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A Study on the Activation of Forearm Muscles during Gripping by Handle Thickness

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Abstract. [Purpose] This study examined the muscle activation when subjects gripped a handle with a circumference equal to 0%, 25%, 50%, 75%, or 100% of their hand length to determine the size that can be gripped most stably relative to the hand length. [Subjects and Methods] The muscle activation of 34 subjects was measured using electromyography. To make a cylinder proportionate to the hand length, multiple pencils were combined and the circumference was measured with a tape measure. The cylinders were made with circumferences of 0 %, 25 %, 50 %, 75 %, and 100 % of the hand length. [Results] The largest muscle activation was observed at handle circumferences of 50% and 75% of the hand length in the wrist extensor bundle and at 75% of the hand length in the flexor digitorum superficialis. [Conclusion] Therefore, circumferences of the middle range of hand length seems to be most appropriate for hammer handles and handles with high resistance which require large strength at industrial sites.
Key words: Grip, Muscle activation, Thickness of a handle

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INTRODUCTION

Hands are the effectors of upper extremities and are used for support, manipulation, and grasp, and to perform various functions with objects. Furthermore, hands are frequently used cause sites for the the motions such as holding tongs, scissors and plates[1)]. How the hands are used can cause disability of the upper extremities[2)]. Many tasks at industrial sites require repetitive motions using force with hands holding tools[3)], and such repetitive use of maximum squeeze can cause Carpal Tunnel Syndrome which is a type of overuse syndrome[4)].

Recently, work-related musculoskeletal disorders have been increasing[5)] Work-related musculoskeletal disorders which occur in the hands and wrists are caused by repetitive work, excessive force, and inappropriate postures[6)], and work with inappropriate wrist posture, power grip or frequent wrist movement is known to be the main work-related cause[7,8)].

According to Kilbom et al.[1)], the three factors considered in the ergonomic assessment of holding objects are the demand for force, the demand for elaborateness and the continuation of the given work. Among these, the amount of force can cause disability of the hands. The power grip motion which includes both fingers and the thumb is used to hold a tennis racket, a baseball, or the handle of a bag, and much power is needed in these motions[9)]. In most power grips, the cylinder grip is used with much force. Most previous studies have reported that the higher the load, the higher the incidence of hand dysfunction becomes. Many studies have investigated the grip strength according to shoulder joint angle, elbow joint angle, and wrist joint angle based on the biomechanics of the upper extremities[10,11)], but few studies have measured muscle activation according to different handle circumferences relative to the hand lengths of individuals. Accordingly, this study examined muscle activation when subjects gripped a handle with a circumference equal to 0%, 25%, 50%, 75%, or 100% of their hand length so as to determine the size that can be gripped most stably relative to the hand length.

SUBJECTS AND METHODS

This study subjects were 34 male and female students attending G University in Gyeongsangnam-do and it was conducted from September 1 to 6, 2010. The subjects were selected from among those who understood the content of this study and agreed to actively participate in the study. The experimental process was sufficiently explained to the subjects and written consent was received from each subject who voluntarily agreed to participate before starting the experiment. The subjects were young adults in their 20s who were right-handers and had no musculoskeletal or nervous disorders in their upper extremities or neurologic disorders in their cervical spines. The subjects of this study were normal adults with a mean age of 23.34 years, a mean height

Table 1. Forearm muscle activation by circumference of handle Unit: %MVIC

Muscle	0%	25%	50%	75%	100%
WEC*	41.26 ± 14.76[a]	51.81 ± 16.71[b]	59.84 ± 17.48[b]	60.82 ± 19.75[b]	57.15 ± 19.10[b]
FCR	57.97 ± 24.59	58.69 ± 28.89	60.46 ± 32.66	48.21 ± 25.11	46.08 ± 26.45
FCU	49.54 ± 24.85	42.40 ± 21.15	50.54 ± 22.27	39.73 ± 18.40	40.73 ± 19.40
FDS*	56.42 ± 23.84[a]	66.98 ± 23.98	76.53 ± 25.29	81.10 ± 16.36[b]	76.73 ± 20.84

WEC: Wrist extensor bundle, FCR: Flexor carpi radialis, FCU: Flexor carpi ulnaris, FDS: Flexor digitorum superficialis.
NOTE. Each value represents the mean ± SD. The values with different superscripts in the same column are different significantly ($p<0.05$) by Scheffe's post hoc test.

of 171.94 cm, a mean weight of 70.23 kg, and a mean hand length of 18.05 cm.

To measure change in muscle activation between before and after the experimental task, an MP36 (Biopac System Inc, USA) surface electromyograph, Biopack Student Lab, was used and the analog biological signals in response to the MP36 were digitized. The digitized signals were filtered and processed on a PC using Acknowledging software. Before measuring the signals, foreign matter on the electrode attachment points was removed using an alcohol cotton swab and three pole surface electrodes (Triode^{TM} electrode, Thought Technology Ltd., Canada) consisting of three poles (positive-ground-negative) were attached. On the forearm, the electrodes were attached to the forearm extensor bundle which is a wrist extensor and the flexor carpi radialis and flexor carpi ulnaris which is a wrist flexor. The electrodes were also attached to the flexor digitorum superficialis as it is a muscle involved in finger movements. For this experiment, each of the subjects sat in front of a table that could be adjusted in height to allow the elbow joint to have a comfortable posture at an angle of 90°. Movement of the distal part of the forearm was restricted and the subject's wrist was extended at 30° and radially deviated at 5°[12]. In this study, the %MVIC(maximal voluntary isometric contraction) was used as the measure of muscle activation, To make a cylinder proportionate to the hand length, multiple pencils were combined and the circumference was measured with a tape measure. The cylinders were made with circumferences of 0 %, 25 %, 50 %, 75 %, and 100 % of the hand length.

After sufficient explanation of this study was given to the subjects, the hand length from the proximal part of lunette to the end part of distal phalanx was measured, and cylinders with circumferences of 0 %, 25 %, 50 %, 75 %, and 100 % of the measured hand length were used in the experiments. Maximum isometric contraction was performed for each of the four target muscles and the muscle activation of each muscle was measured using electromyography. The subjects held a cylinder with a circumference chosen at random and applied maximum force in isometric contraction. The maximum isometric contraction was conducted for 5 seconds. The values of the first and last one second were discarded and the mean muscle contraction of the middle 3 seconds was calculated. The results were compared by muscle and by hand length.

The results of the measurement were analyzed using the statistics package SPSS/PC 12.0 for Windows and the significance level of all the statistics was chosen as 0.05. For the general characteristics of the subjects, the mean, standard deviation, frequency, and percentage were calculated. Each muscle was analyzed by handle using one-way ANOVA and Scheffe's post hoc test.

RESULTS

The %MVIC of forearm muscle activity of the wrist extensor bundle was 41.24% at a handle circumference of 0%, 51.81% at 25%, 59.84% at 50%, 60.82% at 75%, and 57.15% at 100%, with significant differences ($p<0.05$). Scheffe's post hoc test found statistically significant differences between handle circumferences of 0% and 50%, 0% and 75%, and 0% and 100% ($p<0.05$). The %MVIC of muscle activity of the flexor carpi radialis was 57.97% at a handle circumference of 0%, 58.69% at 25%, 59.84% at 50%, 60.46% at 75%, and 46.08% at 100%, with no significant differences ($p<0.05$). The %MVIC of muscle activity of the flexor carpi ulnaris was 49.54% at a handle circumference of 0%, 42.40% at 25%, 50.54% at 50%, 39.73% at 75%, and 40.73% at 100%, with no significant differences ($p<0.05$). The %MVIC of muscle activity of the flexor digitorum superficialis was 56.42% at a handle circumference of 0%, 66.98% at 25%, 76.53% at 50%, 81.10% at 75%, and 76.73% at 100%, with significant differences ($p<0.05$). Scheffe's post hoc test found a statistically significant difference between handle circumferences of 0% and 75% ($p<0.05$) (Table 1).

DISCUSSION

Since most products with a handle are used by the hands, work efficiency can be improved by making the hands comfortable and using them comfortably. Many products designed in tune with bodily characteristics such as motion, use of force, and body shape from ergonomic aspects are being sold which improve work efficiency by reducing errors[13]. However, the designs of handles of various products for patients could be better. Hence, this study attempted to determine the circumferences of handles that can be most stably gripped, an action which requires much strength, such as those of instruments given to patients or hammers and highly resistive handles used at industrial sites.

In gripping motion, the contraction of the wrist extensor causes passive insufficiency, facilitating finger flexion[14].

The wrist extensor bundle which is closely related to gripping showed the greatest muscle activity at handle circumferences equal to 50% and 75% of the hand length. This result suggests that the wrist extensor bundle activates in a manner that provides an easy grip on handle circumferences of 50% and 75% of hand length, and the flexor digitorum superficialis also exhibited the greatest muscle activation when gripping a handle circumference of 75% of hand length. Therefore, it appears that the flexor and extensor are facilitating stable gripping motion. A previous study measured the flexor digitorum superficialis muscle at four grip circumferences (10 cm, 13 cm, 16 cm, 18 cm) and the results showed significant differences between the different grip circumferences[15]. In that study by Blackwell et al.[15], only the circumferences of cylinders were measured without calculating the ratios to the hand sizes of the subjects. In the present study, no differences were found in the forearm flexor muscles which act as the protagonist in direct gripping action. In general, the gripping action requires large strength in the forearm flexor muscles, and these muscles did not show differences with different handle circumference. However, the flexor digitorum superficialis muscle at the handle circumference of 75% of hand length appears to have generated the greatest strength according to the length-tension curve of the muscles. Furthermore, the forearm extensor bundle plays a stabilizing role during the holding of an object and must act according to the thickness of the object, and it showed the greatest activation at handle circumferences of 50% and 75% according to the length-tension curve, just as in the case of the flexor digitorum superficialis muscle[12].

This study investigated the activation of forearm muscles during the gripping of handles with different thicknesses. We was found that the activation of the forearm flexor muscle, which is the protagonist of the gripping motion, did not change, but the flexor digitorum superficialis muscle which is involved in finger movement and the forearm extensor bundle that controls it were most activated at handle circumferences equal to 50% and 75% of the hand length. Therefore, 50% to 75% of hand length seems to be most appropriate for the circumference of handles of instruments for patients as well as hammer handles and handles with high resistance that require large strength at industrial sites.

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