

Analysis on the Change of Hand Grip Strength as per the Circumference of Upper Arm and Forearm and the Muscle Activity of Upper Arm and Forearm as per the Duration of Gripping

The purpose of this study is to analyze the grip strength by the girth of upper arm and forearm and their muscle activities by duration of grip strength. The subjects were consisted of 20 healthy adults(10 males & 10 females) who had no medical history of neurological and surgical problems with their arms. Girth of upper arm/ forearm and maximum grip strength for 4sec and 30sec were measured. Muscle activity was by wireless electrode EMG system. Co-relation of girth of upper arm/ forearm was significantly high. Upper arm's muscle activity performed for 4sec and 30sec was significantly high. In this study. It suggests that training of upper arm should be performed with the training of grip strength because both of upper arm and forearm affected grip strength.

Key words: *Grip Strength; Girth of Upper Arm and Forearm; Grip Duration; Muscle Activity*

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INTRODUCTION

Recently, people's interest in health are being increased and it is easily found in a fitness center that women show keen interest in muscle development and muscular strength as well as men.

When it comes to the symbol of exerciser, you can't beat the abdominal muscles, pectoralis muscle, firm arm muscle and broad shoulders. Everyone may have his own reason for exercising. However, most of exercisers try to make their arm muscle so firm as to be exposed even with the clothes on it. And people estimate the arm strength generally with the girth of arm, that is, the extent of muscle thickness of arm.

The grip strength is the grasping power of hands and normally indicates the muscular strength of muscles of arm. The hand is a part of human body that is used frequently in activities of daily living and carries out complex functions. The hand movements are assorted into 3 big categories of clenching, picking up and grasping. Making all these movements requires various kinds of element, among which the

grip strength comes under the most important element(1).

The item of grip strength is indispensable to evaluate the hand function in the fields of orthopedics, rehabilitation medicine and industrial medicine. Not only the muscles of hand are related to the grip strength but also such muscles as flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, flexor pollicis longus, flexor hallucis brevis, flexor digiti minimi brevis, lumbricale and interosseous muscle are related and the grip strength appears as the result of cooperation among all these related muscles. Generally the grip strength is recalled when people talk about the strength of arm(2).

The grip strength both of male and female starts to grow from the age of 10s and it reaches the top level at the age of 30s to dwindle afterwards. The highest grip strength of female in their 30s is weaker by 43.31%, compared to that of male in their 30s and females are weaker by 39.67% than males when we compare them in terms of overall average(3).

The grip strength turns out to show the highest

when the arm length is 100%(the length from the right shoulder tip point to radiale is defined as 100% of arm length), based on the result of research on the length of test subjects' arms(4).

It was noticed that the muscle activity of 1st dorsal interossei was brisker than that of thenar muscle group and the extent of muscle fatigue was similar each other, while gripping(5).

When we measure one's grip strength under the standing posture after 15 seconds since starting, the position of shoulder angle 0° and elbow angle 90° shows the higher grip strength, compared to the position of shoulder angle 0° and elbow angle 0° and the maximal grip force under the position of shoulder angle 0° and elbow angle 0° is higher than that under the position of elbow angle 90° (6).

Though it is difficult to say that the joint angle exerts main influence on the subjects' grip strength, the joint angle may give influence to grip strength under some posture. When one holds the shoulder angle of 0° under the standing posture, the more the elbow angle increases, the stronger the grip strength is apt to become. In case of the shoulder angle of 90°, the more the elbow angle increases, the weaker the grip strength is apt to become. Speaking of the sitting posture, the shoulder angle of 45° among 0°, 45° and 135° showed the strongest grip strength and the shoulder angle of 0° showed the lowest grip strength (7).

Speaking as for the shoulder angle of 0°, some researches maintained that the angle of 90° showed the higher grip strength than the angle of 0° as ASHT(American Society of Hand Therapists) did, while some others maintained that the angle of 0° showed the higher grip strength than the angle of 90° (6, 8).

Previous researches regarding the grip strength have made a study on the angle of shoulder joint and elbow joint(4, 6, 7, 8), the standing posture and the sitting posture(7), the length of arm(4), the age and gender(3), the position of hand(4), the muscles of hand(5) and the hand size and grip width(9) but the study on the grip strength as per the girth of arm and the elapsed time, has been insufficient.

The forearm and hand muscles are measured to check 'the grip strength' as the forearm has direct relevance with grip strength and the way to measure the girth and the skin thickness of upper arm is frequently used when we check the nutritional aspect(10).

This research came to be designed in an attempt to study to what extent the upper arm influence the grip strength and whether one of stout forearm has

stronger grip strength than the one of stout upper arm. In this research, it is suggested with regard to the measurement of grip strength that we should measure and analyze the muscle activity of upper arm in addition to the checking of maximal force, offered by previous researchers because the muscle of upper arm has relevance with grip strength while trying to maintain the strength for a certain time. Accordingly, this research intends to investigate what change would occur in the grip strength depending on the variance of angle with shoulder, arm and hand and what influence the girth of arm(upper arm and forearm) would give to the grip strength, and also aims to study how the muscle activity of upper arm would change after a certain time have elapsed.

METHODS

Subjects

This research was conducted, having set 20 university students in their 20s(10 male students, 10 female students) who attend N university in Cheon-An city, as subjects. The subjects were composed of healthy adults who had no nervous system disease or musculoskeletal disorders at the time of check or have had no history of such diseases for the past 6 months and had no external injury or pain in upper extremity. The content and method of experiment were briefed to the subjects, prior to the commencement of experiment and all the subjects signed a consent form, upon becoming well-acquainted with the content and method.

Measurement Equipment

In this research, the girths of upper arm and forearm were measured by tape measure and the skin thickness was gauged, using the skin fold caliper of Baseline company. A grip dynamometer was used to

Table 1. Experiment tools

Name of apparatus	Product name	Manufacturer
Tape measure	Fitting joolja	R.O.K/Fine trading
Electromyogram-analyzer	Free EMG	BTS/Italy
Caliper	Skin fold caliper	Baseline
Grip dynamometer mirror	Jamar Dynamometer mirror	Ikakikae

measure the grip strength and Wireless Electrode EMG System was chosen to look into the muscle activity(table 1).

Procedure

The upper arm girth and skin thickness of all subjects were measured at the same time. The method explained by Jelliffe was adopted to gauge the upper arm's girth, so the circumference of middle part between acromion process of scapula and olecranon was measured to one decimal place(0.1cm), using a tape measure (10).

When gauging the skin thickness, the researcher took up the subject's skin and subcutaneous fatty tissue erectly with his left thumb and forefinger and attached the contact point of measuring instrument to the place a bit lower than the taken up part after relaxing the subject's arm, following the notes pointed out by Ruiz and then, the scale record was written to two decimal place(0.1mm)(11).

Girth of upper arm = (Upper arm)($\pi \times$ the thickness of upper arm's bifold skin)

The forearm girth and skin thickness of the subjects were measured at the same time. Though a previous research(12) had measured the 3/4 middle part in the direction of body between the styloid process and the olecranon of the ulna as well as the central part between the styloid process and the olecranon of the ulna, this research has measured the girth of forearm because the girth of forearm(the thickest part of forearm that is measured under the state of having the whole arm stretched, the indicator of muscular strength) is more significant as an indicator of muscular system, that is, the developmental status of muscles including skeleton than as an indicator of nutritive conditions.

When measuring the girth of forearm, the subject was ordered to gather the shoulder joint under the posture of standing and then, to raise his forearm to the shoulder height without rotation. After getting the subject to relax his hand and arm, the researcher measured, moving a tape measure in the perpendicular direction to the major axis of forearm. The researcher put the tape measure just next to the part of styloid process of Radius and Ulna and moved gradually towards the direction of hand to measure the thickest part and the measured value was written to one decimal place(0.1cm)(13).

The skin thickness of forearm was measured in the same way as was done in the measurement of upper

arm. The same formula as was adopted to measure the girth of upper arm, was applied to the measurement of the girth of forearm. Considering that the measurements are to be done by a tape measure, only one representative researcher assumed full charge of measuring to enhance the reliability.

Girth of forearm = (Forearm)($\pi \times$ the thickness of forearm's bifold skin)

As each subject has different muscle size and muscular power, the standardized muscle activity (%MVIC) was measured, using the value of MVIC(maximal voluntary isometric contraction). In order to obtain MVIC value, the researcher had the subjects attach the EMG surface electrode to their Biceps brachii and Triceps brachii of upper arm and Brachioradialis, Flexor carpi radialis and carpi ulnaris of forearm and the subjects conducted the maximal isometric exercise for 4 seconds under the posture of manual muscle testing upon being given some resistance from the researcher. Then, the initial one second at the beginning stage of each exercise was excluded from the calculation and the average figure for 3 seconds was adopted as MVIC value.

The standing posture that showed the highest reliability and reproducibility in previous researches, was set as the basic posture in this experiment. The subjects were asked to gather their shoulders with no rotating action and to bend their elbow joint to 90° under the basic posture. Then, the researcher measured the value of grip strength and the RMS(root mean square) value. It was decided that the grip power of dominant hand was to be measured and Jamar grip dynamometer that was proved to show the highest grip strength when measuring gripping force, was used upon being fixed at the level 2(14, 15). Maximal grip strength for 4 seconds was measured two times (16, 17) and the average figure of them was adopted as the data for maximal grip strength. The figures of RMS which were obtained two times herewith, were also averaged out. The researcher analyzed by which one out of the two girths of upper arm and forearm, the maximal grip strength are more influenced. Two minutes' rest was allowed between measurements in order to minimize the muscle fatigue(18).

After resting, the subjects were told to maintain the continuous strength for 30 seconds(19), grasping the grip dynamometer. The subjects were briefed that they should try to keep the level of continuous strength to be between 75% and 85%(20, 21) of their own average maximum strength(kg), watching a

mirror. This was also carried out two times and the interval of 2 minutes was allowed between the two for rest. The figures of RMS, obtained herewith, were also averaged out.

The muscle activity signal, obtained from the evaluation of respective muscle, was processed into the RMS value and then, it was standardized by the percentage to the RMS value of maximum voluntary isometric contraction(MVIC)(%MVIC). The %MVIC of upper arm and forearm that was obtained through measuring of the maximal grip strength during 4 seconds, was compared with the %MVIC of upper arm and forearm that was gained through the measurement of maximal grip strength for the continuous 30 seconds.

Data Analysis

Statistical analysis was performed by SPSS ver 18.0 for WINDOW in order to analyze the data for this research. Pearson correlation coefficient was used in order to look into the change of grip strength as per the change of girths of upper arm and forearm. Also Paired T-test was used in order to watch the muscle activity changes of upper arm and forearm during the continuance of 30 seconds while maintaining the grip strength and at the time of measuring the maximal grip strength for 4 seconds. The significant level was set at .05.

RESULTS

General Features of the Research Subject

General features of research subject are shown in Table 2.

Table 2. General features of research subject

	Experiment group(n=20)
Age(yrs)	21±1.30
Height(cm)	169.50±8.42
Weight(kg)	61.30±10.72
Girth of upper arm(cm)	21.13±3.08
Girth of forearm(cm)	21.49±3.06

Change of Grip Strength as per the Girths of Upper Arm and Forearm

Correlation between the grip strength and the girth of upper arm and forearm, turned out to be statistically significant(Upper arm: $r=.716$, Forearm: $r=.793$)(Table 3).

Table 3. Correlation between the grip strength and the girth of upper arm and forearm

	Girth of upper arm	Girth of forearm
Maximal grip strength	.716*	.793*

Table 4. Comparative analysis of muscle activity with upper arm and forearm as per the continuance of gripping

		Mean	SD	t	p
Triceps brachii	4sec	.161	.120	-3.198	.005**
	30sec	.254	.179		
Biceps brachii	4sec	.238	.128	-2.956	.008**
	30sec	.314	.184		
Brachio radialis	4sec	.756	.447	-1.950	.066
	30sec	.832	.544		
Flexor carpi radialis	4sec	.418	.221	-1.447	.164
	30sec	.445	.231		
Flexor carpi ulnaris	4sec	1.579	.875	-1.658	.114
	30sec	1.691	.908		

**p < .01

Comparative Analysis of Muscle Activity with Upper Arm and Forearm as per the Continuance of Gripping.

The longer one retains the grip strength, the higher the muscle activity turns out to be limitedly with the muscles of upper arm (Table 4).

DISCUSSION

This research was conducted, intending to analyze the correlation between the girth of arm and the grip strength and also to analyze the muscle activity of upper arm and forearm as per the duration time of gripping.

Supposing that one's own average of maximal grip strength is set as 1RM, the subjects were instructed to retain the maximal grip strength for 4 seconds and to maintain 75~85% of 1RM for 30 seconds (21). When the subjects were trying to keep 75~85% of 1RM, a mirror was placed in front of them to help them maintain 75~85% of maximal strength, watching the mirror. This arrangement was made, considering the effect of self control KR (22).

Chatterjee and Chowdhuri have verified the grip strength is correlated with Body surface area (BSA) and also with age, weight and height (23). And Fransson and Winkel have verified the hand size exerts an absolute influence on the grip strength (24). Thus, all the subjects in this research were instructed to keep their grip dynamometer set at the level 2, as per the opinions of Crosby et al. and Bechtol (14,15).

With respect to the correlation between the grip strength and the girths of upper arm and forearm, this research ascertained that both the girth of upper arm and the girth of forearm are statistically correlated with grip strength (upper arm: $r=.716$, forearm: $r=.793$). This signifies that both the girths of upper arm and forearm have high correlation with grip strength.

Lin et al, who had studied about the strength for lifting up an object with handle by static forces, have conducted an experiment, attaching the EMG electrode to biceps brachii and verified that the girth of upper arm exerts an important influence when the lifting strength was measured under the posture of elbow joint bent to 90° (25).

Cedric and Daniel mentioned that the grip exercise, grasping and spreading hand, is related to the training of forearm muscles (26). If we suppose the girth of forearm vary in direct proportion to the training,

this corresponds with the result of this research. The researcher considers that the future research should compensate the defect by focusing on the relation between the girth of arm and the actual muscle activity, in terms of maximal grip strength.

When the muscle activity was measured after the subject had retained the maximal grip strength for 4 seconds and the sub-maximal strength for 30 seconds, the upper arm's muscle activity was shown to be significantly higher than that of forearm (triceps brachii: $p=.005$, biceps brachii: $p=.008$).

Nicolay and Walker have announced that the grip strength during the 1st half of 30 seconds was stronger than that during 2nd half of 30 seconds and the data of EMG attached to the forearm was shown to be higher in the early stage and dwindled down as time elapsed, when the grip strength of dominant hand and non-dominant hand was measured for 30 seconds (27). This announcement by Nicolay and Walker is considered to be meaningful to the result of this research. The researcher considers that the future research needs to be conducted upon the creation of the condition through which the muscle fatigue can be observed, by prolonging the continuance of maximal grip strength.

Also the previous research, mentioned above reported that the dominant hand got fatigued faster, regardless of whether it is male and female. And 3/4 of all the subjects disclosed that the muscle endurance of non-dominant hand was stronger than that of dominant hand.

Though this research was designed with the dominant hand, based on the theory of Nitesh Bansal that the dominant hand is stronger in terms of grip strength, it is considered that the research design should be planned with non-dominant hand for better consequences, when we measure the grip strength from the aspect of sustainment time (28).

Accordingly, it is supposed that the grip strength training contributes to the enlargement of muscle girth through developing muscles and it is considered that the upper arm training should be given as well as the forearm training at the time of grip strength training.

The limit of this study is as follows. Only 20 persons of limited number participated in this research, most of subjects were the university students in their early 20s and the research was conducted irrespective of gender. Also, it could be pointed out as shortcomings that the various factors such as exercise habit, eating habits, body type, occupation and the genetic factors were not taken into consideration although they may give influences to the grip strength. The

researcher wishes that the future studies would compensate the defect, mentioned above.

CONCLUSION

This research has investigated which one out of the two girths of upper arm and forearm has more relevance to the grip strength, having selected 20 N university (in Cheon-An city) students in their 20s as the research subjects, irrespective of gender. This research also made a study on how the muscle activity of upper arm and forearm change in the wake of continuance of gripping action and the research results are as follows.

1) The fact that the thicker both the girth of upper arm and of forearm get, the stronger the maximal grip strength becomes, had statistical significance.

2) Examining how the activity of arm muscle changes as per the continuance of gripping action of hand, it was noticed that Triceps brachii and Biceps brachii of upper arm were more activated when maintaining the max. grip strength for 30 seconds than when exerting max. power of gripping for 4 seconds. And this fact, noticed herewith had high statistical significance.

Consequently, we came to the conclusion that one who has both the thicker girth of upper arm and the thicker girth of forearm is presumed to have stronger grip strength. The researcher also considers that one should train not only his forearm muscle but also his upper arm muscle, if he needs to have his grip strength maintained for a certain time, then he can have his upper arm muscles be activated to maintain his muscular strength for long hours. Thus, the researcher wishes that the result of this research would become the preliminary data for the development of an exercise promoting both the maximal grip force and the endurance of gripping in future.

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