Evaluation of the Loading of Neck and Shoulder Musculature in Overhead Pushing and Pulling Exertions

Ashish D. Nimbarte,[1] Fereydoun Aghazadeh,[2] Laura Ikuma,[2] and Yun Sun[1]

1 Industrial and Management Systems Engineering, West Virginia University, Morgantown, WV 26506-6107
2 Department of Construction Management and Industrial Engineering, Louisiana State University, Baton Rouge, LA 70803

Abstract

Despite substantial epidemiological evidence relating overhead exertions with work-related musculoskeletal disorders (WMSD) of the neck, effects of such exertions on the loading of neck or cervical spine musculature are not well understood. In this study, the effects of overhead pushing and pulling exertions on the loading of the cervical spine were evaluated using electromyography (EMG) and subjective discomfort ratings. Additionally, the role of gender as well as individual strength on the loading of neck musculature during such exertions was evaluated. Twenty-four healthy individuals (12 men and 12 women) participated in this study. Each participant performed overhead pushing and pulling exertions, exerting 25%, 50%, and 75% of their respective maximum strengths. Overhead pushing exertions were found to be significantly more strenuous to the neck musculature than were the pulling exertions. Gender had no significant effect on the activities of the neck muscles. Participants with high strength, however, were able to exert more force at comparatively low muscle activation levels. Subjective discomfort ratings were strongly correlated with the EMG data. At various workplaces, avoiding overhead exertions is rather impossible due to material, interface, and site constraints. Based on the results of this study, however, during such exertions, an interchange between directions of force application could prevent sustained loading of the neck muscles, fatigue, and consequently the probability of neck WMSD incidents.

Keywords: Overhead exertions; Musculoskeletal disorders; Neck muscle electromyography; Gender difference; Strength difference

1. INTRODUCTION

Work-related musculoskeletal disorders (WMSD) are a leading cause of work disability and productivity losses in developed nations (Baldwin, 2004). In the United States, the direct cost associated with lost workdays due to WMSD of the neck, upper extremity, and low back range from $13 to $20 billion annually (National Research Council and the Institute of Medicine, 2001). In addition to this direct cost, WMSD of the neck and shoulder place substantial burden on organizations in terms of healthcare cost and human suffering. Epidemiological investigations propose several physical risk factors associated with neck disorders such as 1) awkward and prolonged sustained postures of upper extremities, neck, and head; and 2) repetitive and forceful arm exertions (Ariens, van Mechelen, Bongers, Bouter, & van der Wal, 2000; Malchaire, Cock, & Vergracht, 2001; National Institute for Occupational Safety and Health [NIOSH], 1997; Walker-Bone & Cooper, 2005). Contemporary trends in workplace design based on ergonomics interventions have made

Correspondence to: Ashish D. Nimbarte, Industrial and Management Systems Engineering, PO Box 6070, West Virginia University, Morgantown, WV 26506-6107. Phone: 304-293-9473; e-mail: Ashish.Nimbarte@mail.wvu.edu

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manual material handling tasks increasingly simplified and less strenuous, avoiding most of these physical risk factors. At various work sites, however, it is impossible to avoid tasks that demand awkward hand–arm postures and repetitive and sustained exertions due to material, interface, and site constraints. One such task is working with elevated arms.

The common expressions used to describe the work with elevated arm postures are "overhead work," "over shoulder work," "working with hands overhead," and "working with elbows above mid chest." A working definition of overhead work is any work performed with the hands above the height of the shoulder (Grieve & Dickerson, 2008). Workers in occupations such as construction, automobile manufacturing, mining, agriculture, carpentry, simulated and field welding, maintenance, and repair frequently perform overhead exertions and have been reported to suffer from neck and shoulder pain, discomfort, and limited productivity (Anton et al., 2001; Garg, Hegmann, & Kapellusch, 2006; Grieve & Dickerson, 2008; Haslegrave, Tracy, & Corlett, 1997; Rosecrance, Rodgers, & Merlino, 2006). Additionally, a number of epidemiological studies have predominantly listed overhead exertions as a physical risk factor associated with neck and shoulder musculoskeletal disorders (Hagberg & Wegman, 1987; Sakakibara, Miyao, Kondo, & Yamada, 1995; Svendsen, Bonde, Mathiassen, Stengaard-Pedersen, & Frich, 2004).

Several studies have reported unsafe loading of the upper extremity musculature because of overhead exertions. Electromyography (EMG) has been extensively used in most of these investigations to quantify muscular load or fatigue. A study of construction workers showed that overhead working height was associated with significantly higher upper trapezius muscle activity than below shoulder heights during wall-building tasks (Anton et al., 2001). Simulated overhead automotive assembly tasks were evaluated by Sood, Hager, and Nussbaum (2002) to study the EMG of three shoulder muscles (anterior deltoid, middle deltoid, and trapezius) to estimate shoulder fatigue. Higher working heights were associated with higher EMG readings and ratings of subjective discomfort. In another study evaluating the effect of simulated overhead drilling tasks on the shoulder joint moment and EMG activity of the anterior deltoid, biceps brachii, and triceps brachii muscles, moving the task closer to the worker was found to reduce the muscle activity (Anton et al., 2001). A similar conclusion was drawn by Chopp, Fischer, and Dickerson (2010) upon evaluation of activity of eleven upper extremity muscles during overhead work performed under different work configuration, target angle, and hand force direction. Additionally, a number of authors have studied the effect of elevated arm postures on various shoulder arm muscles and have concurred that the shoulder musculature, especially the upper trapezius muscle, shows higher activities when working with the arms held in elevated postures. In addition, muscle activity increases with the increase in working heights, and leads to a more rapid onset of fatigue (Ebaugh, McClure, & Karduna, 2006; Garg et al., 2006; Herberts & Kadefors, 1976; Järvholm, Palmerud, Karlsson, Herberts, & Kadefors, 1991; Jensen, Finsen, Hansen, & Christensen, 1999; Sporrong, Palmerud, & Herberts, 1996; Sporrong & Styf, 1999; Vasseljen & Westgaard, 1995).

As noted, a number of existing studies have evaluated the effect of overhead exertions on the behavior of the shoulder musculature. Despite epidemiological evidence relating overhead exertions with neck WMSD, the effects of such exertions on the loading of neck musculature is not well understood. Moreover, there is limited research on the effect of direction of overhead exertions (pushing vs. pulling) on the behavior of shoulder and neck musculature and the role played by various other individual factors, such as gender and strength in the load response relationship during such exertions. Therefore, the purpose of this research was to determine the effect of overhead pushing and pulling exertions on the behavior of major neck and shoulder muscles. Additionally, the role of gender as well as individual strength on the loading of neck musculature during such exertions was studied. Objective (surface EMG) as well as subjective (rating of discomfort) measures were used to determine the effect of overhead exertions on neck and shoulder muscle loading.

2. METHODS

2.1. Participants

Twenty-four healthy participants (12 men and 12 women) with no history of musculoskeletal abnormalities participated in this study. The Physical Activity Readiness Questionnaire (Hafen & Hoeger, 1998) was used to screen the participants for cardiac and other health problems (e.g., dizziness, chest pain, heart trouble). Age, weight, and height of the participants were 23.2 (3.0) years, 74.3 (16.1) kg, and 170.3 (10.5) cm, respectively. For male participants, the age, weight, and height were 23.6 (3.7) years, 84.3 (13.5) kg, and 178.7 (6.3) cm, respectively. For female participants, the respective values were 22.8 (2.3) years, 64.3 (11.9) kg, and 162.0 (6.4) cm, respectively. Prior to 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.

2.2. Experimental Task

Each participant performed vertical isometric pushing and pulling tasks at overhead heights with the head in neutral posture. During each exertion, the participant stood in the normal upright standing posture with her/his feet placed parallel and shoulder width apart. The joint configuration during the exertions was such that the shoulder joint was approximately 0° abducted and 80–90° flexed and the elbow joint was 70–80° flexed and 0° supinated (Figure 1).

2.3. Experimental Design

A full factorial experimental design was used. The independent variables were the lifting direction, force exertion level, gender, and strength. The dependent variables were the EMG activity and the subjective discomfort rating. Each participant performed exertions in two different directions: overhead pushing and overhead pulling (2 levels). The levels of force exertion were 25%, 50%, and 75% of the individual's maximum strength (3 levels). Thus, each participant performed 6 (2 × 3) trials, and the trial order was randomized.

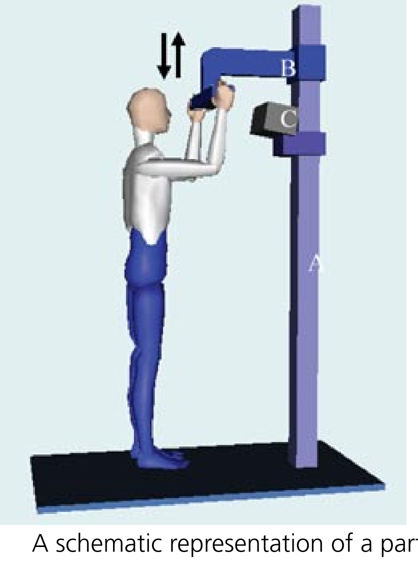

Figure 1 A schematic representation of a participant performing an isometric overhead pushing and pulling task.

2.4. Data Collection and Processing

The data collection session for each participant consisted of the following steps:

- Each participant was introduced to the equipment, data collection procedures, and specifics of the experimental tasks. His or her demographic as well as anthropometric measurements were recorded. The anthropometric measurements were used for determining the placement of the EMG electrodes.
- EMG data were recorded using an eight-channel wireless EMG system (Delsys Inc., Boston, MA). Parallel bar single differential active surface electrodes (DE-2.3 EMG Sensors; Delsys Inc.) were used for EMG signal acquisition. These electrodes have a CMRR of 92 dB and input impedance greater than $10^{15}\Omega$. The sensor contacts are made from 99.9% pure silver bars, measuring 10 mm in length and 1 mm in diameter, and are spaced 10 mm apart.
- EMG was recorded from the 1) sternocleidomastoid, 2) trapezius muscle in the cervical region along the C4 level referred to as the cervical trapezius muscle, and 3) trapezius muscle in the shoulder region along the C7 acromion level referred to as the upper trapezius muscle. The location of EMG electrodes for these muscles is the same as described by Nimbarte, Aghazadeh, Ikuma, and Harvey (2010).
- Subsequent to the placement of EMG electrodes, maximum overhead pushing and pulling strengths, measured in N, were determined using a strength measurement platform (ST-1; Prototype Design Fabrication Company, MI, Ann Arbor). This platform (Figure 1) consists of a horizontal lever arm (B) and a vertical post (A). A load cell was mounted between the horizontal lever arm and the handle. The output of the load cell was displayed/recorded using a force monitor (C) (ST-1; Prototype Design Fabrication Company). The force monitor is capable of recording instantaneous, peak, and average forces. During the maximum

isometric strength measurement step, the force monitor was used to record the peak forces during the exertion period.

- Upon determination of maximum overhead pushing and pulling strength, each participant performed a series of isometric head and arm exertions as described by Nimbarte et al. (2010) to determine the peak EMG activation for the neck and shoulder muscles (denoted by *Max[EMG(m,i,p)]* in Equation 1), which were used for data normalization.
- Participants then performed pushing and pulling experimental trials. Participants pushed or pulled the handle, exerting 25%, 50%, and 75% of the respective maximum isometric strengths. The force exertion during each experimental trial was precisely controlled by providing visual feedback to the participants. The instantaneous force values were displayed to the participants on a force monitor screen located in front of them. Participants exerted the target force for 7 seconds.
- Upon completion of exertion in one direction, each participant rated his or her discomfort in the neck and shoulder region separately on a scale of 0 to 10, where 0 indicated no discomfort at all and 10 indicated extreme discomfort. In addition to reporting subjective discomfort, each participant also answered yes or no to the question of whether he or she felt an increase in the level of discomfort with the increase in the level of force exertion.
- EMG data processing: The raw EMG signal from each electrode location was first demeaned and then full-wave rectified. The full-wave–rectified EMG signal was then 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 were averaged to determine the mean absolute values (MAV) (Acierno, Baratta, & Solomonow, 1995). The MAV data were then normalized with respect to the peak activation using the following equation to obtain the Normalized MAV (NMAV):

$$NMAV_{m,w,p} = \frac{MAV(m,w,p)}{Max[EMG(m,i,p)]} \qquad [1]$$

where
m = neck and shoulder muscle (sternocleidomastoid, cervical trapezius, upper trapezius muscle);
w = lifting weight (25%, 50%, and 75% of maximum isometric strength);
p = participant (1 to 24); and
i = peak activation determined during isometric head exertions (Flexion, extension, overhead pushing).

2.5. Statistical Analysis

Repeated-measures analysis of variance was used for statistical analysis. Independent variables, lifting direction and force exertion level, were treated as within-subject variables, and gender and strength were treated as between-subject variables. Three strength groups (low, medium, and high) were formed based on the strength percentile ranks of the participants in this study. Participants with strength between 0 and the 33rd percentiles were treated as Group 1 (low strength). Participants with strengths between the 33rd and 66th percentiles and between the 66th and 100th percentiles were treated as Groups 2 (medium strength) and 3 (high strength), respectively. There were eight participants in each group. Group 1 was consist of five women and three men, Group 2 was consist of four women and four men, and Group 3 was consist of three women and five men. The significance level was set at 5%.

3. RESULTS

3.1. Strength

Overhead pushing strength of male participants was 232.4 (61.8) N and of female participants was 181.7 (54.0) N, respectively (Figure 2). The corresponding pulling strengths were 287.5 (101.3) N for men and 222.4 (64.9) N for women. Overhead pushing strength of participants, when grouped based on their strengths, were 143.6 (21.1) N, 197.9 (21.9) N, and 279.7 (34.0) N for Groups 1, 2, and 3, respectively (Figure 3). The corresponding pulling strengths were 168.0 (25.8) N, 239.0 (17.7) N, and 358.2 (65.8) N, respectively. The average overhead pulling strength of participants was higher than the pushing strength ($p = 0.0037$), independent of strength and gender. Although the overhead pushing and pulling strengths of male participants were higher than those of the female participants, the data were

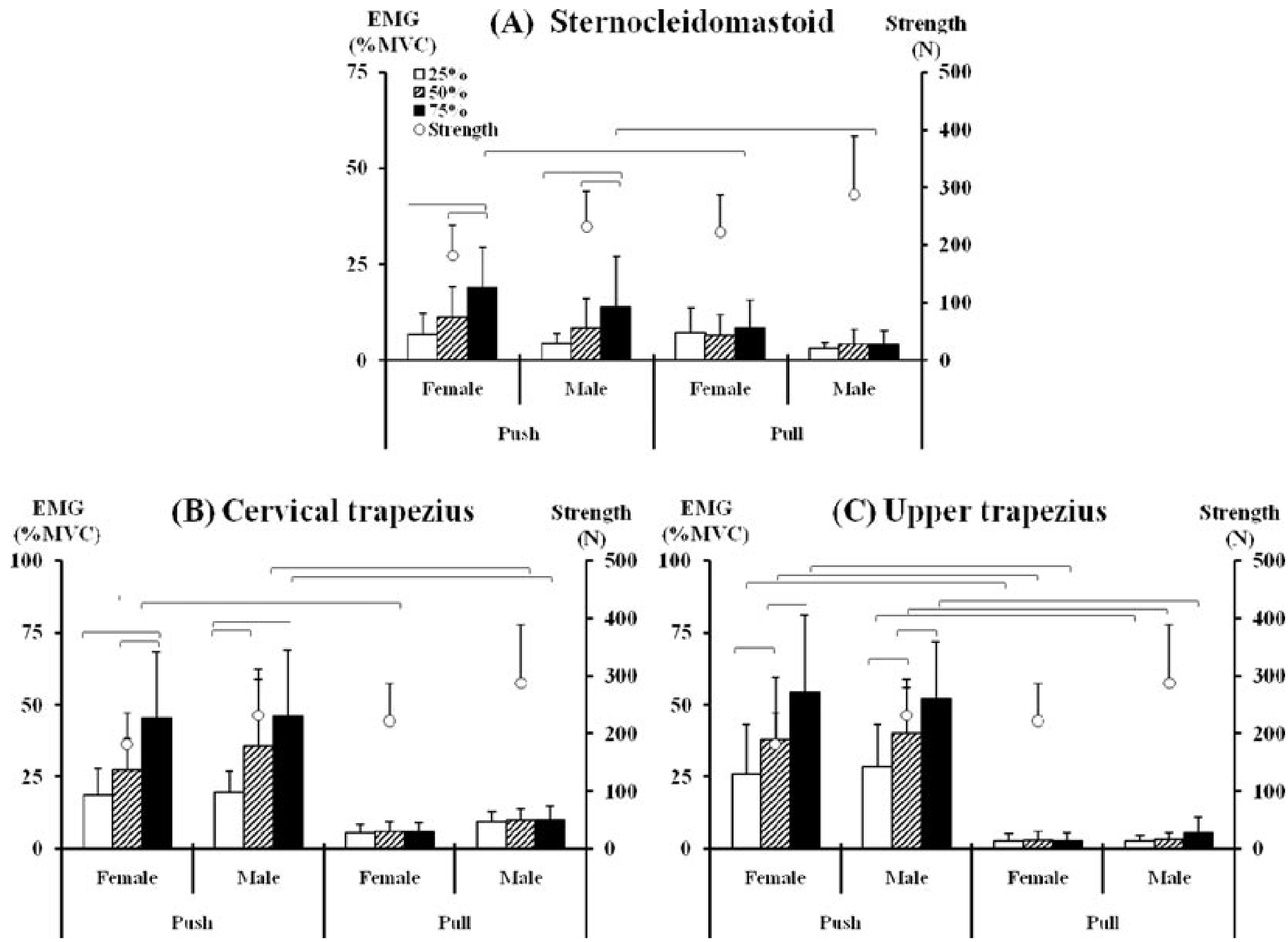

Figure 2 Normalized EMG activities of neck and shoulder muscles: (A) sternocleidomastoid, (B) cervical trapezius, and (C) upper trapezius during overhead pushing and pulling exertions for male and female participants. The primary axes to the left of the charts represent EMG (plotted using bars), and the secondary axes on the right side of the charts represent strength (plotted using circles). Results of post hoc comparisons are shown by the horizontal lines with two ends. Two bars under the ends are significantly different.

statistically significant for pushing strength only ($p = 0.0440$ for pushing; $p = 0.0743$ for pulling). The overhead pushing strength of Group 3 was significantly higher than that of Group 1. The overhead pulling strength of Group 2 was significantly higher than that of Group 1, and that of Group 3 was significantly higher than that of Group 2 ($p < 0.05$).

3.2. EMG

3.2.1. Within-Subject Comparison

Neck muscles showed higher levels of activation during pushing than pulling ($p < 0.001$). Post hoc trend analysis showed that for male and female participants, the data were statistically significant at the 75% exertion level for the sternocleidomastoid muscle (Figure 2). For the cervical trapezius muscle, the data were statistically significant at the 50% and 75% exertion level, and for upper trapezius muscle, significance was observed at all force exertion levels. Based on the strength group comparison, significance was observed for the upper trapezius muscle at the 50% and 75% exertion levels and for the cervical trapezius at 75% exertion level.

The activation of the neck muscles increased with the increase in the level of force exertion from 25% to 50% to 75% during pushing ($p < 0.001$). Post hoc trend analysis showed that, in most cases, the sternocleidomastoid and cervical trapezius muscles at the 75% exertion level were significantly higher than at the 25% and 50% exertion levels, and no difference was found between the 25% and 50% exertion levels.

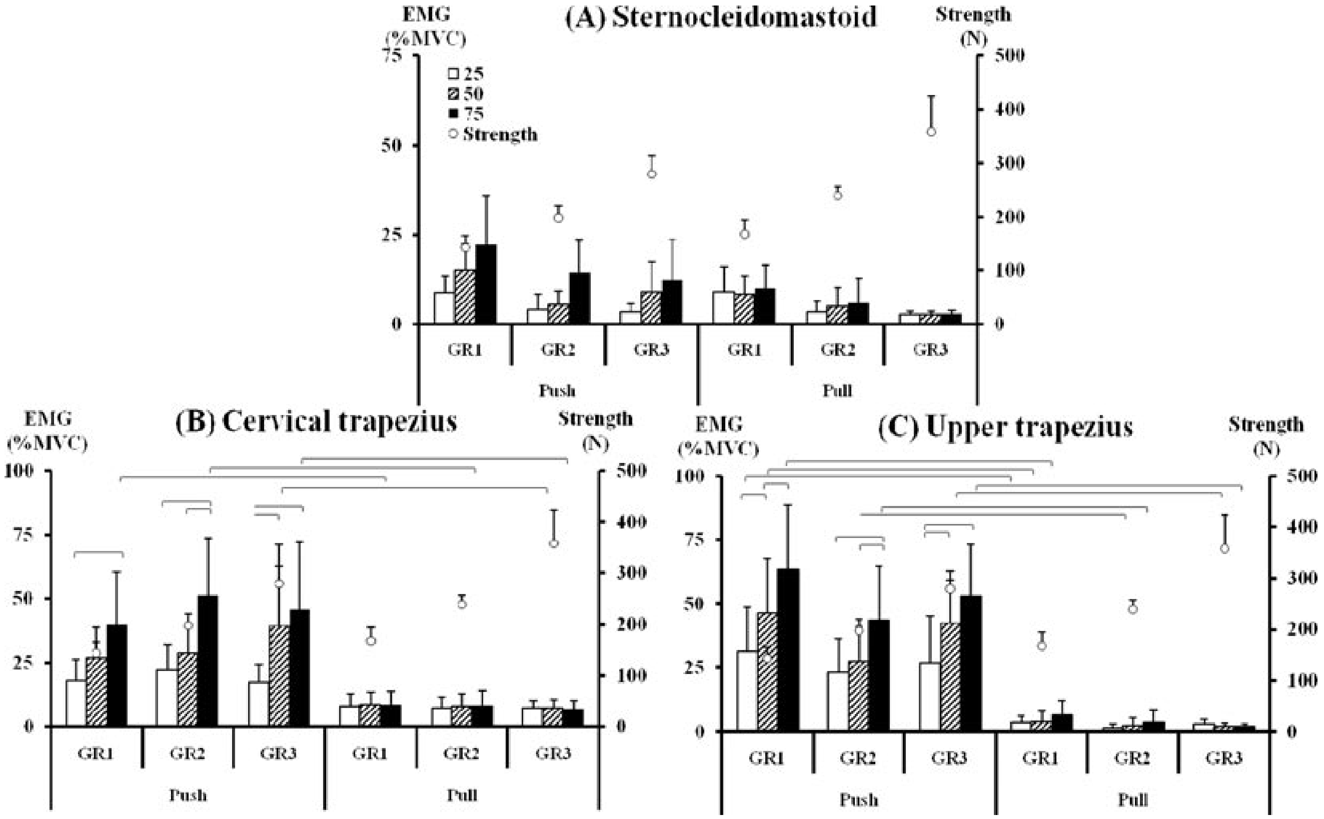

Figure 3 Normalized EMG activities of neck and shoulder muscles: (A) sternocleidomastoid, (B) cervical trapezius, and (C) upper trapezius during overhead pushing and pulling exertions for different strength groups. The primary axes to the left of charts represent EMG (plotted using bars), and the secondary axes on the right side of the charts represent strength (plotted using circles). Results of post hoc comparisons are shown by the horizontal lines with two ends. Two bars under the ends are significantly different.

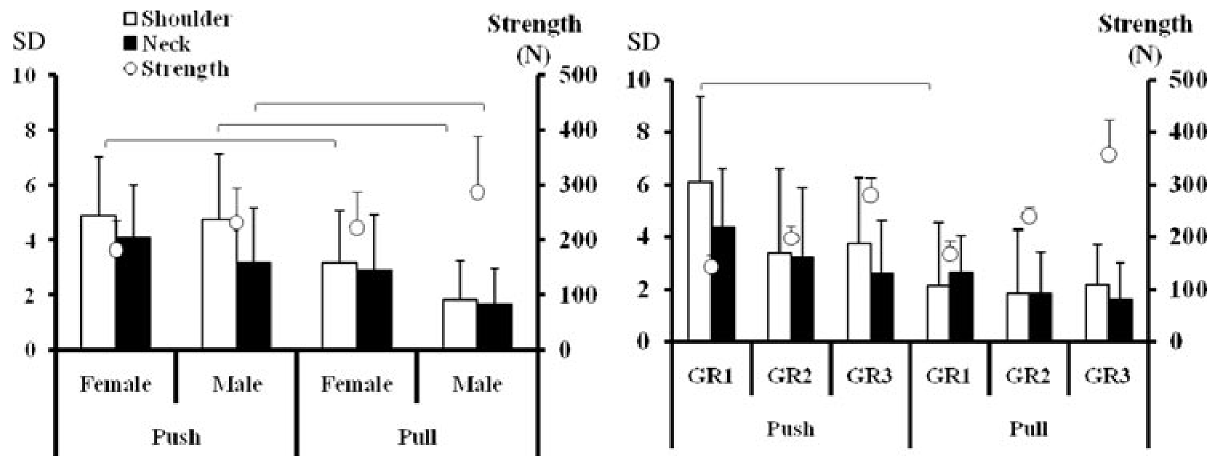

Figure 4 Subjective discomfort (SD) during overhead pushing pulling exertions by (A) gender and (B) strength groups. Secondary axes on the right side of the charts represent strength, which was plotted using dotted lines. Horizontal lines with two ends represent results of post hoc comparisons. Two bars under the ends are significantly different. SD.

For the upper trapezius muscle, in most cases, muscle activation at the 50% exertion level was higher than at the 25% exertion level, and the 75% exertion level was higher than the 50% exertion level. During pulling exertions, in general, activation of the neck muscles increased with the increase in the level of force exertion, but this trend was not consistent and was statistically insignificant.

3.2.2. Between-Subject Comparisons

The activities of the neck muscles during overhead pushing and pulling exertions were not significantly affected by the gender of the participant. For the sternocleidomastoid muscle, during pulling and pushing exertions, higher activation was observed for female participants than for male participants (Figure 2A). The data, however, were statistically insignificant. No consistent trends were observed in the muscle activity data for the cervical and upper trapezius muscles with respect to gender during overhead pushing (Figure 2B). For the male participants, higher activation levels were observed for the upper trapezius muscle during overhead pulling (Figure 2C).

The strength of the individual participants did not significantly affect neck muscle activities during overhead pushing and pulling exertions. During pushing exertions, the participants in Group 1 showed the highest activation of the sternocleidomastoid and upper trapezius muscles, followed by Groups 2 and 3 (Figure 3). No consistent trend was observed in muscle activation levels between participants in Groups 2 and 3 (Figure 3) for these two muscles. For the cervical trapezius, no consistent trend was observed in muscle activation data across the groups during pushing or pulling.

3.2.3. Between-Muscle Comparisons

Between-muscle comparisons showed that, during pushing, the upper trapezius muscle worked the hardest, followed by the cervical trapezius and sternocleidomastoid muscles for male as well as female participants. In most of the cases, the activation of upper and cervical trapezius muscles was the same and was significantly higher than that of the sternocleidomastoid muscle (Figures 2 and 3). A similar trend in the muscle activation levels was observed for Groups 2 and 3. For Group 1, in addition to the usual trend, during the 50% and 75% exertion levels, the activation of upper trapezius muscle was found to be significantly higher than that of cervical trapezius muscle. During overhead pulling, for male participants, cervical trapezius muscle worked the hardest, followed by sternocleidomastoid and upper trapezius muscles. For female participants, sternocleidomastoid muscle worked the hardest, followed by cervical and upper trapezius muscles. Among the different strength groups, in general, cervical trapezius muscle worked the hardest, followed by the sternocleidomastoid and upper trapezius muscles.

3.3. Subjective Discomfort Ratings

Subjective discomfort during overhead pushing in the neck and shoulder regions was higher than during pulling ($p < 0.001$). The discomfort in the shoulder region was higher than in the neck region during pushing as well as pulling (Figure 4). In general, when men were compared with women, the average discomfort for women was higher than for men. Similarly, when compared based on strengths, the average discomfort was highest for Group 1 followed by Group 2 and Group 3. Most of the participants reported an increase in discomfort in the neck and shoulder areas with an increase in the level of force exertion during pushing (Table 1). Comparatively fewer participants felt increased discomfort in the neck and shoulder areas during pulling exertions. A similar trend of more participants reporting an increase in discomfort during pushing than pulling was observed when compared based on strength. In general, participants reported an increase in discomfort with an increase in the level of force exertion in Group 1 followed by Group 2 and Group 3 (Table 1).

4. DISCUSSION

In this study, overhead pushing and pulling exertions were studied to evaluate their effect on the loading of the following major neck and shoulder muscles: 1) sternocleidomastoid, 2) cervical trapezius, and 3) upper trapezius. The first two muscles are the major neck muscles with the primary action of head movements, and the third is the major shoulder muscle with the primary action of scapular movement. Typical overhead exertion requires upward or external rotation of scapula (McClure, Michener, Sennett, & Karduna, 2001); therefore, active contribution from the upper trapezius muscle was expected. The results of this study

TABLE 1. Subjective Discomfort Scores (out of 10) and the Percentage of the Participants Reporting an Increase in Discomfort with an Increase in Force Exertion from 25% to 50% to 75%

	Subjective discomfort				Percent of participants reporting increase in the discomfort with increase in level of force exertion			
	Push		Pull		Push		Pull	
	Shoulder	Neck	Shoulder	Neck	Shoulder	Neck	Shoulder	Neck
Male	4.75 (2.37)	3.16 (1.99)	1.83 (1.40)	1.66 (1.30)	80	90	50	20
Female	4.91 (2.10)	4.08 (1.92)	3.16 (1.89)	2.91 (2.02)	92	100	50	58
Group 1	6.12 (2.16)	4.37 (2.66)	3.25 (2.37)	2.25 (1.38)	100	88	50	62.5
Group 2	3.37 (1.84)	3.25 (1.83)	3.25 (2.43)	2.62 (1.59)	88	100	75	50
Group 3	3.75 (2.18)	2.62 (1.59)	2.5 (1.51)	2 (1.41)	75	100	25	12.5

show that, during overhead pushing, the activation of the upper trapezius muscle increased with the force exertion level, confirming its active role in overhead exertion. Identical findings for the activation level of the upper trapezius muscle during overhead exertions were reported in a number of investigations (Anton et al., 2001; Chopp et al., 2010; Garg et al., 2006; Sood, Nussbaum, & Hager, 2007).

The sternocleidomastoid and upper trapezius muscles are oriented such that their one end is attached to the skull and other end is attached to skeletal structures in the shoulder region. The sternocleidomastoid muscle is attached to the clavicle, and the cervical trapezius muscle is attached to the acromion process in the shoulder region. During overhead exertions, both of these skeletal structures elevate and retract (Ludewig, Behrens, Meyer, Spoden, & Wilson, 2004; McClure et al., 2001), activating the sternocleidomastoid and upper trapezius muscles. The results of this study show that both of these muscles actively contract during overhead pushing tasks, and the contraction level showed consistent increases with the increase in force exertion level. Westgaard (1999), based on a review of physical risk factors associated with neck/shoulder pain, stated that muscle activation at or above 8–10% of MVC is associated with musculoskeletal pain. The activation level for the sternocleidomastoid muscle was observed to be above 10% of MVC and for the upper trapezius muscle was approximately 30% of MVC during the 50% overhead pushing exertion. These values are substantially higher for heavy exertions (75%) and could increase three- to fourfold during exertions performed in flexed and extended neck postures (Nimbarte et al., 2010). Overhead exertions performed in various occupational settings (construction, automobile manufacturing, etc.) demand exertions that could be well above 50% of maximum strength of most workers (Wiker, Chaffin, & Langolf, 1989) and are performed in rather extreme neck postures. Thus, the results of this study indicate that overhead exertions cause unsafe loading of the neck muscles in addition to the shoulder muscles.

The change in the direction of force application from pushing to pulling allowed the participants to exert more force at a considerably lower activation of the neck and shoulder muscles. During pulling, muscle activation levels were relatively stable, corresponding to the increase in the level of force exertion. The upper trapezius muscle was most sensitive to the change in the direction of force application, followed by the cervical trapezius and sternocleidomastoid. On average, muscle activation was 10 to 14 times lower during overhead pulling compared to overhead pushing for the upper trapezius muscle. For the cervical trapezius and sternocleidomastoid, activations were 3 to 5 times and 1.5 to 2.5 times lower during overhead pulling than overhead pushing, respectively. Although muscle activation levels were found to be lower during pulling, the participants were actually able to exert on average of 25% more force during pulling than pushing.

Gender comparison showed that female participants exerted comparatively lower forces than male, but showed higher or almost equal muscle activation levels. The overall strength of the female participants was lower than the strength of the male participants. A further analysis based on the strengths of the participants showed that, independent of gender, a group of participants with low strength showed high muscle activation for relatively low force exertion levels. During pushing, for the sternocleidomastoid and upper trapezius muscles, participants exerted an average of 2 to 3.5 times less force than the medium- and high-strength groups, and yet their muscle activities were almost 2 times higher. During overhead pulling, a similar trend was observed for the sternocleidomastoid and upper trapezius muscles. Medium- and high-strength participants were able to pull 2 to 3.5 times more with muscle activities almost 2 to 2.5 less than the low-strength group. Low EMG amplitude for participants with high strengths has been previously reported by a few researchers (Komi, Viitasalo, Rauramaa, & Vihko, 1978; Mooney et al., 1997). Among several factors that govern the strength of individuals, the number of muscle fibers and motor unit firing rate correspond with EMG readings (Kumar, 2004). Low EMG readings among the high-strength participants could be mainly due to the low firing rate of fewer muscle fibers. In other words, high strength participants were able to use their muscles more economically than their lower strength counterparts. Komi et al. (1978) have also reported similar improved muscle economy based on EMG data among higher strength participants.

The overall trend in the subjective discomfort ratings corresponded well with the physiological EMG readings. Similar to the trend in the EMG data, higher subjective discomfort scores were observed during pushing than during pulling. Female participants reported higher discomfort than male participants, and lower strength groups reported higher discomfort than medium or higher strength groups. Also, the majority of participants reported relatively higher discomfort in the shoulder region than in the neck region. In addition to the fact that the upper trapezius muscle in the shoulder region showed higher muscle activation, its bigger size may have caused a stronger perception of discomfort in the shoulder region than in the neck region. In agreement with our findings, a strong association between the EMG and subjective discomfort ratings was also reported by Kimura, Sato, Ochi, Hosoya, and Sadoyama (2007) during 30% MVC exertions. Sundelin and Hagberg (1992) also reported a significant relationship between subjective discomfort ratings and EMG of the trapezius muscle during repetitive manual work.

From a job design perspective, a few interventions could be suggested based on the findings of this study. In workplaces, avoiding overhead exertions is rather impossible due to material, site, and equipment constraints (Garg et al., 2006). The results of this study show that overhead pushing exertions were significantly more strenuous for the neck and shoulder musculature than were pulling exertions. Motion of the sternoclavicular joint during pulling is opposite to that during pushing, requiring muscles in the trunk or mid-back region to contract during such exertions. Thus, changing the direction of force application between pushing and pulling would allow different muscle groups to load at different instances. Such interchange between directions of force application will prevent sustained loading of one muscle group and help the worker to avoid fatigue and musculoskeletal injuries. Furthermore, the results showed that participants with higher strength were able to use their neck and shoulder muscles more economically during overhead exertions. Therefore, strength training of workers whose daily work demands overhead exertions could be beneficial in preventing early fatigue and consequently chances of developing a WMSD.

There are a few limitations of this study that need to be acknowledged. The postures evaluated in this study do not closely resemble the postures commonly used by workers. At workplaces, overhead exertions many times are performed in relatively awkward postures (non-neutral neck postures, complex hand–shoulder orientation, etc.). College students with little experience in performing overhead exertions participated in this study. Simulation of awkward overhead postures using such a participant group was extremely difficult in the laboratory setting due to inconsistent style and posture adaptation. Furthermore, for standardization purposes, each participant exerted 25%, 50%, and 75% of their maximum strength and exerted forces using an easy-to-grip handle. At actual workplaces, workers lift objects, tools, and equipment of different weights and sizes, and many times the coupling between the hand and tool is not excellent. Standardization of posture and weight, however, allowed us to control a number of confounding variables associated with various individual styles, further allowing us to clearly understand the effect of pushing/pulling overhead exertions on the loading of the neck and shoulder musculature.

5. CONCLUSION

In summary, results of this study indicate that major neck muscles play an active role in overhead pushing exertions. Overhead pushing exertions are significantly more strenuous for the neck and shoulder musculature than pulling exertions. Independent of gender, participants with high strength were able to exert more force at lower muscle activation levels and reported less subjective discomfort.

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