Brief Report

Effect of workstation height and distance on upper extremity muscle activity during repetitive below-the-knee assembly work

Seung-Je SHIN¹ and Won-Gyu YOO²

¹Department of Physical Therapy, The Graduate School, Inje University, Republic of Korea and ²Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University, Republic of Korea

Abstract: Effect of workstation height and distance on upper extremity muscle activity during repetitive below-the-knee assembly work: Seung-Je SHIN, et al. Department of Physical Therapy, The Graduate School, Inje University, Republic of Korea—**Objectives:** To determine the activity of the upper trapezius, serratus anterior, anterior deltoid, biceps brachii, and lower trapezius muscles in healthy adults during below-the-knee assembly work. **Methods:** Fifteen right-handed male subjects participated in this study. The electrical activities, measured by EMG, of the right upper trapezius, serratus anterior, anterior deltoid, biceps brachii, and lower trapezius were measured during below-the-knee assembly work at four workstations of varying height and distance from the participant (workstation 1, below-the-knee assembly work with a height of 15 cm above the floor and a reach distance of 30 cm; workstation 2, height of 15 cm and distance of 45 cm; workstation 3, height of 30 cm and distance of 30 cm; workstation 4, height of 30 cm and distance of 45 cm). Muscle activity at the four workstations was represented as a percentage of the reference voluntary isometric contraction (RVIC). **Results:** Height: Upper and lower trapezius activity increased significantly during below the knee assembly work as height above the floor increased. The activities of the serratus anterior and biceps brachii muscles increased significantly during low-height below-the-knee assembly work. Distance: The activities of the upper trapezius, serratus anterior, anterior deltoid and biceps brachii increased significantly during below-the-knee assembly work at a far distance (45 cm). The lower trapezius muscle activity increased significantly during below-the-knee assembly work at a close distance (30 cm). **Conclusions:** Below-knee workers should engage in work close to themselves, since distance appears to be a stronger risk factor for injury than height above the floor.

(J Occup Health 2015; 57: 193–196)

Received Jul 17, 2014; Accepted Nov 24, 2014

Published online in J-STAGE Jan 10, 2015

Correspondence to: W.-G. Yoo, Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University, 607 Obang-dong, Gimhae, Gyeongsangnam-do, 621-749, Republic of Korea (e-mail: won7y@inje.ac.kr)

Key words: Below the knee assembly work, Electromyography, Shoulder pain

Upper-extremity musculoskeletal diseases are highly prevalent in manual-intensive occupations¹⁾ and are a common concern in the modern workplace^{2, 3)}. Repetitive assembly work is a known risk factor for musculoskeletal diseases and overload injuries⁴⁾.

Stooping and kneeling postures that involve sustained knee and trunk flexion are required to complete below-the-knee assembly work. Multiple studies have reported that these postures are potential risk factors for work-related musculoskeletal disease⁵⁾ and are related to neck and shoulder pain⁶⁾.

Muscle activity indicates that an increase in muscular demand is related to shoulder pain and other musculoskeletal disorders⁷⁾. In addition to muscle activity, the position at which tasks are conducted is also important; variation in the height from which boxes are handled, along with the weight, affected upper limb movements during manual handling of industrial boxes⁸⁾.

However, few studies have evaluated the effects of different below-the-knee assembly work heights and distances. The purpose of this study was to evaluate the physical risk factors (height and distance) associated with upper extremity disorders among below-the-knee assembly workers. The goal of this study was to determine if the height of or distance from the workstation represented the greatest risk of injury and identify below-the-knee work conditions that would minimize upper extremity muscle activity and injury.

Subjects and Methods

Subjects

Fifteen right-handed males with a mean age of 21.5 ± 1.5 years, height of 174.7 ± 7.6 cm, and weight of 67.9 ± 10.3 kg participated in this study. The participants were not accustomed to repetitive below-the-knee assembly work and had no previous history of orthopedic disorders affecting the neck or shoulder

region. or neurological disorders. This study was approved by the Inje University Faculty of Health Sciences Human Ethics Committee. Informed consent was obtained from each participant.

Measurement and data collection

Surface EMG data were collected with a Trigno wireless system (Delsys, Boston, MA, USA). Signals were amplified and band-pass filtered (20–450 Hz) before being digitally recorded at 2,000 samples/s. Then the root mean square (RMS) was calculated. Before attaching electrodes, the skin was prepared by shaving the site and cleaning it with alcohol to reduce skin impedance. Surface electrodes (Trigno sensors, Delsys) were placed at five locations on the following muscles of the right (dominant) side: 1) upper trapezius (2 cm lateral to the midpoint of a line drawn between the C7 spinous process and the posterolateral acromion), 2) serratus anterior (vertically along the midaxillary line at ribs 6–8), 3) anterior deltoid (anterior aspect of the arm, ~4 cm below the clavicle running parallel to the muscle fibers), 4) biceps brachii (two electrodes (2 cm apart) parallel to the muscle fibers at the center of the dorsal muscle mass located with the arm flexed in the supinated position). and 5) lower trapezius (oblique angle, centered at a point 10 cm medial to the inferior angle of the scapula)⁹.

EMG data were normalized using the reference voluntary isometric contraction (RVIC) of all muscles and measurements were obtained by the same examiner. To collect RVIC data, participants were asked to wear a 7-lb sandbag on each forearm. The RVIC was measured for all muscles while seated and while raising the arms in the scaption plane (almost 35° anterior to the frontal plane) until the shoulder was flexed at a 90° angle¹⁰. Participants maintained this posture for 3 seconds, and the mean muscle activity of two trials was recorded as the RVIC. Participants were allowed to rest for 2 minutes between trials to prevent muscle fatigue. All participants performed below-the-knee

assembly work (bolt and nut assembly) for 3 minutes per workstation using the same workstations.

Four below-the-knee assembly workstations with the following heights above the floor and distances from the participants were used: 1) height 15 cm and distance 30 cm, 2) height 15 cm and distance 45 cm, 3) height 30 cm and distance 30 cm. and 4) height 30 cm and distance 45 cm (Fig. 1). The testing order of the workstations was randomized. The electrical activities of the right upper trapezius, serratus anterior, anterior deltoid, biceps brachii. and lower trapezius were measured at each below-the-knee assembly workstation. EMG signals were collected for 3 minutes, and the first and last 10 seconds were discarded. During data collection, participants were barefoot.

Statistical analyses

Data were subjected to two-way repeated-measures analysis of variance (ANOVA). The two factors were height and distance. A Bonferroni correction was performed to identify specific differences between multiple pairwise comparisons. The SPSS software version 20.0 (IBM, Armonk, NY, USA) was used for statistical analyses. A $p < 0.05$ was considered to indicate statistical significance.

Results

Effect of height

Muscle EMG data are presented as percentages of the RVIC. The electrical activities of the upper and lower trapezius were decreased significantly at workstation 1 compared with workstation 3 ($p < 0.05$, Table 1). The lower trapezius activity was also decreased significantly at workstation 2 compared with workstation 4 ($p < 0.05$, Table 1). In contrast, the activities of the serratus anterior and biceps brachii were increased significantly at workstation 2 compared with workstation 4 ($p < 0.05$, Table 1).

Fig. 1. Below-the-knee assembly work at the four workstations.

Table 1. Comparison of normalized EMG data of the five muscles during below-the-knee assembly work at the four workstations

Muscles	Mean $\pm$ SD (%RVIC)				<i>p</i> value		
	WS1	WS2	WS3	WS4	Height	Distance	Height* Distance
Upper trapezius	13.7 $\pm$ 15.8	25.7 $\pm$ 21.5	18.2 $\pm$ 19.3	28.6 $\pm$ 24.4	0.039*	0.000*	0.328
Serratus anterior	25.4 $\pm$ 12.6	47.5 $\pm$ 18.3	25.5 $\pm$ 13.6	40.7 $\pm$ 18.1	0.027*	0.000*	0.042*
Anterior deltoid	22.9 $\pm$ 13.5	52.6 $\pm$ 23.6	25.2 $\pm$ 14.3	47.8 $\pm$ 20.3	0.512	0.000*	0.110
Biceps brachii	19.3 $\pm$ 8.9	23.9 $\pm$ 9.3	20.0 $\pm$ 9.1	21.5 $\pm$ 8.3	0.297	0.015*	0.007*
Lower trapezius	21.0 $\pm$ 21.5	15.1 $\pm$ 15.4	25.2 $\pm$ 22.1	23.3 $\pm$ 20.7	0.007*	0.072	0.209

WS: workstation. * $p < 0.05$.

Effect of distance

The electrical activities of the upper trapezius, serratus anterior, anterior deltoid, and biceps brachii were decreased significantly at workstation 1 compared with workstation 2 ($p < 0.05$, Table 1). In contrast, the lower trapezius activity was increased significantly at workstation 1 compared with workstation 2 ($p < 0.05$, Table 1). The upper trapezius, serratus anterior, and anterior deltoid muscle activities were also decreased significantly at workstation 3 compared with workstation 4 ($p < 0.05$, Table 1).

Effect of height and distance

The activities of the serratus anterior and biceps brachii muscles generally decreased significantly as the height at which the below-the-knee assembly work was performed increased. The electrical activities of the serratus anterior and biceps brachii were increased significantly at workstation 2 compared with workstation 4 ($p < 0.05$, Table 1). The activities of the serratus anterior and biceps brachii muscles generally increased significantly as the distance at which the below-the-knee assembly work was performed increased. The electrical activities of the serratus anterior and biceps brachii were decreased significantly at workstation 1 compared with workstation 2 ($p < 0.05$, Table 1). The electrical activity of the serratus anterior was decreased significantly at workstation 3 compared with workstation 4 ($p < 0.05$, Table 1). A statistically significant interaction existed between the two heights (15 cm and 30 cm) and two distances (30 cm and 45 cm) ($p < 0.05$, Table 1).

Discussion

This study investigated the electrical activity of the upper trapezius, serratus anterior, anterior deltoid, biceps brachii, and lower trapezius muscles in healthy adult participants during below-the-knee assembly work with four different height and distance combinations.

Upper and lower trapezius activity increased significantly during below-the-knee assembly work as

height above the floor increased. The activities of the serratus anterior and biceps brachii muscles increased significantly during low-height below-the-knee assembly work. Multiple EMG studies have investigated the role of upper trapezius, serratus anterior and lower trapezius muscle activity in upper-limb musculoskeletal disease^{11, 12}. As the shoulder flexion angle increases during active arm elevation, the activity of the upper trapezius, lower trapezius, serratus anterior and anterior deltoid muscles increases¹³. Anton *et al.*¹⁴ investigated muscle activity during overhead drilling while using either a high or low stepladder with the work site at close, medium or far reach distances. Anton *et al.*¹⁴ found that the activity of the anterior deltoid and triceps brachii muscles increased on the low stepladder, irrespective of a close or far reach distance; however, the biceps brachii muscle activity was increased on the low stepladder with a far reach distance, but increased on the high stepladder with the close and medium reach distances. The results of the present study support this previous research, as the activities of the upper and lower trapezius increased during below-the-knee assembly work at a height of 30 cm compared with that at a lower height (15 cm). Also, the activities of the serratus anterior and biceps brachii were increased during low-height below-the-knee assembly work compared with work at a greater height.

The activities of the upper trapezius, serratus anterior, anterior deltoid and biceps brachii increased significantly during below-the-knee assembly work at a far distance (45 cm). The lower trapezius muscle activity increased significantly during below-the-knee assembly work at a close distance (30 cm). Anton *et al.*¹⁴ reported that the activities of the biceps brachii and anterior deltoid muscles increased when performing overhead work positioned far from the body, and Haslegrave *et al.*¹⁵ found that working with the arms away from the body increases the potential for shoulder disorders. These results indicate that moving tasks closer to below-the-knee assembly workers would decrease the activity of the upper trapezius,

serratus anterior, anterior deltoid. and biceps brachii muscles.

The activities of the serratus anterior and biceps brachii muscles generally decreased significantly as the height at which the below-the-knee assembly work was performed increased. The activities of the serratus anterior and biceps brachii muscles generally increased significantly as the distance at which the below-the-knee assembly work was performed increased. These results indicate that the increased activity of the serratus anterior and biceps brachii muscles of below-the-knee workers during low-height work may lead to scapular protraction and eccentric contraction. They also show that the activities of the serratus anterior and biceps brachii muscles increased significantly in below-the-knee assembly with far reach distances.

Below-knee assembly work is a risk factor for musculoskeletal disorders. A limitation of this study was the small sample size. In addition, participants were not accustomed to repetitive below-the-knee assembly work, and fatigue was purposefully minimized. Further studies should include female participants and subjects who are accustomed to below-the-knee assembly work.

Conclusion

Workers should engage in below-the-knee work close to their bodies, since distance appears to be a stronger risk factor for injury than height above the floor.

Acknowledgments: This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2012R1A1B4001058).

References

- 1) Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol* 2004; 14: 13–23.
- 2) Bernard B. Musculoskeletal disorders and workplace factors. DHHS(NIOSH) Publication 1997; 97–141. Cincinnati (OH): US Department of Health and Human Services, NIOSH.
- 3) Punnett L, Fine LJ, Keyserling WM, et al. Shoulder disorders and postural stress in automobile assembly work. *Scand J Work Environ Health* 2000; 26: 283–91.
- 4) Szeto GP, Straker LM, O’Sullivan PB. EMG median frequency changes in the neck-shoulder stabilizers of symptomatic office workers when challenged by different physical stressor. *J Electromyogr Kinesiol* 2005; 15: 544–55.
- 5) The Center to Protect Worker’s Rights, The Construction Chart Book, The U.S. Construction Industry and Its Workers, 3rd edition, CPWR, Silver Spring (MD): 2002.
- 6) Holmström EB, Lindell J, Moritz U. Low back and neck/shoulder pain in construction workers: occupational workload and psychosocial risk factors. Part 2: Relationship to neck and shoulder pain. *Spine (Phila Pa 1976)* 1992; 17: 672–7.
- 7) Wiker SF, Chaffin DB, Langolf GD. Shoulder posture and localized muscle fatigue and discomfort. *Ergonomics* 1989; 32: 211–37.
- 8) Oliveira AB, Silva LC, Coury HJ. How do low/high height and weight variation affect upper limb movements during manual material handling of industrial boxes? *Rev Bras Fisioter* 2011; 15: 494–502.
- 9) Cram JR, Kasman GS, Holtz J. Introduction to surface electromyography, 1st ed (1998), Aspen.
- 10) Park SY, Yoo WG. Effect of sustained typing work on changes in scapular position, pressure pain sensitivity and upper trapezius activity. *J Occup Health* 2013; 55: 167–72.
- 11) Holte KA, Westgaard RH. Daytime trapezius muscle activity and shoulder-neck pain of service workers with work stress and low biomechanical exposure. *Am J Ind Med* 2002; 41: 393–405.
- 12) Yoo WG, Yi CH, Kim MH. Effects of a ball-backrest chair on the muscles associated with upper crossed syndrome when working at a VDT. *Work* 2007; 29: 239–44.
- 13) Ebaugh DD, McClure PW, Karduna AR. Three-dimensional scapulothoracic motion during active and passive arm elevation. *Clin Biomech* 2005; 20: 700–9.
- 14) Anton D, Shibley LD, Fethke NB, et al. The effect of overhead drilling position on shoulder moment and electromyography. *Ergonomics* 2001; 44: 489–501.
- 15) Haslegrave CM, Tracy MF, Corlett EN. Force exertion in awkward working postures--strength capability while twisting or working overhead. *Ergonomics* 1997; 40: 1335–62.