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IMPACT OF PHYSICAL AND PSYCHOSOCIAL DEMAND ON NECK AND SHOULDER MUSCLE FATIGUE

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Abstract: Injuries of neck and shoulder significantly contribute to morbidity among healthcare workers. Working conditions for these occupations typically require exposure to physical and psychosocial demands. In this study, bed-to-stretcher patient transfer tasks were studied under the presence and absence of psychosocially stressful conditions. Surface electromyography data from three neck muscles were collected. This data was further processed and analyzed using the discrete wavelet transform (DWT) to quantify neuromuscular fatigue. The results showed that the power of the fatigue frequency band (12-23 Hz) was significantly affected presence of psychosocial stress; indicating that neck and shoulder muscles were more fatigued during combined physical and psychosocially stressful exertions than during physical exertions alone.

1. INTRODUCTION

In the recent years, although the incidence rate of nonfatal occupational injuries and illnesses requiring days away from work was statistically unchanged from 2009-2010, it has increased among the healthcare workers. In 2010, neck and shoulder injuries among the healthcare workers resulted in higher number of median days (8 days) away from work than low back (7 days) (BLS, 2011).

Work-related neck and shoulder musculoskeletal disorders (MSD) have been believed to have multidimensional etiologies. Among the healthcare workers, the risk factors that are frequently associated with the neck and shoulder musculoskeletal disorders consist of physical and psychosocial demands. Physical activities that are commonly associated with the neck and shoulder MSD among the healthcare workers consist of moving or lifting heavy loads/patients, lifting or lowering patients/objects to/from the floor, and pushing/pulling heavy objects or people (Trinkoff et al., 2003). In addition to these physical demands, healthcare workers are frequently exposed to other work-related factors such as mental demand, administrative hassles, time pressure, lack of social support, conflicting demands, lack of control over job pace, etc (Camerino et al., 2001; Gunnarsdottir et al., 2003; Salminen et al., 2003). These factors, typically known as psychosocial or psychological factors, draw on the mental reserve of the workers and cause cognitive dissonance (Davis et al., 2002; Bloemsaat et al., 2005). An interaction between the factors that cause work-related psychosocial stress, physical demanding exertions and musculoskeletal symptoms of neck and shoulder pain among the healthcare workers has been reported in a number of studies (Andersen et al., 2003; Aasa et al., 2005; Warming et al., 2009).

Neuromuscular fatigue generated by the work-related exertions is a known precursor of the musculoskeletal disorders (Torma-Krajewski, 2008). Risk of work-related MSDs could be accurately assessed by quantitative determination of fatigue caused by the work-related exertions. In order to understand pathophysiology of neck and shoulder MSD among the healthcare workers, effect of healthcare related physical and psychosocially stressful exertions on the development of neuromuscular fatigue was examined in this study. Surface electromyography (SEMG) was used for the objective assessment of neuromuscular fatigue. It was hypothesized that combined physical and psychosocial exertions would generate higher fatigue than physical exertions alone.

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2. METHODS

2.1 Approach

Human participants performed isometric pulling exertions typically performed during bed to stretcher patient transfer under psychosocially stress-full and stress-free conditions. Psychosocial stress was generated using skill-based cognitively demanding tasks. Healthcare workers perform various skill-based tasks in daily work activities, such as remembering patients' medications, recalling physical therapy schedules, and checking vital signs. The musculoskeletal loading of neck and shoulder musculature was evaluated using SEMG.

2.2 Participants

Fourteen (12 males and 2 females) participants were recruited for this study. 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). Before the data collection, the experimental procedures and possible risks associated with the study were explained to the participants and their signatures were obtained on the consent form approved by local Institutional Review Board.

2.3 Equipment

2.3.1 Telemyo 2400 EMG System

This is a 16 channel telemetry EMG system consisting of Telemyo 2400T transmitter, pre-amplified lead wires, and disposable, self-adhesive Ag/AgCl snap electrodes (Noraxon, 2011). The bipolar Ag/AgCl pre-gelled surface electrodes (1 cm diameter, inter-electrode distance is 2 cm) connect to Telemyo 2400T transmitter via pre-amplified lead wires. The pre amplifier on the lead wires have a band-pass of 10-1000 Hz (gain 500), CMRR >100 dB, input impedance >100 MΩ. The frequency of EMG data acquisition was set at 1500 Hz.

2.3.2 Custom-Built Isometric Pulling Strength Testing Device

To simulate a bed-to-stretcher patient transfer task, a custom-built isometric pulling strength testing device was used. This device consists of a 6-inch wide slotted steel plate, chain, series 5 advanced digital force gauge (Mark-10 Corporation, NY, USA), and a pair of sheets (Figure 1). A chain attaches the force gauge with the steel plate such that the force gauge can move up and down along the plate and can be locked at any position. The force gauge was attached to the pair of cloth sheets using a double-handle attachment. Cloth sheets were used during the force exertion to make the simulated patient transfer task more realistic.

2.4 Data Collection Procedure

The data collection procedures for each participant consisted of the following two steps: (1) subject preparation and (2) SEMG data collection. Each participant was introduced to the equipment, data collection procedures, and specifics of the experimental tasks. The three muscles considered for this study were the right sternocleidomastoid, cervical trapezius, and upper trapezius muscles.

Each subject participated in two experimental sessions. In session 1 (Physical exertion only), participant performed ten maximal isometric pulling exertions simulating a bed-to-stretcher patient transfer task. During pulling task, the height of the force gauge and double handle attachment was adjusted to 66 cm above the ground level to make it consistent with the average height of beds used in the hospitals (Tzeng and Yin, 2006). During the force exertion, participant stood at a distance of 50 cm from the column. A picture of a participant performing pulling task is shown in the Figure 1. Participants

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were instructed to exert force using their maximum strength. Duration of exertion was approximately 3-5 seconds. Participants then rated the perceived workload using the NASA-Task Load Index (TLX) for 10 seconds (NASA-TLX data is not reported in this paper). A rest of 35 to 45 seconds was provided before the next pulling exertion.

Figure 1. Example of Pulling Task

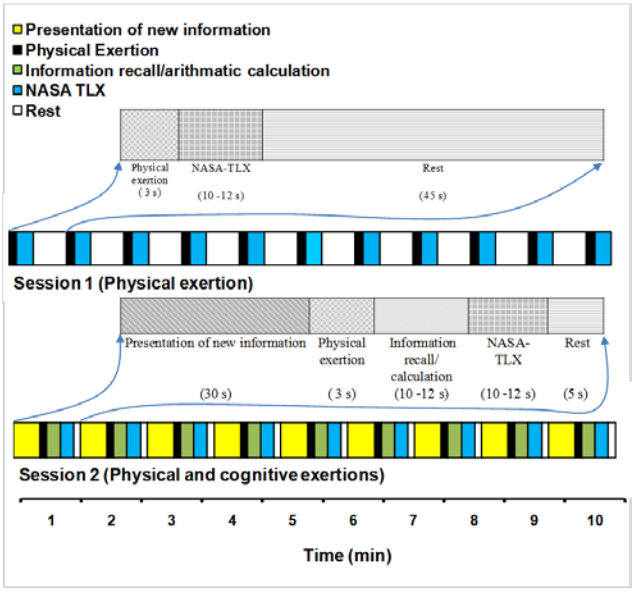

Figure 2. Task Division Time Allotment

In Session 2 (physical and cognitive exertion), in addition to ten isometric pulling exertions (same as Session 1), the participants performed cognitively demanding tasks. Before each pulling exertion, participants were presented with new information comprised of list of symptoms, diseases, and recommended prescription drugs to remember for 30 seconds. Immediately following the pulling exertion, participants were verbally questioned based on the information presented and also performed 3 arithmetic calculations. Participants then rated the perceived workload using the NASA-Task Load Index (TLX) for 10 seconds (NASA-TLX data is not reported in this paper). A rest period of up to 10 to 15 seconds was provided before the beginning of the next cognitive task. Tasks division and the corresponding time allotment during the sessions 1 and 2 are shown in Figure 2. The order of session 1 and 2 were randomized between the participants.

2.5 Data Processing and Analysis

Fast Fourier transform (FFT) based spectral analysis has been widely used in the past to process SEMG signal for the objective assessment of fatigue. However, such analysis is based on the assumption that the SEMG signal is stationary. Under non-stationary or pseudo-stationary conditions, which is likely to be the state of EMG signal recorded during a mix of activities, discrete wavelet transform (DWT) of EMG signal has been recommended as a more appropriate method for the fatigue assessment (Hostens et al., 2004). In this study fatigue generated by mix of physical and psychosocially stressful exertions was studied by using DWT of surface EMG signal. Biorthogonal wavelet function with 3.1 scales (bior3.1) was used to compute DWT. Power of lower frequency band (0-30 Hz) was previously noted as the a reliable index to muscle fatigue (Kumar et al., 2003). In this study power of the 12-23 Hz frequency band was used to access neuromuscular fatigue. SEMG signal recorded during the 1st and 10th isometric pulling exertions of sessions 1 and 2 were used for the power computation.

2.6 Statistical Analysis

A two-way mixed analysis of variance (ANOVA) was used to test the effect of type of exertion and duration of exertion on the fatigue of neck and shoulder muscles. Type of exertion was treated as the fixed effect with two levels: (1) physical exertion (session 1); (2) physical and psychosocially stressful exertion (session 2). Duration was also treated as the fixed

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factor with two levels: (1) first exertion at the start of the session (T =1); (2) last exertion at the end of session (T=10). Participants were treated as a random factor. A result was called significant if P<0.05 according to F-test (95% level of confidence).

4. RESULTS

Power in the 12-23 Hz frequency band was significantly affected by the type of exertions. For all three muscles examined in this study, a significantly higher power during session 2 (combined physical and psychosocial exertions) was observed than session 1 (physical exertions alone) as noted in Table 1. Effect of duration of exertion was statistically significant for the upper trapezius and the cervical trapezius muscles. Increase in the power with the increase in the duration was found to be dependent on the type of exertions (Figure 3).Interaction between the type of exertion and duration of exertion was also statistically significant for the upper trapezius and the cervical trapezius muscles. A significantly higher power was observed during session 2, with the increase in the duration than session 1. Power stayed at almost the same level with the increase in the duration during session 1.

Table 1. Main Effect of Type of Exertion and Duration of Exertion on the Power (mV^2) of SEMG Signals in 12-23 Hz Frequency Band
(Numbers in the parenthesis represent one standard deviation)

Muscle	Type of Exertion (a)			Duration of Exertion(b)			a× b
	Physical	Physical and Cognitive	P-Value	T = 1	T = 10	P-Value	P-Value
Upper trapezius	25.38(28.97)	74.88 (61.24)	<.0001	41.86(47.71)	58.39(58.66)	0.0174	0.0211
Sternocleidomastoid	0.19(0.17)	0.94(1.84)	0.0002	0.57(1.46)	0.55(1.26)	0.7735	0.8952
Cervical trapezius	0.69 (0.53)	2.08(3.17)	0.0007	0.93(0.73)	1.83(3.22)	0.1294	0.0432

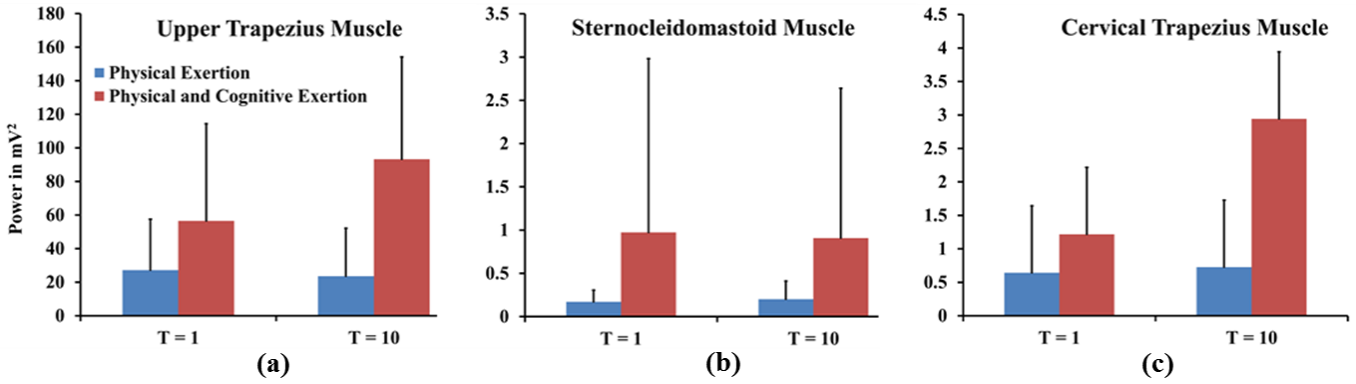

Figure 3. The Graphical Representation of Power (mV^2) in Frequency Band of 12-23 Hz as a Factor of Type of Exertion and Duration of Exertion for the Following Muscles: (a) Right Upper Trapezius, (b) Sternocleidomastoid, and (c) Cervical Trapezius

5. DISCUSSION AND CONCLUSION

In this study, effect of typical healthcare related physical and psychosocially stressful exertions on the neuromuscular fatigue of neck and shoulder muscles was studied using DWT. Results of the study showed that power of fatigue frequency band was significantly higher during the combined physical and psychosocially stressful exertions than the physical exertion alone. Increase in the power of the fatigue frequency band with the development of fatigue has been previously observed in a number of studies (Dolan et al., 1995; Kumar, Pah et al., 2003). The power data observed in this study also correspond very well with the muscle activation pattern. A consistently higher power for upper trapezius muscle than the

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cervical trapezius and sternocleidomastoid muscles was observed. During the pulling exertion used in this study, it is likely that the participants used their upper trapezius muscle more than the cervical trapezius and sternocleidomastoid muscles. This is because upper trapezius muscle is a major shoulder muscle and it plays an active role in the force generation during pulling exertion.

A significant interaction between type of exertion and duration of exertion was observed for the upper and cervical trapezius muscles. When physical and psychosocially stressful tasks were performed simultaneously neck and shoulder muscles show signs of faster fatigue development. In this study a very short duration of experimental sessions (10 minutes) were used, yet, significant increase in the power towards the end of the experimental session was observed. In the real world healthcare setting, workers work long shifts (8-12 hours). These workers are likely to be engaged in various psychosocially stressful activities, prior or subsequent to the physically demanding exertions. Even though forces are not exerted by the muscles during psychosocially stressful activities, results of this study suggest that such exertions performed prior or subsequent to the forceful exertions significantly affect muscle fatigue development process. Therefore, it is essential that in addition to the actual physical work, overall psychosocial stress in the work-environment should be considered in estimating rest periods during long work-shifts. Appropriate administration of rest periods may avoid early development of neuromuscular fatigue and subsequently reduce incidences of work-related MSDs.

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