challenging computer work increases perceived anxiety (STAI), cardiac demand (RPP), and forward head posture in asymptomatic office workers. The introduction of psychosocial stress with identical cognitive demands evokes an even greater increase in arousal, along with an increase in UT muscle activity that is unrelated to any further change in cervical posture. Importantly, the observed increases in muscle activity with exposure to psychosocial stress occur only in the UT muscles, and cannot be attributed to changes in neck posture, muscle fatigue, mousing speed, or task order.

The observation that increases in forward head posture with mental concentration are associated with cervical extensor muscle activity is consistent with previous literature reporting increased activation of cervical musculature with changes in neck posture (Szeto et al., 2005; Edmondston et al., 2011) and during mental concentration (Johnston et al., 2008). Interestingly, mental concentration caused a 1.2- to 4-fold increase in EMG activity for all cervical muscles in the low stress condition compared to baseline (Fig. 5). This observation suggests that high cognitive demands, alone, can evoke a generalized increase in activation of the cervical stabilizers. Concurrent increases in forward head posture, however, were only associated with activation of the cervical extensors. When an identical cognitive task was performed in the presence of an acute psychosocial stressor, only the upper trapezius demonstrated a further increase in muscle activity that was not associated with any further changes in neck posture. Although participants required less time to perform the psychomotor task with similar accuracy in the high stress condition, changes in mousing speed were not associated with increases in trapezius muscle activity. Moreover, increases in UT EMG were observed not only for the physically active dominant limb, but also for the resting non-dominant limb which was not involved in the mousing task. Finally, the control experiment confirmed that muscle activity did not change across two consecutive low stress

Author Manuscript

trials, thereby eliminating task order and muscle fatigue as potential explanations for the observed increases in trapezius muscle activity over time. The absence of muscle fatigue was further supported by similar peak EMG values obtained during maximal contractions of the trapezius performed before and after the experimental session.

Author Manuscript

Previous studies support a discrepancy in the responsiveness of the upper trapezius and cervical extensor muscle groups to changes in posture, mental concentration, and psychosocial stress. One study found that slumped postures increase activity of cervical extensors but not the upper trapezius (Caneiro et al., 2010), suggesting that the trapezius muscle is not as responsive to changes in cervical posture compared to the intrinsic neck muscles. Another study by Johnston et al. (2008) found similar increases in activation of all cervical muscles during a stressful concentration task, however the upper trapezius exhibited a delayed return to resting levels of activity after completion of the task that was not evident in the other muscle groups. Concurrent changes in cervical posture were not measured in the aforementioned study, making it difficult to differentiate the effects of posture and psychosocial stress on these different muscle groups. The increase in trapezius muscle activity from the low stress to high stress condition without a concurrent change in cervical angle in the present study confirms previous observations of selective activation of the upper trapezius in response to acute psychosocial stress (Lundberg et al., 1994, 2002). Taken together, these observations may suggest that activation of the cervical extensors underlie postural changes that occur with mentally challenging computer work, whereas the upper trapezius may be more responsive to psychosocial stressors in the workplace.

Author Manuscript

Previous literature has implicated abnormal and prolonged postures (Larsson et al., 2007; Johnston et al., 2009; Eltayeb et al., 2009), as well as psychosocial stress (Lundberg et al., 2002, U.S. Department of Health & Human Services, 1997, Ariens et al., 2001; Bongers et al., 1993; Hales and Bernard, 1996; Larsman et al., 2006), as risk factors for the development of neck pain. Discrepant patterns of activity among muscles that act to stabilize the cervical spine suggest that cumulative trauma injuries of different muscle groups may have different etiologies. For example, greater responsiveness of the upper trapezius muscle to psychosocial stressors may contribute to trapezius myalgia in some individuals, whereas pain in more proximal areas of the posterior neck may be related to extreme forward head postures while working at the computer. Prospective studies are needed to determine how different patterns of muscle activity in response to both psychosocial and biomechanical stressors in the workplace may contribute to the development of pain in different regions of the cervical spine. Additionally, future studies should investigate what amplitude of muscle activity is necessary to pose a significant increase in the risk of developing neck pain. Prevention and treatment programs can then be customized to address the specific occupational stressors that are most responsible for injury of distinct muscle groups in individual office workers.

6. Limitations

Author Manuscript

There are several limitations to the current study. The study population comprised relatively young and healthy office workers, therefore the findings may only be generalized to similarly aged individuals with comparable occupational profiles. Similarly, the findings

cannot be extrapolated to individuals with existing neck pain who may respond differently to mentally challenging or stressful computer work. The mental task was relatively short in duration and specific to utilizing a computer mouse, and may not fully represent the variety of activities that office workers are required to perform in the workplace. Additionally, the experimental protocol was limited in duration and elicited minimal changes in cervical angle, so it is not known how activity of the cervical musculature might differ for individuals who demonstrate larger postural excursions throughout a full workday.

7. Conclusion

Mental concentration combined with an acute psychosocial stressor selectively increases activation of the upper trapezius, but not the cervical extensor or flexor muscle groups. This is the first study to demonstrate that increases in upper trapezius muscle activity cannot be explained by changes in cervical posture during exposure to the stressor, or by the effects of test order or muscle fatigue over time. These findings may have implications for the prevention and treatment of neck pain in office workers who are responsive to psychosocial stressors in the workplace. For example, stress-management may be beneficial as an adjunct to biomechanically focused interventions for individuals with trapezius myalgia. Findings from this study also suggest a need for prospective investigations of psychomotor responses to stress as a potential risk factor for the development of neck pain.

Acknowledgments

This research was supported by NIH R01 AR056704 awarded to K.S.M., and a graduate scholarship from the Foundation for Physical Therapy awarded to B.S.

References

- Ariens GA, van Mechelen W, Bongers PM, Bouter LM, van der Wal G. Psychosocial risk factors for neck pain: a systematic review. *Am J Ind Med.* 2001; 39(2):180–93. [PubMed: 11170160]
- Bao S, Mathiassen SE, Winkel J. Normalizing upper Trapezius EMG amplitude: comparison of different procedures. *J Electromyogr Kinesiol.* 1997; 5:251–7. [PubMed: 20719656]
- Bongers PM, de Winter CR, Kompier MA, Hildebrandt VH. Psychosocial factors at work and musculoskeletal disease. *Scand J Work Environ Health.* 1993; 19(5):297–312. [PubMed: 8296178]
- Bruflat A, Balter J, McGuire D, Fethke N, Maluf KS. Stress management as an adjunct to physical therapy for chronic neck pain. *Phys Ther.* 2012; 92 Epub ahead of print.
- Burden A. How should we normalized electromyograms obtained from healthy participants? What we have learned from over 25 years of research. *J Electromyogr Kinesiol.* 2010; 20(6):1023–35. [PubMed: 20702112]
- Caneiro JP, O'Connell P, Sullivan P, Burnett A, Barach A, O'Neil D, Tveit O, et al. The influence of different sitting postures on head/neck posture and muscle activity. *Man Ther.* 2010; 15:54–60. [PubMed: 19643658]
- Conway AR, Kane MJ, Bunting MF, Hambrick DZ, Wilhelm O, Engle RW. Working memory span tasks: a methodological review and user's guide. *Psychon Bull Rev.* 2005; 12(5):769–86.
- Cote P, et al. The burden and determinants of neck pain in workers: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. *Spine.* 2008; 15(33):S60–74. [PubMed: 18204402]
- De Looze V, Burnotte F, Cagnie B, Stevens V, Van Tiggelen D. Prevalence and risk factors of neck pain in military office workers. *Mil Med.* 2008; 173(5):474–9. [PubMed: 18543569]

- Edmondston S, Sharp M, Symes A, Alhabib N, Allison G. Changes in mechanical load and extensor muscle activity in the cervico-thoracic spine induced by sitting posture modification. *Ergonomics*. 2011; 54(2):179–86. [PubMed: 21294015]
- Eltayeb S, Staal JB, Hassan A, de Bie RA. Work related risk factors for neck, shoulder and arms complaints: a cohort study among Dutch computer office workers. *J Occup Rehabil*. 2009; 19(4): 315–22. [PubMed: 19685174]
- Falla D, Dall'Alba P, Rainoldi A, Merletti R, Jull G. Location of innervation zones of sternocleidomastoid and scalene muscles – a basis for clinical and research electromyography applications. *Clin Neurophysiol*. 2002; 113(1):57–63. [PubMed: 11801425]
- Falla D, Jull G, Russel T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys Ther*. 2007; 87(4):408–17. [PubMed: 17341512]
- Hales TR, Bernard BP. Epidemiology of work-related musculoskeletal disorders. *Orthop Clin North Am*. 1996; 27(4):679–709. [PubMed: 8823390]
- Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for sEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol*. 2000; 16(2):175–87.
- Hogg-Johnson S, et al. The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000–2010 task force on neck pain and its associated disorders. *Spine*. 2008; 33(4):39–51. [PubMed: 18165747]
- Johnston V, Jimmieson NL, Jull G, Souvlis T. Contribution of individual, workplace, psychosocial and physiological factors to neck pain in female office workers. *Eur J Pain*. 2009; 13(9):985–91. [PubMed: 19111487]
- Johnston V, Jull G, Souvlis T, Jimmieson NL. Neck movement and muscle activity characteristics in female office workers with neck pain. *Spine*. 2008; 33(5):555–63. [PubMed: 18317202]
- Larsman P, Sandsjö L, Klipstein A, Vollenbroek-Hutten M, Christensen H. Perceived work demands, felt stress, and musculoskeletal neck/shoulder symptoms among elderly female computer users. The NEW study. *Eur J Appl Physiol*. 2006; 96(2):127–35. [PubMed: 15609027]
- Larsman P, Thorn S, Sjøgaard K, Sandsjö L, Sjøgaard G, Kadefors R. Work related perceived stress and muscle activity during standardized computer work among female computer users. *Work*. 2009; 32(2):189–99. [PubMed: 19289872]
- Larsson B, Sogaard K, Rosendal L. Work related neck-shoulder pain: a review on magnitude, risk factors, biochemical characteristic, clinical picture and preventive interventions. *Best Pract Res Clin Rheumatol*. 2007; 21(3):447–463. [PubMed: 17602993]
- Lundberg U, et al. Psychophysiological stress responses, muscle tension, and neck and shoulder pain among supermarket cashiers. *J Occup Health Psychol*. 1999; 4(3):245–55. [PubMed: 10431284]
- Lundberg U, Kadefors R, Melinn B, Palmerud G, Hassmenn P, Engstrom M, et al. Psychophysiological stress and EMG activity of the trapezius muscle. *Int J Behav Med*. 1994; 1(4):354–70. [PubMed: 16250795]
- Lundberg U, Forsman M, Zachau G, Eklof M, Palmerud G, Melin B, et al. Effects of experimentally induced mental and physical stress on motor unit recruitment in the trapezius muscle. *Work Stress*. 2002; 16(2):166–78.
- Marker, RJ.; Maluf, KS. Validation of a novel method of cardiac artefact removal from trunk muscle electromyography. XIX Biennial conference of the international society of electrophysiology and kinesiology; 2012.
- Metzger RL. A reliability and validity study of the state-trait anxiety inventory. *J Clin Psychol*. 1976; 32:276–8.
- Rissen D, Melin B, Sandsjö L, Dohns I, Lundberg U. Surface EMG and psychophysiological stress reactions in women during repetitive work. *Eur J Appl Physiol*. 2000; 83(2–3):215–22. [PubMed: 11104063]
- Silva A, Punt T, Johnson M. Variability of angular measurements of head posture within a session, within a day, and over a 7-day period in healthy participants. *Physiother Theory Pract*. 2011; 27(7):503–11. [PubMed: 21548815]
- Sogaard K, Sjøgaard G, Finsen L, Olsen HB, Christensen H. Motor unit activity during stereotyped finger tasks and computer mouse work. *J Electromyogr Kinesiol*. 2001; 11(3):197–206. [PubMed: 11335150]

- Sommerich C, Joines S, Hermans V, Moon S. Use of surface electromyography to estimate neck muscle activity. *J Electromyogr Kinet.* 2000; 10:377–98.
- Stephenson JL, Christou EA, Maluf KS. Discharge rate modulation of trapezius motor units differs for voluntary muscle contractions and instructed rest. *Exp Brain Res.* 2011; 208(2):203–15. [PubMed: 21063691]
- Straker L, Skoss R, Burnett A, Burgess-Limerick B. Effect of visual display height on modeled upper and lower cervical gravitational moment, muscle capacity and relative strain. *Ergonomics.* 2009; 52(2):204–21. [PubMed: 19296320]
- Szeto G, Straker L, O'Sullivan P. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work-2: neck and shoulder kinematics. *Man Ther.* 2005; 10:281–91. [PubMed: 15996890]
- U.S. Department of Health & Human Services. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. National Institute for Occupational Safety and Health; Cincinnati, OH: 1997. Publication No. 97-178628
- Wasmund WL, Westerholm EC, Watenpugh DE, Wasmund SL, Smith ML. Interactive effects of mental and physical stress on cardiovascular control. *J Appl Physiol.* 2002; 92:1828–34. [PubMed: 11960930]
- Westgaard RH, Bonato P, Westad C. Respiratory and stress-induced activation of low-threshold motor units in the human trapezius muscle. *Exp Brain Res.* 2006; 175(4):689–701. [PubMed: 16871416]

Biographies

Bahar Shahidi received a B.S. degree in biochemistry from University of California, Berkeley (2005) and a Doctor of Physical Therapy degree (DPT) in 2009 from University of Colorado Denver. She is currently working on her PhD thesis at the University of Colorado Denver working in the Applied Neuromuscular Physiology Lab in the department of Physical Medicine and Rehabilitation. Her research focus is on neurophysiologic and clinical risk factors for development of chronic musculoskeletal disorders.

Ashley Haight received a BS degree in Psychology (2012) from the University of Colorado Denver. She is currently a Professional Research Assistant for the Rehabilitation Science Program at the University of Colorado Anschutz Medical Campus. She assists with research

regarding neurophysiologic mechanisms and management of stress-related musculoskeletal pain.

Katrina Maluf received an MS degree in Physical Therapy (1999) and a PhD degree in Movement Science (2002) from Washington University in St. Louis, followed by a post-doctoral fellowship in neuromuscular physiology (2005) at the University of Colorado Boulder. She is currently an Associate Professor of Physical Therapy and founding Director of the Rehabilitation Science PhD Program at the University of Colorado Anschutz Medical Campus. Her research combines neurophysiologic and clinical techniques to investigate the mechanisms and management of stress-related musculoskeletal pain.

Fig. 1. Schematic of cervical posture assessments obtained in the baseline, low stress, and high stress conditions using digital photography. Cervical angle was quantified as the angle measured from the horizontal to a line drawn between reflective markers located at the tragus of the ear and the spinous process of the seventh cervical vertebrae (C7). The horizontal was referenced 90° to a vertical plumb line.

Fig. 2.

Electromyographic (EMG) activity recorded from four cervical muscles in the low stress (left panel) and high stress (right panel) conditions in a representative participant. Raw EMG is plotted as a percentage of the total duration of the Operation Span task in each condition. Shaded windows indicate the 5 s region of EMG data corresponding to the time at which cervical posture assessments were obtained with digital photography. Abbreviations: dominant upper trapezius (DUT); non-dominant upper trapezius (NDUT); dominant cervical extensors (DCE); non-dominant cervical extensors (NDCE); dominant sternocleidomastoid (DSCM); non-dominant sternocleidomastoid (NDSCM).

Fig. 3. Changes in physiologic arousal (Rate Pressure Product, RPP) and perceived anxiety (Spielberger State Anxiety Index, STAI-State) during mental concentration performed with (High Stress) and without (Low Stress) exposure to an acute psychosocial stressor compared to the resting seated posture (Baseline). Values are mean (SE), * $p < 0.05$.

Fig. 4.

Changes in cervical angle during mental concentration performed with (High Stress) and without (Low Stress) exposure to an acute psychosocial stressor compared to the resting seated posture (Baseline). Smaller cervical angles correspond to an increase in forward head posture during low and high stress conditions compared to baseline, with no significant change in neck posture between the two stress conditions. Values are mean (SE), $*p < 0.001$.

Fig. 5.

Changes in electromyographic (EMG) activity of the dominant (left column) and non-dominant (right column) upper trapezius (UT, panel a), cervical extensor (CE, panel b), and sternocleidomastoid (SCM, panel c) muscles during mental concentration performed with (High Stress) and without (Low Stress) exposure to an acute psychosocial stressor. EMG signals from each muscle were normalized to values obtained in the resting seated posture at baseline, as indicated by dashed horizontal lines. Values are mean (SE), * $p < 0.05$.

Table 1

Participant characteristics.

	Experimental group (<i>n</i> = 60)	Control group (<i>n</i> = 19)	<i>P</i> value
Age (mean (SD))	29.8 (7.7)	28.4 (4.6)	0.36
Sex (M:F)	15:45	7:12	0.16
Body mass index (kg/m ²)	23.5 (3.9)	24.1 (3.4)	0.56
Computer use (h/week)	35.6 (4.7)	32.6 (6.9)	0.09
STAI-trait (points)	31.7 (8.6)	29.6 (6.6)	0.27