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

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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.

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 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

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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.

Table 1
Participant characteristics.

	Experimental group ($n = 60$)	Control group ($n = 19$)	P 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

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.