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Neck Muscle Reflex Responses Post Fatigue of Cervical Spine

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1. Background

Neck pain is the second most common musculoskeletal disorders (MSDs) after back pain (Kazeminasab et al., 2022). It is estimated that 65% of people suffer neck pain at some point of their lives. Incidence of neck pain per 100,000 population was 806.6 in 2017 (Safiri et al., 2020), and it requires 11 days away from work for recovery (BLS, 2021). In 2019, age-standardized prevalence rate for neck pain was reported to be 27.0 per 1000 people (Kazeminasab et al., 2022). Physical work demands, such as sustained awkward postures, repetitive motion, and forceful exertions are consistently identified as potential risk factors for neck MSDs. They induce neck muscle fatigue which may affect the stability of the cervical spine. Spinal stability is achieved by a highly coordinated interaction between active and passive components of the neuromuscular system. The effect of muscle fatigue on the stability of the cervical spine is currently not well understood. The objective of this study was to quantify the post-fatigue changes in the cervical spine's stability. Sudden perturbations (SP) protocol was used to study the variables that influence the cervical spine stability. SP protocol allows quantification of the muscle reflex responses necessary to maintain spinal stability.

2. Methods

2.1 Participants

The average age of the participants was 26.6 years (SD = 4.2), average height 169.3 cm (SD = 9.2), and average weight 63.4 Kg (SD = 10.7). The primary inclusion criteria required participants be free from any type of musculoskeletal, degenerative, or neurological disorders and to have had no history of upper extremities, neck, back, and shoulder injury or notable pain. Prior to data collection, participants were required to sign the consent form.

2.2 Data Collection

The surface electromyography (EMG) was used to measure neck muscle activity at C-4 level using a Bangoli-16 channel desktop EMG system. Head-neck kinematic data was collected using Vicon optical motion system by placing three 14 mm retro-reflective markers on the head (one on the forehead and one on each side of the head). Additionally, a six degree of freedom force-torque sensor, Mini 45 F/T, was used to record the head-neck force profile data. Sudden Perturbation protocol was conducted using a custom-built perturbation workstation. Neck muscle fatigue was generated using the Sorenson protocol (Lee et al., 2005) where participants lay prone on a table with hands on sides and head is exposed to gravitational forces. A pendulum of 0.5 Kg was attached to head to accelerate the fatiguing process.

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2.3 Experimental procedure

After collecting demographic data and placing the EMG sensors on the neck at C-4 level, participants were stabilized in a custom-built perturbation workstation to be exposed to the sudden perturbation protocol. A dropping load of 1kg was used to generate the head sudden perturbation using an electromagnet system. A headband was mounted on the participant head which was attached to a wire going through a pulley to the Mini 45 F/T sensor which then was connected to a 1Kg dropping load ((Simoneau et al., 2008). Participants were instructed to relax and maintain their head still in a neutral position. To avoid any visual and audio feedback, participants were asked to close their eyes before, during and after perturbation and listen to music using headphones. When participants were observed relaxed, the electromagnet was deactivated to release the load resulting in sudden forward perturbation of the head. Next, the Sorenson protocol was used to induce neck muscle fatigue. The protocol was stopped when the participants could not hold the lay down position or when they got to a score of 8 on CR-10 Borg Scale, whichever came first. After that, participants repeated the SP protocol. The protocol was repeated three times.

2.4 Data analysis

The raw EMG data was demeaned, full-wave rectified, and low pass filtered at 4 Hz to form a linear envelope. Force profile was generated using the Mini 45 F/T sensor software. Head-nick kinematic data was reconstructed, labeled, gap filled, and low-pass filtered. The response of the head-neck system to sudden perturbation was assessed by evaluating changes in the stiffness of the cervical spine and muscle reflex temporal parameters including Time to Peak (EMG activity) and Peak to Peak Time (time between the EMG and Force profiles' peaks) (Sánchez-Zuriaga et al., 2010). Stiffness is the rigidity of an object (e.g., spine) necessary to maintain and control its stability. Cervical spine stiffness was calculated by relating head kinematics to head kinetics (Hendershot et al., 2011). ANOVA repeated measures (Pre – Post fatigue) was used to analyze the data. Post-hoc using Tucky's HSD procedure was conducted following the ANOVA results to compare the dependent variables across the independent variables.

3. Results

The results showed that muscle fatigue significantly delayed the neck muscle reflex response. The effective stiffness was significantly reduced from 1404.6 ± 122.3 Kg/sec^2 to 1086.5 ± 123.7 Kg/sec^2 ($p < .001$). The temporal parameters were also affected by muscle fatigue. Post-fatigue, Time to Peak and Peak to Peak values significantly increased from 231.1 ± 39.6 to 325.5 ± 50.0 msec and 89.4 ± 36.4 to 178.2 ± 49.3 msec, respectively ($p < .001$).

4. Discussion and Implication

The sudden perturbation protocol utilized in this study provides an ideal setting to evaluate post-fatigue changes in the neuromuscular control strategies of the cervical spine. When exposed to sudden and unexpected perturbations, the neck-head system (cervical spine) is stabilized by a quick (reflex) response by the neck muscles. The magnitude and timing of the muscle reflex response is critical to attain sufficient stability and minimize the risk of spinal injury. In this study, the effect of fatigue on neck muscle reflex responses were assessed. These findings indicate that muscle fatigue affects the stability of cervical spine by delaying the muscle reflex response and decreasing cervical spine stiffness. Muscle fatigue decreased muscular stiffness due to the reduction in the active tissue (muscle) force generation ability. Reduced stiffness and delayed temporal response (Time to Peak and Peak to Peak) observed during the SP protocol further substantiate that the neck muscle fatigue compromises the stability of the cervical spine. Head-neck exertions are common among several occupational groups, such as assembly lines, food processing, agriculture, modern offices, wholesale and retail industry, fishing, healthcare, etc.

Study limitations include induced fatigue by Sorenson protocol does not represent workplace related fatigue, Borg Scale is subjective, convenient sampling was used, and constant load of 1 Kg was used to induce muscle fatigue. This is a small weight and was independent of the participant's strength. It is recommended for future research to use a load as a percentage of the participants' MVC.

5. Conclusions

The results of this study indicate that muscle fatigue affect the stability of cervical spine by delaying the muscle reflex response and decreasing its amplitude. These findings could be used as valuable markers to assess post-fatigue changes in the neuromuscular control of the cervical spine and to derive possible MSD development pathways.

6. References

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