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Effects of Wearing the Wrong Glove Size on Shoulder and Forearm Muscle Activities during Simulated Assembly Work

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Abstract: This study was performed to determine the changes in electromyographic activities in the shoulder and forearm muscles when using the bare hands, well-fitting gloves, and gloves that are one size smaller or one size larger for simulated assembly operations. Sixteen asymptomatic seated workers with normal hands and no obvious deformities, skin diseases, or allergies were recruited. The subjects were asked to simulate assembly operations using their bare hands, well-fitting gloves, and one size smaller or one size larger. This study showed that wearing the wrong glove size led to a decrease in forceful activation of the forearm muscle and a compensatory increase in shoulder movement. In contrast, use of the bare hands or wearing well-fitting gloves led to effective forearm muscle activation, which decreased inefficient shoulder movement. These data indicate that wearing the wrong glove size will lead to continuous inefficient use of the forearm and shoulder muscles, and result in overuse of the shoulder.

Key words: Assembly operation, Electromyography, Shoulder and forearm muscles, Well-fitting gloves, Workers

Introduction

The use of gloves is a common practice in many industries, including meat packing, construction, and warehousing. Many employees use gloves for a variety of reasons; in particular, they help protect arms and hands from abrasive conditions and hazardous materials[1]. The use of gloves is beneficial for the hands; however, only limited information is available regarding the effects of gloves on the quality and efficiency of work performed, or as a potential risk associated with cumulative trauma[2].

Cumulative trauma disorders (CTDs) are caused by repetitive tasks, forceful exertions, vibrations, mechanical compression, and sustained or awkward positions[3]. Risk factors for CTDs of the wrist and hands include continual precision or forceful gripping[4]. Repetitive motion places stresses on the nerves and tendons of the hands and arms, and tasks that require excessive muscle force and effort can result in muscle fatigue and inflammation[4–6]. The need for higher operating ratios may increase the time workers spend exposed to the same movement.

The number of tasks associated with work-related CTDs that involve the use of gloves is unknown.

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However, many industrial jobs require some style and/or type of glove. Furthermore, recent reports have suggested that gloves contribute to the high incidence of CTDs[7], and interfere with the wearer's ability to perform fine motor activities and effect object manipulation[1, 8]. Rodger's reported that wearing gloves was a risk factor for CTDs among workers whose jobs required repetitive motions and the exertion of large forces with the hands. Riley *et al*.[1] showed that gloves affect manual dexterity, and generally delay task completion. In addition, different glove conditions affect manual tasks. Shih and Wang[9] evaluated gloves of different thickness and found that subjects wearing thick gloves had more difficulty exerting force. Sawyer and Bennett[10] compared the levels of dexterity provided by latex and nitrile SafeSkin gloves, and found that fine finger dexterity was impeded by nitrile gloves.

Wearing the wrong glove size can affect manual dexterity and contribute to CTDs; good manual dexterity is a key to performing many tasks safely and efficiently[11]. Gloves that are too small can decrease blood flow to the fingertips, cause unpredictable pain and numbness, constrain finger and hand movements[11], and decrease dexterity. In contrast, gloves that are too large cause the worker's hands to slide around inside and impair fine motor performance[11].

Although empirical evidence suggests that wearing the wrong glove size decreases the efficiency of tasks requiring manual dexterity, there have been few formal investigations of this issue. Studies to evaluate the effects of gloves on manual dexterity have only examined the task completion time and number of errors when using the hands and forearms. The associations between tasks involving hand manipulations and hand, forearm, and secondary shoulder pain have not been investigated. Therefore, the present study was performed to assess the effects of wearing the wrong glove size (one size smaller or one size larger) on electromyographic (EMG) activities in the shoulder and forearm muscles when performing simulated model-assembly operations.

Methods

Subjects

Sixteen asymptomatic seated workers with normal hands and no deformities, skin diseases, or latex allergies were recruited. The subjects were selected from 12 laboratories by consecutive sampling. Ethical approval was obtained from the Health Sciences Human Ethics Committee of the Yonsei University Faculty, and the subjects provided written informed consent prior to participation in the study. The characteristics of the subjects are summarized in Table 1.

Instrumentation: Nitrile Exam glove

Nitrile Exam gloves (Invacare® Nitrile Exam gloves; Invacare, Elyria, OH) were used in the study. Nitrile exam gloves are an excellent alternative to latex gloves. The synthetic fiber is tear resistant and allows dexterity (*i.e*., can be used for computer assembly and laboratory work). Nitrile Exam gloves are 9 inch length, nonsterile, powder free, and ambidextrous gloves (S; Small, M; Middle, L; Large, XL; XLarge) (Table 2). These gloves can be easily fitted and provides comport condition over a long period time (Fig. 1).

Hand and glove dimensions

The dominant side of each subject and glove were measured (width of thumb, index, and middle finger at the halfway point on the distal phalange; length of thumb, index, and middle finger) using calipers prior to the simulated assembly task[10]. These dimensions are

Table 1. General characteristics of the subjects (N=16)

Variable	Subjects
Age (yr)	22.4 ± 1.7
Height (cm)	174.4 ± 5.2
Mass (kg)	67.8 ± 9.1
Arm length (cm)	53.0 ± 2.0

Table 2. The measurement size of gloves

Digit and dimension (cm)	Small	Middle	Large	XLarge
Thumb width	2.30	2.50	2.70	2.90
Index finger width	2.10	2.30	2.50	2.70
Middle finger width	2.30	2.50	2.70	2.90
Thumb length	6.00	7.00	8.00	9.00
Index finger length	6.50	7.50	8.50	9.50
Middle finger length	7.00	8.00	9.00	10.00

Fig. 1. Nitrile Exam Glove.

Table 3. The hand dimensions of the subjects (N=16)

Subjects	Finger width (cm)			Finger length (cm)			Well-fitting
	Thumb	Index	Middle	Thumb	Index	Middle	
Subject 1	1.70	1.60	1.60	6.00	6.00	7.70	Middle
Subject 2	2.70	2.00	1.90	6.10	6.00	7.70	Middle
Subject 3	1.80	1.70	1.80	7.50	8.00	8.10	Large
Subject 4	1.90	1.70	1.80	7.50	6.70	8.10	Large
Subject 5	2.20	1.70	1.90	7.50	7.80	8.00	Large
Subject 6	1.50	1.50	1.50	8.00	6.90	8.20	Large
Subject 7	2.20	1.60	1.60	7.20	6.60	7.80	Middle
Subject 8	2.70	1.70	1.70	8.00	7.50	8.00	Large
Subject 9	1.60	1.50	1.50	7.30	6.60	7.90	Middle
Subject 10	2.70	2.00	2.00	6.40	6.40	7.80	Middle
Subject 11	1.70	1.70	1.70	6.40	6.20	7.70	Middle
Subject 12	2.40	1.80	1.80	7.00	7.70	7.80	Middle
Subject 13	2.30	1.60	1.70	6.70	8.00	8.40	Large
Subject 14	1.50	1.50	1.50	6.10	6.00	7.60	Middle
Subject 15	1.70	1.70	1.70	6.10	6.20	7.30	Middle
Subject 16	2.80	2.10	2.10	6.00	6.00	7.20	Middle

summarized in Tables 2, 3.

Simulated assembly work

The effect of improper glove size on muscle activation in the shoulder and forearm should influence the fine motor tasks performed by computer assemblers and laboratory workers[12].

The Valpar Component Work Samples (VCWS) are a widely used work-assessment tool. They have become standard-setting vocational evaluation tools, and have attracted the attention of professionals in a number of health-related disciplines[12].

Valpar Component Work Sample No.204 (VCWS 204; Valpar Inc., Tucson, AZ) simulates sedentary work requiring small objects to be turned with both right and left hands. The exercise involves the use of tweezers to grasp, lift, and hold small items with one hand while performing other operations with the other hand. The work sample is a square box constructed from particle-board. The flat surface has 20 holes, each of which contains a threaded jack pin. A nylon string is attached to a metal plug to the left of the 20 holes when the box is aligned to the front. During the exercise, the subject threaded the nylon wire through the 20 metal pins that were first lifted out of the holes and held in place by reverse-tension tweezers as the wire was threaded. The nylon string was picked up with the left hand, and the tweezers were operated with the right hand (Fig. 2).

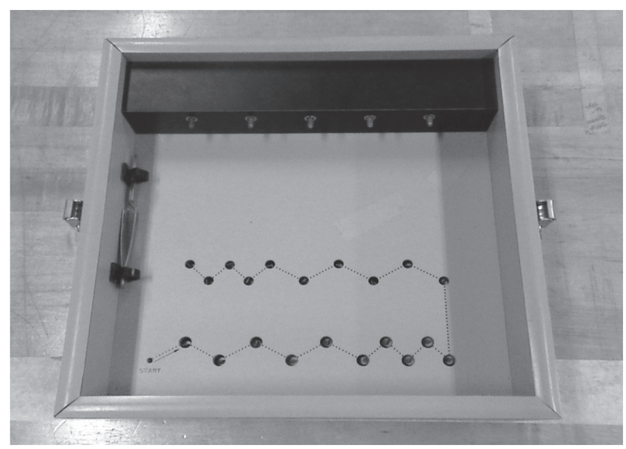

Fig. 2. Valpar Component Work Samples 204.

Surface electromyography recording

Surface EMG data were collected, amplified, digitized and analyzed using an ME6000-biosignal monitor (Mega Electronics Ltd., Kuopio, Finland). The raw EMG signals were analogically band-pass filtered with an anti-aliasing filter (Butterworth, band-pass 20–450 Hz), amplified (CMRR=130 dB; gain=1,000) and sampled at a rate of 1,000 Hz. Disposable Ag/AgCl electrodes (Blue Sensor M-00-S; Medicotest, Ølstykke, Denmark) were used for EMG registration. Surface electrodes to detect muscle activities on the subject's right side were attached to the skin after it had been shaved and cleaned using alcohol. The electrode locations were as follows: (1) upper trapezius—slightly lateral to and halfway between the cervical spine at C-7 and the acromion; (2) serratus anterior—just below the axillary area, at the level of the inferior tip of the scapula and with the electrodes anterior to the latissimus dorsi muscle; (3) flexor digitorum superficialis—approximately 5 cm from the bicep tendon at the elbow; (4) extensor digitorum—placed at the muscle belly, one third of the way between the head of the ulna and the olecranon[13]. The electrodes were attached bilaterally over the belly of the muscle with an interelectrode spacing (center to center) of 3 cm, which was large enough to obtain information about the functioning of a sufficient number of motor units. The reference electrodes were located 6–7 cm lateral to the recording electrodes.

Experimental conditions

The order of the glove conditions under which the subjects performed the trials (*i.e.*, bare hands, well-fitting gloves, one size smaller gloves, one size larger gloves) was randomly assigned for each subject. The simulated work environment was set up at a distance from the trunk corresponding to 70% of the arm length to prevent excessive trunk motion. A 5-min rest period was allowed between multiple repetitions under the different glove conditions to prevent muscle fatigue. In addition, the subjects used a metronome during the task to allow them to perform at a constant frequency over a 30 min period. The task involved picking up 10 jack pins within a period of 120 s, and was based on the average time taken to complete the task during training. The subjects were given verbal instructions to begin and terminate the trial ("start" and "stop," respectively).

Data processing

Normalization of the data was achieved using Megawin 3.0 software, and data are expressed as mean percentages relative to reference voluntary contractions (RVCs) (*i.e.*, %RVC=average root mean square(rms) EMG/RVC × 100). All subjects performed RVCs of the shoulder and forearm muscles; the experimental data were normalized to the submaximal RVCs, thus minimizing the effects of interindividual differences. RVCs were obtained while holding a 1.0-kg dumbbell in each hand, with the arm abducted at 90° in the frontal plane and parallel to the floor. Subjects completed five submaximal exertions 20 s each time with a 5-min rest period between contractions. The mean RMS values were normalized to submaximal RVCs rather than to the maximal voluntary contractions (MVCs) to prevent the negative effect of injury or residual muscle soreness, and because there was no assurance that maximum contraction could be obtained[14)].

Statistical analysis

The SPSS statistical package (SPSS 12.0, Chicago, IL) was used to analyze differences in the shoulder and forearm muscle activities. The Kolmogorov-Smirnov test was performed to test for a normal distribution prior to using parametric statistics. The significance of differences between working with the well-fitting gloves and a one size smaller or one size larger glove was tested by one-way repeated-measures ANOVA; $p<0.05$ was taken to indicate significance. For the significant main effect, Bonferroni's correction was used to identify the specific mean differences.

Results

One-way repeated-measures ANOVA of normalized EMG data obtained during the simulated assembling operations revealed significant differences in the upper trapezius ($p<0.01$), serratus anterior ($p<0.01$), and extensor digitorum ($p<0.01$) muscles between the bare hands, well-fitting gloves, one size smaller and one size larger glove size conditions (Table 4). In multiple comparisons, the activities of the upper trapezius and serratus anterior muscles were significantly higher in the one size smaller and one size larger glove conditions than with the bare hands or well-fitting gloves, but there was no significant difference between the bare hands and well-fitting gloves conditions. The activity of the extensor digitorum muscle was significantly lower in the one size smaller and one size larger glove conditions than in bare hands and well-fitting gloves, but there was no significant difference between the bare hand and well-fitting gloves conditions. In particular, upper trapezius muscle activity was significantly greater in the one size smaller than the one size larger glove condition. However, flexor digitorum superficialis muscle activity did not differ significantly among the bare hand, well-fitting gloves, one size smaller, and one size larger

Table 4. Normalized EMG data of the shoulder and forearm muscles in the three study conditions during simulated assembling operation

Muscle activities (% RVC)	Glove Size Conditions				p
	Bare hand	Just right	One size smaller	One size larger	
UT	69.09 ± 5.64*	70.28 ± 5.75	83.51 ± 7.49	77.91 ± 6.67	0.007
SA	39.09 ± 4.39	40.34 ± 4.85	48.25 ± 5.22	46.36 ± 5.55	0.001
ED	92.28 ± 7.15	93.71 ± 7.10	78.82 ± 5.48	76.97 ± 4.33	0.005
FDS	87.62 ± 21.05	84.32 ± 16.63	84.27 ± 15.62	79.29 ± 16.16	0.639

*mean ± SD.

UT: Upper trapezius, SA: Serratus anterior, ED: Extensor digitorum, FDS: Flexor digitorum superficialis.

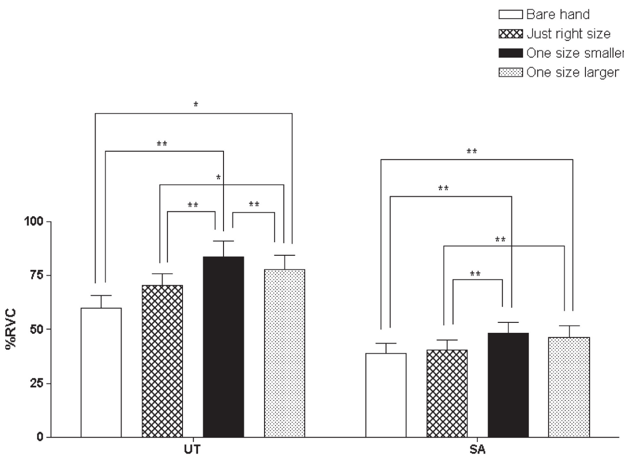

Fig. 3. Shoulder muscle activation in the four glove conditions (Mean ± SD).
UT: Upper trapezius, SA: Serratus anterior.
*p<0.05 (Bonferroni-corrected), **p<0.01.

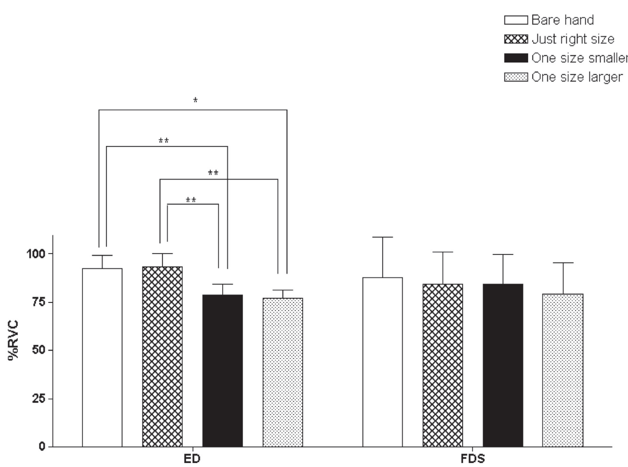

Fig. 4. Forearm muscle activation in the four glove conditions (Mean ± SD).
ED: Extensor digitorum, FDS: Flexor digitorum superficialis.
*p<0.05 (Bonferroni-corrected), **p<0.01.

glove conditions (Figs. 3 and 4).

Discussion

It has been shown that the use of gloves that are one size smaller restricts hand and finger movements and causes pain, while the use of gloves that are one size larger feels sloppy and interferes with the ability to manipulate materials quickly and efficiently[11, 15–17]. Our study revealed statistically significant differences in shoulder and forearm muscle activation when participants performed simulated assembly work wearing the wrong glove size compared with well-fitting gloves. The upper trapezius, serratus anterior, and extensor digitorum muscles of the shoulder and forearm muscles showed significantly altered activities in subjects wearing the wrong glove size; there was increased activation of the trapezius and serratus anterior and decreased activation of the extensor digitorum in comparison to subjects wearing gloves of the well-fitting gloves.

The upper trapezius and serratus anterior muscles are used in combination to produce shoulder flexion and abduction. There was a significant increase in the EMG activities of these muscles under one size smaller and one size larger glove conditions in comparison to the use of bare hands and the well-fitting gloves. The increases in EMG activity were due to a greater number of shoulder and scapular movements[18, 19]. Cumulatively increased shoulder and scapular movements may result in fatigue of the upper trapezius and serratus anterior muscle. These results were consistent with those of previous studies. Bernard[20] and Punnett, Fine, Keyserling, Herrin and Chaffin[21] reported that assembly workers (secondary workers that work with elevated arms) had an increased incidence of shoulder pain.

The extensor digitorum and flexor digitorum superficialis muscles in the forearm operate in coordination to produce wrist and hand movements. The extensor digitorum muscle showed a significantly decreased EMG activity under one size smaller and one size larger glove conditions when compared to the use of bare hands and the right glove size. Decreased forearm muscle activation led to a compensatory increase in shoulder movements[18, 19, 22]. This is in accordance with data from Jensen *et al.*[23], and Sporrong *et al.*[24] who found that manual material handling or light manual precision work depended on effective grip force exertion. The grip force exerted was weakened by impaired recruitment of the extensor digitorum and flexor digitorum superficialis, which resulted in an increased incidence of secondary shoulder pain. The glove conditions had no effect on the EMG activity of the flexor digitorum superficialis muscle, which operates flexion of the middle phalanges of the fingers at the proximal interphalangeal joints[18]. This was because the subjects performed the task using wrist extension and finger tip pinch movements.

Our study showed that wearing the wrong glove size can lead to increased shoulder muscle activation. In addition, we found that the upper trapezius muscle exhibited significantly higher EMG activity when the subjects wore gloves that were one size smaller compared to those that were one size larger when they performed a simulated assembly operation. These data illustrate the importance of using the well-fitting gloves when performing tasks involving fine motor skills, but suggest that workers should select gloves that are one size larger rather than one size smaller if the proper size is not available.

Subjects commented that their grip on the jackpin was improved by all the gloves in comparison with bare hands, a finding also reported in a study of manual dexterity in assembly workers. Almost all subjects mentioned that their hands felt fatigued in the gloves that were one size smaller—a sensation that would likely increase if the gloves were worn for longer periods. None of the subjects felt discomfort in their fingertips with the one size larger gloves, although several said that their performance during the task was compromised as their hands were covered with sweat. Also, our study showed the individual dimension data with respect to well-fitting glove size (6 subjects: large size glove, 10 subjects: middle size glove) in Table 3. These data are shown more adjacent to digit length measurements than width measurements.

This study had several limitations. First we used a single test of manual dexterity; other tests may have produced different results. Second, the task selected was not identical to specific applications performed during sedentary work while wearing gloves. Third, we only examined the short-term effects of assembly work, and our sample size was small. Fourth, the results of our study may not be generalized to other types of gloves used in other industries (e.g. latex or vinyl gloves). Finally, this study measured the activity of only two muscle groups in the forearm using surface electrodes. Future studies should investigate alternative and/or additional muscle groups.

Glove research can help industries select the types of gloves that produce the most efficient performance while providing suitable protection for a specific job. Information gained from glove studies can help set guidelines for workplace, equipment, and device designs. Originally, such guidelines were designed to reduce the risk of injury in the workplace for non-gloved workers. The results of this study should allow health care workers to find and use the well-fitting gloves when performing tasks requiring manual dexterity, and to select a glove that is one size larger rather than one size smaller if the suitable size is not available. Wearing correctly fitting gloves will improve safety and comfort in the workplace, and help assembly workers perform their activities both rapidly and efficiently.

Conclusions

This study compared the EMG activities of shoulder and forearm muscles when bare hands, well-fitting gloves, and gloves that were either one size smaller or one size larger were used during tests of manual dexterity. We found that wearing the wrong glove size led to decreased forearm muscle activation, which resulted in increased shoulder movements. In contrast, bare hands or wearing the well-fitting gloves caused effective forearm muscle activation, which decreased inefficient shoulder movements. Myofascial pain syndrome in the shoulder may be caused by the continuous operation of inefficient shoulder and forearm muscle activation patterns while wearing gloves of the wrong size during tasks that require manual dexterity. Therefore, selection of the appropriate glove size is important for the prevention of disorders resulting from overuse of the shoulder muscles.

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