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Risk of neck musculoskeletal disorders among males and females in lifting exertions

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ABSTRACT

Work-related neck disorders are common among various occupational groups. Despite clear epidemiological evidence for the association of these disorders with forceful arm exertions, the effect of such exertions on the biomechanical behavior of the neck muscles is currently not well understood. In this study, the effect of lifting tasks on the biomechanical loading of neck muscles was investigated for males and females. Twenty-six participants (13 males and 13 females) performed bi-manual isometric lifting tasks at knuckle, elbow, shoulder, and overhead heights by exerting 25%, 50%, and 75% of their maximum strength. The activity of the cervical trapezius and sternocleidomastoid muscles was recorded bilaterally using surface electromyography. Higher activity of the cervical trapezius muscle (10% MVC–43% MVC) compared to the sternocleidomastoid muscle (4% MVC–18% MVC) was observed. Females tend to use the sternocleidomastoid muscle to a greater extent than males, whereas, higher cervical trapezius muscle activation was observed for males than females. The main effect of weight and height, and weight by height interaction on the activity of neck muscles was statistically significant (all $p < 0.001$). The results of this study demonstrate that the neck muscles play an active role during lifting activities and may influence development of musculoskeletal disorders due to resulting physiological changes.

Relevance to industry: Lifting and forceful arm exertions are common at workplaces. The effect of lifting tasks on the biomechanical loading of neck muscles was evaluated in this study. Understanding this effect would improve our pathophysiological understanding of neck WMSDs caused by physically demanding exertions. This will further facilitate development of workplace intervention to modify workplace methods and/or designs so that incidences of neck WMSDs caused by lifting and forceful arm exertions could be minimized.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) are the nontraumatic soft tissue disorders that are caused and/or exacerbated by workplace exertions. One-third or more of registered occupational diseases in the United States, Canada, the Nordic countries, and Japan are caused by WMSDs (Punnett and Wegman, 2004). These disorders require more days away from work than any other group of occupational diseases (National Research Council, 2001). In 2010, WMSDs in the United States accounted for 29% of the injuries and illnesses requiring a median of 10 days away from work, a percentage that has not changed a lot since 2005 (BLS, 2011). The annual cost of WMSDs as measured by compensation costs, lost wages, and lost productivity, are between \$45 and \$54 billion annually (Dunning et al., 2010). Regardless of the actual dollar cost, the impact of WMSDs is enormous in terms of individual health and corporate economics.

WMSDs of the neck and/or cervical spine result in longer sick leaves, constitute a substantial level of human suffering, and contribute significantly to morbidity among various working populations (Hales and Bernard, 1996). In a recent report by the Task Force of Bone and Joint Decade, a wide range of neck pain prevalence across different occupations and populations was reported, from 4.8% for Mexican males in shoe-making factories to 50.8% in California drivers. Among the general population, annual prevalence of neck pain ranged between 27.1% in Norway to 33.7% in the U.K. to 48% in Quebec, Canada (Côté et al., 2008). Epidemiological studies identify various work-related physical exertions as the possible risk factors for the development of neck WMSDs. Walker-Bone and Cooper (2005) presented a review of epidemiological studies on soft tissue musculoskeletal disorders of the neck and upper extremity among a wide range of occupations. The studies

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listed in the Embase and Medline databases performed during 1998–2001 were included in this review. An association between neck pain and prolonged abnormal posture, forceful and/or repetitive arm exertions, was reported by the authors. Malchaire et al. (2001) reviewed 57 cross-sectional and seven longitudinal studies concerning neck and upper limb musculoskeletal disorders. A majority of the studies reported a clear association between physical workload or force, awkward posture, and repetitiveness and musculoskeletal disorders of the neck and shoulder. Based on a review of 22 cross-sectional studies, two prospective cohort studies, and one case-referent study, Ariens et al. (2000) found evidence for a positive relationship between neck pain and work-related exertions that demand awkward head, trunk, and arm postures, arm force, and prolonged sitting.

A few experimental studies have further investigated the effects of the aforementioned risk factors on the biomechanical loading of the neck and shoulder musculature. A majority of these studies focused on awkward head–neck postures typically used during computer work, sewing machine operation, and dental work. Flexed head–neck postures adopted during such work activities were linked with increased muscular load and fatigue of the neck extensor muscles (Åkesson et al., 2011; Jensen et al., 1993; Turville et al., 1998; Villanueva et al., 1997). Repetitive arm movements and static neck posture used in assembly tasks and cash register use were found to generate neuromuscular fatigue and discomfort in the neck and shoulder musculature (Bosch et al., 2007). However, no studies have examined the effect of forceful arm exertions on the behavior of the neck musculature. While forceful arm exertions and/or heavy lifting have been traditionally associated with lower back disorders, existing studies mostly focus on the effect of such exertions on the lumbar spine. However, epidemiological literature clearly indicates that neck or cervical spine disorders or disc-specific pathologies such as disc herniation, cervical syndrome, and cervical myelopathy (Hagberg and Wegman, 1987; Larsson et al., 2007) are common among workers in industries that demand forceful arm exertions or heavy lifting. These include construction (Silverstein et al., 2002), healthcare (Lipscomb et al., 2004; Trinkoff et al., 2003), agriculture (Aublet-Cuvelier et al., 2006; Rosecrance et al., 2006), transportation and warehousing (Silverstein et al., 2002), and manufacturing (Chee and Rampal, 2004). These pathological conditions mostly involve impingement of nerves and the spinal cord passing through the cervical spine, and are associated with pain and discomfort in many cervical tissues including neck muscles, intervertebral discs, posterior longitudinal ligament, and facet joints (Bland, 1994; Cailliet, 1981; Jeffreys, 1993).

In addition to the above-stated physical work-related factors, gender has been listed as one of the most predominant non-modifiable risk factors of WMSDs of the neck (Hogg-Johnson et al., 2008). A higher prevalence of work-related neck pain was reported among females than males (Côté et al., 2008; Fejer et al., 2006; Widanarko et al., 2011). Different physical features (e.g., anthropometry, strength, flexibility, pain tolerance, endurance, etc.) affect the work methods used by females in order to balance work demands with work ability, which may increase the risk of WMSDs for females more than males (Dahlberg et al., 2004). A few previous studies have shown that during repetitive and/or submaximal motions, females use different upper extremity kinematics and encounter higher joint motion stressfulness than males (Kee, 2005; O'Sullivan and Gallwey, 2002). More strenuous forward tilted postures were also reported for female computer users than males (Straker et al., 2011). However, currently, there is a lack of data that translate how the physical differences and the altered work methods used by females affect their biomechanical response of neck and shoulder muscles to the physically demanding workloads.

As noted, the effect of forceful arm exertions on the biomechanical response of neck muscles and the role played by the gender in this response is currently not well understood. Therefore, the aims of this study were twofold. First, quantify the biomechanical loading of neck muscles during isometric lifting tasks performed at various working heights and weight conditions. Second, assess how the gender difference further influences the response of neck muscles to these isometric lifting exertions. It was hypothesized that conditions of the lifting task (e.g., weight, height) will significantly affect the biomechanical loading of neck muscles and that the relationship between the external work-related exertions and the internal loading of neck muscles will be inconsistent between the males and females.

2. Methods

2.1. Participants

Twenty-six healthy participants (13 males and 13 females) were recruited for data collection. The average age, weight, and height of the participants were 22.7 $\pm$ 2.2 years, 75.2 $\pm$ 16.7 kg, and 170.9 $\pm$ 9.8 cm, respectively. The following inclusion and exclusion criteria were used in this study: (1) participants are free from any type of musculoskeletal disorders; (2) they had no history of neck injury or notable neck pain. The Physical Activity Readiness Questionnaire (PAR-Q, Canadian Society for Exercise Physiology) was used to screen participants for cardiac and other health problems (e.g., dizziness, chest pain, heart trouble). Participants who met the inclusion criteria were asked to read and sign a consent form approved by the local Institutional Review Board.

2.2. Apparatus/Tools

2.2.1. Electromyography (EMG) system

Activity of the neck muscles was recorded using a Bagnoli-16 desktop EMG system (Delsys Inc., Boston, USA). The surface electrodes used were parallel bar, active surface electrodes (DE-2.3 EMG Sensors, Delsys Inc., Boston, USA). The sensor contacts are made from 99.9% pure silver bars, measuring 10 mm in length, 1 mm in diameter and spaced 10 mm apart. The common-mode rejection ratio (CMRR) for the electrodes is 92 dB and input impedance is greater than 10^{15} Ω. The frequency of EMG data acquisition was set to 1000 Hz.

2.2.2. Isometric strength measurement device

This device was used to measure maximum lifting strengths at different lifting heights. It consists of a column and base assembly (Fig. 1). A horizontal lever arm is mounted on the column. This lever arm moves up and down along the column and can be fixed at any position. A force measurement device consisting of a load cell–handle assembly is mounted on the horizontal lever arm (Fig. 1(a)). The output of the load cell was recorded using a force monitor (ST-1, Prototype Design and Fabrication Company, Ann Arbor, MI, USA). This device was also used to standardize location of load with respect to the participants during the isometric lifting tasks by replacing the load cell–handle assembly with a small wooden board to carry a box (Fig. 1(b)).

2.3. Experimental design

A 4 $\times$ 3 full factorial experimental design was used. Factor 1, lifting height, was treated at four fixed levels: (1) Knuckle height; (2) Elbow height; (3) Shoulder height; and (4) Overhead height. Factor 2, lifting weight, was treated at three fixed levels: (1) 25%; (2)