Understanding the Physical Risk Factors Affecting Cervical Musculoskeletal Disorders

Ashish D. Nimbarte[1], Fereydoun Aghazadeh[2], Yun Sun[1]
[1]Industrial and Management Systems Engineering, West Virginia University, PO Box 6070, Morgantown, WV 26506-6107
[2]Department of Construction Management and Industrial Engineering, Louisiana State University, Baton Rouge, LA 70803

In spite of strong epidemiological evidence associating neck or cervical spine disorders with forceful arm exertions common at workplaces, effect of such exertions as causative of neck musculoskeletal disorders (MSD) is currently not well understood. In this study the effect of isometric lifting tasks at elbow, shoulder and overhead heights on the activities of two major neck muscles, sternocleidomastoid (anterior neck muscle) and upper trapezius (posterior neck muscle), was evaluated by using electromyography (EMG). Thirty healthy participants performed isometric lifting tasks exerting 25%, 50% and 75% of their respective maximum strengths at neutral and extended neck postures. Activities of sternocleidomastoid and upper trapezius increased with the increase in the lifting weights and heights. Extended neck posture caused a higher load on the neck musculature than the neutral posture. In conclusion, this study demonstrates a positive load-response relationship between forceful arm exertions and activation of the neck muscles.

INTRODUCTION

Work-related musculoskeletal disorders are among the most costly health problems in society today. The direct cost associated with lost workdays in United States due to such complaints ranged from $13 to $20 billion annually (National Research Council and Institute of Medicine, 2001). Regardless of the actual dollar cost, the impact of work-related musculoskeletal disorders (MSD) is enormous in terms of health and economics. The MSD of the neck 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 & Bernard, 1996).

Epidemiological literature clearly indicate that neck or cervical spine disorders are common among various occupational groups such as construction (Silverstein, Viikari-Juntura, & Kalat, 2002), healthcare (Lipscomb, Trinkoff, Brady, & Geiger-Brown, 2004; Trinkoff, Brady, & Nielsen, 2003), agriculture (Aublet-Cuvelier, Aptel, & Weber, 2006; Rosecrance, Rodgers, & Merlino, 2006),transportation and warehousing (Silverstein, et al., 2002),and manufacturing (Chee & Rampal, 2004). Routine work activities of the workers in these occupational groups demand forceful arm exertions or heavy lifting tasks. Anatomically, the neck muscles, primarily sternocleidomastoid and upper trapezius, are the major muscles, which run parallel to the cervical spine couple the shoulder to the skull. Such an anatomical orientation of these muscles likely requires them to support the shoulder during lifting activities.

However, no previous studies have evaluated the effect forceful arm exertions on the behavior of the neck muscles. In this study effect of such exertions on the behavior of neck muscles was evaluated electromyography (EMG) during simulated bimanual isometric lifting tasks.

METHODS

Participants

Thirty healthy participants (15 males and 15 females) with no history of musculoskeletal abnormalities participated in this study. The participants were graduate or undergraduate students at Louisiana State University and their age, weight, and height were 23.2(3.0), 163.8(35.5) lb, and 170.3(10.5) cm, respectively. The Physical Activity Readiness Questionnaire (PAR-Q, British Columbia Ministry of Health) was used to screen participants for cardiac and other health problems (e.g., dizziness, chest pain, and heart trouble). Participants who answered yes to any of the questions on the PAR-Q were excluded. Prior to the data collection, the experimental procedures and the demands of the testing were explained to the participants, and their signatures were obtained on the informed consent forms approved by the local Institutional Review Board.

Experimental Design

Each participant performed simulated bimanual isometric lifting and holding task at elbow, shoulder, and overhead heights. The joint configuration during each lifting and holding tasks are shown in Figure 1. In addition to neutral neck posture, often workers tend to perform forceful exertions at extended neck postures because of necessary visual focus points (e.g. carrying objects up- or down- stairs, working on inclined surfaces, etc.). Therefore, the lifting tasks were carried out at neutral and extended neck postures. At each neck posture the participants exerted 25%, 50% and 75% of their respective maximum static strength. Thus, each participant performed a total of 18 trials (3 heights × 3 weights × 2 neck postures). A full factorial experimental design was adopted and the trial order was randomized.

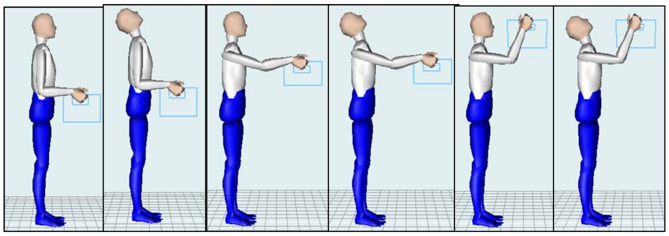

Figure 1: Joint configurations during the bimanual isometric lifting tasks.

Equipment

Eight channel wireless EMG system (Delsys Inc.,Boston, USA) was used for EMG data acquisition. 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 10mm in length, 1mm in diameter and spaced 10mm apart. The CMRR for the electrodes is 92 dB and input impedance greater than $10^{15}\Omega$.

Maximum static strength during various isometric lifting exertions at various heights was determined using isometric strength testing equipment (Prototype Design and Fabrication Company, Ann Arbor, MI, USA). Bimanual lifting tasks were simulated by the participants by lifting and holding boxes of two different dimensions. The two boxes used were 30 cm wide (30 cm × 30 cm × 20 cm) and 42 cm wide (25 cm × 42 cm × 20 cm). To avoid excessive axial rotation of the upper arm, participants with a shoulder width of less than 35 cm simulated the lifting tasks using the 30 cm wide box, while the participants with a shoulder width more than 35 cm used the 42 cm wide box. The weight of the box was adjusted to a predetermined weight, using metal pieces of various masses.

Data Collection and Analysis

1. Participant orientation and measurement. Each participant was introduced to the equipment, data collection procedures, and specifics of the experimental tasks. The demographic, as well as anthropometric, measurements were then recorded. The anthropometric measurements were used for determining the placement of the EMG electrodes.

2. EMG data collection preparation. The skin over the anatomical landmarks was shaved (if needed), abraded and cleaned with 70% alcohol, prior to the placement of the EMG electrodes. The EMG electrodes were then placed on the sternocleidomastoid and upper trapezius muscles in the cervical region using the locations described by Nimbarte, Aghazadeh, Ikuma, & Harvey (2010).

3. Determination of maximum voluntary contraction (MVC) for neck muscles and maximum strength during isometric lifting tasks. Neck Muscles' activation at MVC was determined during isometric head exertions in flexion, extension, and lateral bending postures. The participants then performed the maximal isometric lifting tasks at elbow, shoulder, and overhead heights. The duration of each maximal isometric exertion was approximately 3-5 seconds followed by a rest period of two minutes (Sommerich, Joines, Hermans, & Moon, 2000).The participants were instructed to apply force slowly and steadily without a jerking motion, until maximum exertion is reached. Three trials were carried out for each exertion. In case of a variability>10% among trials, a fourth trial was performed and the average of the three closest values was used for data evaluation (Aghazadeh, Waly, & Nason, 1997).

4. Simulation of the experimental tasks. During this step, the participants performed bimanual isometric lifting and holding tasks at different heights, exerting 25%, 50% and 75% of their respective maximum isometric lifting strengths in neutral and extended neck postures. The duration of each exertion was 5 seconds.

5. EMG data processing. The raw EMG signal from each electrode location was first demeaned and then fullwave rectified. The full wave rectified EMG signal was low pass filtered at 4 Hz, using a fourth-order dual pass Butterworth digital filter, to form a linear envelope (Burnett, Green, Netto, & Rodrigues, 2007).The resulting data was averaged to determine the mean absolute values (MAV) (Sommerich, et al., 2000). The MAV data was then normalized with respect to the peak activation determined during isometric head exertions using the following equation to obtain the Normalized MAV (N-MAV):

$$N-MAV_{\text{m, s, w, h, p}} = \frac{MAV(m,s,w,h,p)}{Max[EMG(m,i,p)]} \qquad (1)$$

Where,
m = neck muscle; sternocleidomastoid, upper trapezius.
s = side; left and right
w = lifted weight; 25%, 50%, and 75% of maximum isometric strength
h = lifting height; knuckle, elbow, shoulder, and overhead
p = participant; 1 to 30
i=peak activation (95th percentile of the amplitude probability function) determined during isometric head exertions; flexion, extension, lateral bending

6. Statistical analysis. A repeated measures analysis of the variance (ANOVA) model was used for statistical analysis. Within subject variables were the lifting heights, weights, and neck postures. N-MAV values of sternocleidomastoid and upper trapezius muscles were treated as the dependent variables. A post hoc trend analysis was performed, using Tukey's HSD (Honestly Significant Differences) test when necessary. The significance level was set at 5%.

RESULTS

No difference was found in the N-MAV values from right and left sides for both muscles (P<0.05), therefore, the right and left side data was averaged for statistical analysis.

1. Effect of weight. The activation of the sternocleidomastoid muscle increased significantly with an increase in the weight lifted at all lifting heights and neck postures (F=77.20, P<0.001) (Figure 2). Based on the post hoc analysis, while lifting at the elbow height with the neck extended, muscle activation at 75% weight condition was significantly higher than 25% and 50% weight conditions. At shoulder and overhead heights, muscle activation at 75% weight condition was significantly higher than at 25% and 50% weight conditions for both neck postures. Highest activation was observed at overhead height in extended neck postures.

An increase in the weight significantly increased the activities of the upper trapezius muscle (F=81.15, P<0.001) (Figure 3). Based on the post hoc analysis, at elbow and shoulder heights muscle activation at 75% were higher than at 25%. At overhead height, muscle activation at 50% was higher than at 25%, and at 75% was higher than at 25%. Highest activation was observed at overhead height in neutral neck postures.

2. Effect of neck posture. The activities of the sternocleidomastoid muscle during lifting at elbow, shoulder, and overhead heights, were significantly affected by the change in the neck posture (F=40.07, *P<0.001*). Based on post hoc analysis, at all the heights, independent of the weight lifted, sternocleidomastoid muscle showed higher activation at extended neck posture. No difference was observed in the activities of upper trapezius muscle with respect to change in the neck posture.

3. Effect of lifting height. Statistically, the activities of the sternocleidomastoid muscle increased significantly with the increase in the lifting heights from elbow to shoulder to overhead (F=29.49, P<0.001). Based on post hoc analysis, at

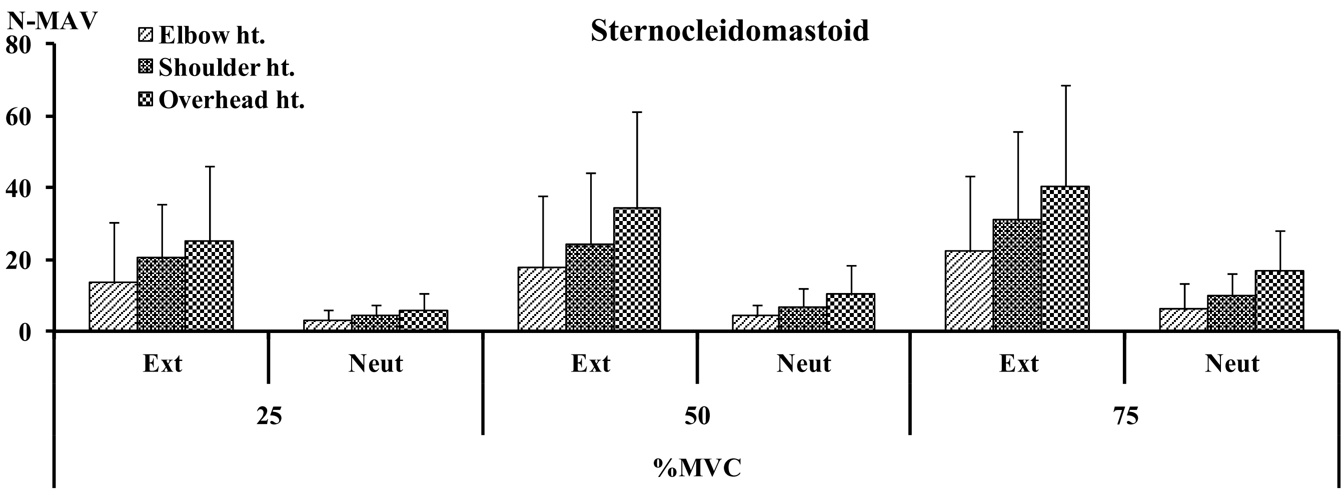

Figure 2: Effect of lifting heights (elbow, shoulder, and overhead) on the activities of the sternocleidomastoid muscle while lifting 25%, 50%, and 75% weights in neutral and extended neck postures.

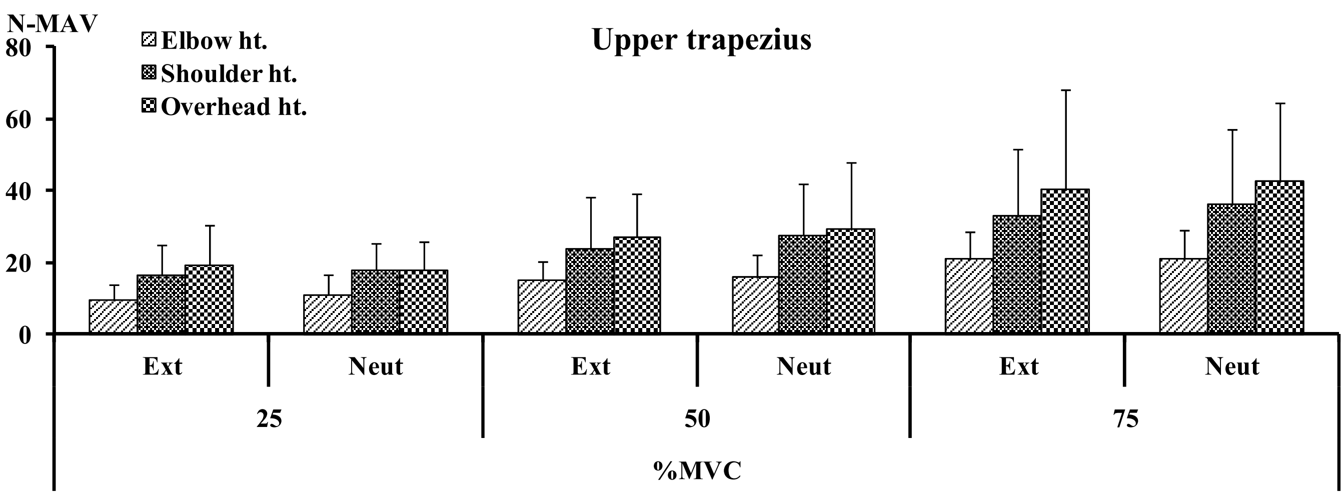

Figure 3: Effect of lifting heights (elbow, shoulder, and overhead) on the activities of the upper trapezius muscle while lifting 25%, 50%, and 75% weights in neutral and extended neck postures.

neutral neck posture muscle activities during 25%, 50%, and 75% weight conditions were higher at overhead height than at elbow height. At extended neck posture, however, muscle activities at overhead height were higher than at shoulder height, and at shoulder height were higher than at elbow height for all weight conditions. An increase in lifting height also increased the activation of the upper trapezius muscle (F=29.64, *P<0.001*). Based on post hoc analysis, at both the neck postures, muscle activities at overhead heights were higher than at shoulder height, and at shoulder height was higher than at elbow height at all weight conditions.

DISCUSSION

The aim of this study was to understand the effect of forceful arm exertions on the behavior of neck or cervical spine musculature. Manual material-handling tasks common at various workplaces i.e. lifting and/or holding of heavy objects at the elbow, shoulder, and overhead heights was studied by evaluating the EMG activities of major anterior and posterior neck muscles at neutral, and extended neck postures.

The behavior of upper trapezius muscle in the shoulder region (along C7) was studied in a few investigations previously. These studies reported increase in the activation of upper trapezius muscle with the increase in the weight lifted at knuckle (Aström, Lindkvist, Burström, Sundelin, & Karlsson, 2009) and shoulder height (Farina, Madeleine, Graven-Nielsen, Merletti, & Arendt-Nielsen, 2002). A higher activation at eye height compared to hip height and above shoulder height was also reported for this muscle location (Anton, Rosecrance, Gerr, Merlino, & Cook, 2005; Öberg, Sandsjö, & Kadefors, 1994). However none of the previous investigation looked at the activation of muscles in the cervical region during forceful arm exertions. The results of this study clearly indicate that the neck muscles in the cervical regions play an active role during forceful arm exertions. These muscles were found sensitive to the various tasks variables such as weight and height of load. Activities of sternocleidomastoid (anterior neck muscle) and upper trapezius (posterior neck muscle) increased with the increase in the weight from 25% to 50% to 75%. Increase in the height from elbow to shoulder to overhead also increased the activities of neck muscles. Interestingly among the two neck postures tested, at extended neck posture, anterior neck muscles worked harder than during neutral neck posture and no changes in the behavior of posterior neck muscles was observed. Many times at workplaces worker adopt a relatively extended neck posture, but results of this study indicate that during extended neck posture total load on the neck musculature is higher than at the neutral neck postures.

Epidemiologically, lifting tasks are associated with the neck disorders. A precise determination of the biomechanical or physiological pathways between forceful arm exertions and neck or cervical spine MSD requires understanding of the load-response relationship. In the National Research Council's conceptual model about the physiological pathways of the MSD (Armstrong et al., 1993), knowledge about load response relationship has been identified as one of the very basic yet crucial components. Such understanding is linked with learning the adaptation strategies of musculoskeletal system and the analysis of impairment and disability pathways. The results of this study demonstrate a positive load-response relationship between forceful arm exertions and activation of the neck muscles.

The common neck MSD associated with forceful arm exertions are mostly cervical spine or disc specific pathologies such as disc herniation, cervical syndrome, and cervical myelopathy (Hagberg & Wegman, 1987; Larsson, Søgaard, & Rosendal, 2007).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 types of cervical tissues including neck muscles, intervertebral discs, posterior longitudinal ligament, and facet joints (Bland, 1994; Cailliet, 1991; Jeffreys, 1993). Excessive compressive forces acting on the cervical spine could be a possible causal factor associated with the cervical spine MSD. If these muscles contract corresponding to forceful arm exertions then, due to their anatomical arrangement i.e. parallel to the cervical spine, these forces are likely to affect the compressive forces acting on the cervical spine causing excessive loading of cervical spine. Thus, forceful arm exertions or heavy lifting tasks could be the physical risk factors associated with disc related neck disorders.

In summary, based on the results of this study, from a work design perspective, it is important that evaluations of forceful arm exertions and heavy lifting tasks should include their effects on the cervical region.

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