Medicina Sportiva (2017), vol. XIII, no 2, 2897-2904
Journal of the Romanian Sports Medicine Society

Effects of elbow and shoulder joints angle variation on grip strength of apparently healthy undergraduates in a Nigerian institution

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Abstract. The purpose of this study was to determine the effect of elbow and shoulder joints angle variations on the grip strength in apparently healthy undergraduates of a Nigerian University. A total of 400 undergraduates of Obafemi Awolowo University Ile Ife, Nigeria were recruited for the study. A universal goniometer was used to measure the angles of left and right elbow and shoulder joints. Participants was asked to perform maximum grip strength with the shoulder and elbow in each of the following angles while on sitting: 0^0, 90^0 and 180^0 of shoulder flexion with elbow flexed at 90^0 and fully extended. The grip strength was measured with hand grip dynamometer (Wo Li Bao). Data was analyzed using descriptive and inferential statistics. Alpha level was set at 0.05. Result showed that grip strength was significantly strongest at 0^0 shoulder flexion, elbow at 90^0 for right hand ($F= 25.30$ $p< 0.001$) and left ($F= 15.12$, $p< 0.001$). Also grip strength was found strongest at 0^0 shoulder flexion elbow fully extended for right ($F = 7.83$ $p < 0.001$) and left (F= 14. 89 $p < 0.001$). Male grip strength was found significantly ($p <0.001$) stronger than female in all angle variations and right hand was found significantly ($p<0.001$) stronger than the left in all angle variations. It can be concluded from the study that grip strength will be at the best in sitting position when shoulder joint was at 0^0elbow at 90^0 or fully extended.
Key words: *grip strength, elbow, shoulder, goniometer*.

Introduction

The Understanding grip strength is paramount in the evaluation of hand functions and in taking an effective therapeutic measures in rehabilitation of the hand Kong (1). It is one of the basic prerequisites for all body movements which refers to the ability of muscle or groups of muscles to exert or generate maximal assessment of motor fitness of individuals (2). Grip strength is the integrated performances of muscles by determining maximal grip force that can be produced in one muscular contraction (3). It is widely accepted that grip strength provides an objective index of the functional integrity of the upper extremity (4). In addition to being an economical measure that is easy to administer, grip strength is one of the best indicators of the overall strength of the limb (5). Besides, grip strength can be an important index of general health (6), nutritional status (7), overall strength (8) and the amount of protein reserves in the body (9). Hand functionality is considered to be vital in most of the daily activities involving upper limb, be it carrying loads, lifting objects, opening or closing doors to name a few (10). Furthermore the measurement of grip strength has great importance for occupational health purposes (11). The measurement of grip strength is an important component of hand rehabilitation because it helps establish a baseline for treatment and it is a measure of the effectiveness of therapy (12).

Various devices are being used for measuring muscular strength. These include balance, cable-tensiometer, grip dynamometer, strengthometer (13). Manual and mechanical methods are normally employed to assess and evaluate hand grip strength. Hand held dynamometer is considered to be a reliable instrument in evaluating grip strength and is used widely in rehabilitation (14). It is used to measure the force of flexor muscles of hand generated during gripping the dynamometer.

The amount of force generated in a muscle during measurement depends largely on some factors such as cross-sectional area (15), speed of contraction, arrangement of muscle fibers (16), joint angle (17), sex difference and temperature (18). The biceps is the most powerful elbow flexor and its most powerful actions are elbow flexion and supination (19). The joint action of the biceps brachii, brachialis, and brachioradialis flexes the elbow joint of which the joint angle positions for the shoulder, elbow and wrist cannot be neglected in the quantification of arm flexors strength of the fingers (20).
Certain variables like body posture of the participant during test, positions of various segment like the shoulder, elbow, forearm and wrist , dominance of hand , testing time , gender, age, body mass index, hand circumference and limb length and considered to affect grip strength (21,22). Studies have reported that grip strength measurements were found to be significantly lower when subjects were supine, compared with grip strength scores recorded with subjects in a standing and seated position (23). Mathiowetz et al found that grip strength scores were higher with the elbow positioned in 90 degrees of flexion as compared with when the elbow was positioned in full extension (24). The results of Mathiowetz et al; study posed more questions regarding the influence of elbow position on grip strength (24). Ninety degrees of elbow flexion resulted in higher grip strength scores than full elbow extension; however, there study did not encompass what effects other shoulder flexion positions may have on grip strength. The degree of involvement of various shoulder and elbow joints angles have not been fully explored. The study was therefore designed to evaluate the effects of elbow and shoulder joints angle variation on grip strength of apparently healthy undergraduates in a Nigerian University.

Material and Method
The participants were male and female undergraduates of the Obafemi Awolowo University, Ile Ife of the age ranged between 20 to 30 years.
Inclusion criteria. Undergraduates of the age between 20-30 years with no previous report of diseases or sickness for the past 12 months or history of musculoskeletal disorder that might affect the upper extremities strength. *Exclusion criteria.* Undergraduates that are beyond the stipulated age and those that did not give their consent for the study.
The following instruments were used: a hand grip dynamometer (Wo Li Biao, Japan) was used to measure the grip strengths of the subjects; a bathroom weighing scale was used to measure the weights of the subjects; the heights of the participants was measured using a stadiometer; a universal goniometer was used to measure the shoulder and elbow angles (0^0, 90^0, $180\ ^0$); a chair which the participants used to sit; pillow which the subjects used to support the measured shoulder and elbow angles.
All the measurements were carried out in the Physiotherapy Department, Obafemi Awolowo University (OAU), Ile Ife, Nigeria.
Study Design. This research was a cross sectional survey of the effect of shoulder and elbow angle variations on grip strength. *Sample size.* The population of OAU students as at 2014 was 30.000. Hence sample size formula for proportions with population greater than 10,000 was used:

$$n = z^2pq/d^2 \quad (25)$$

where: n = the desired sample size (when population is greater than 10,000); z = 1.96 at 95% confidence interval; p = assumed proportion of persons having knowledge of physiotherapy, because it is not available from literature, 50% will be used (0.50); q = 0- p = 0.05; d = absolute standard error = 0.05; n = (1.962 x 0.5 x 0.5) / (0.05)2 = 384 participants. 400 participants were targeted in case some may not respond.
Procedure. Prior to data collection, the subjects' ages, heights, and weight were measured. A brief interview preceded the determination of the subjects' muscular strength was carried out. Universal goniometer was used to measure the angles of shoulder and elbow at (0^0, 90^0, and 180^0) for each joint according to Norkin and White (26). Each participant was in sitting position on high chair. The elbow joint was supported on a fulcrum on the plinth. The dynamometer was adjusted in which the base rested on first metacarpal (heel of palm), while the handle was on the middle of four fingers. When ready the subject squeezes the dynamometer with maximum isometric effort, which is maintained for about 5 seconds with no other body movement. The subjects were instructed to squeeze the handle of the dynamometer as strong as possible.

Verbal encouragements were offered during the test by commanding the subjects to" pull" for each shoulder and elbow handle position with a five minutes rest interval.

The readings of the dynamometer were taking at the following angles of shoulder and elbow combined: 0^0 shoulder flexion, elbow at right angle; 0^0 shoulder flexion, elbow fully extended; 90^0 shoulder flexion, elbow fully extended; 90^0 shoulder flexion, elbow at 90^0 (right hand), 180^0 shoulder flexion, elbow fully extended; and 180^0 shoulder flexion, elbow at 90^0 .

Data analysis. The data was analyzed using both descriptive and inferential statistics analysis. Specifically, the SPSS 16 (Statistical Packages for Social Sciences) was utilized. Dependent t-test was employed to determine if there is a significant difference between grip strength of right and left upper extremities at each elbow and shoulder angle (0^0, 90^0 and 180^0). Analysis of Variance (ANOVA) was used to determine the difference in grip strength for both right and left hand across the three elbow and shoulder angles.

Results

Anthropometric variables of participants. Presented in table 1 is the summary of anthropometric variables of participants. The mean weight is 59.81±8.07 kg. The mean BMI is 22.2±1.27 kg/m^2.

Comparison among grip strength at 0^0, 90^0, and 180^0 shoulder flexion at 90^0 elbow flexion of the right hand. Shown in table 2 is the summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at 90^0 elbow flexion of the right hand. The grip strength at 0^0 of shoulder flexion at 90^0 of elbow flexion is significantly ($F=25.30$, $p< 0.001$) stronger than that of 90^0 and 180^0 of shoulder flexion at 90^0 of elbow flexion.

Table 1. Physical characteristics of the participants (n=400)

Variables	Minimum	Maximum	Mean±SD
Age/yrs	20.00	28.00	22.85 ±1.90
Weight/kg	44.00	79.00	59.81 ±8.07
Height/m	1.50	1.86	1.64 ±0.08
BMI/kg/m^2	16.90	29.59	22.20 ±2.71
OSFERAr/KF	8.00	120.00	60.00 ±30.44
OSFEFEr/KF	11.00	120.00	57.37 ±29.64
NDSFEFEr/KF	5.00	118.00	55.31 ±26.69
NDSFE90r/KF	8.00	115.00	51.30 ±25.62
OESFEFEr/KF	11.00	120.00	53.42 ±24.82
OESFERAr/KF	4.00	92.00	45.11 ±19.26
OSFERAl/KF	12.00	116.00	44.53 ±20.70
OSFEFEl/KF	0.00	105.00	43.21 ±22.60
NDSFEFEl/KF	4.00	100.00	41.40 ±20.67
NDSFERAl/KF	6.00	90.00	40.35 ±18.68
OESFEFEl/KF	4.00	90.00	40.53 ±19.03
OESFERAl/KF	3.00	75.00	35.88 ±16.85

KEY: OSFERAr: 0^0 shoulder flexion, elbow at right angle(right hand),OSFEFEr(0^0 shoulder flexion, elbow fully extended (right hand),NDSFEFEr: 90^0 shoulder flexion, elbow fully extended (right hand),NDSFE90r: 90^0 shoulder flexion, elbow at 90^0 (right hand),OESFEFEr: 180^0 shoulder flexion, elbow fully extended (right hand); OESFERAr: 180^0 shoulder flexion, elbow at 90^0 (right hand),OSFERAl: 0^0 shoulder flexion ,elbow at right angle (left hand),OSFEFEl: 0^0 shoulder flexion, elbow fully extended (left hand),NDSFEFEl:90^0 shoulder flexion,, elbow fully extended (left hand) ,NDSFERAl:90^0 shoulder flexion, elbow at 90^0 (left hand),OESFEFEl: 180^0 shoulder flexion, elbow fully extended (left hand),OESFERAl: 180^0 shoulder flexion, elbow at 90^0 (left hand). KF: kiloforce.

Table 2. Summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at 90^0 elbow flexion of the right hand (n=400)

Variables (KF)	Mean ± SD	F	p
OSFERAr	60.00±30.44		
NDSFE90r	51.30±25.62		
OESFERAr	45.11±20.70	25.30	0.001

KEY: OSFERAr: 0^0 shoulder flexion, elbow at 90^0 (right hand), NDSFE90r: 90^0 shoulder flexion, elbow at 90^0 (right hand), OESFERAr: 180^0 shoulder flexion, elbow at 90^0 (right hand) KF: kiloforce.

Comparison among grip strength at 0^0, 90^0, and 180^0 shoulder flexion at 90^0 elbow flexion of left hand. Presented in table 3 is the summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended of the left hand. The grip strength is significantly (F= 15.12, p< 0.001) stronger at 0^0 shoulder flexion than when it was 90^0 and 180^0 elbow at 90^0.

Table 3. Summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at 90^0 elbow flexion of the left hand (n=400)

Variables (KF)	Mean ±SD	F	p
OSFERALT	44.53±20.70		
NDSFERALT	40.35±18.68	15.12	0.001
OESFERALT	35.88±16.85		

KEY: NDSFERAl: 90^0 shoulder flexion, elbow at 90^0 (left hand), OSFERALT: 0^0 shoulder flexion, 90^0 (left hand), OESFERAl: 180^0 shoulder flexion, elbow at 90^0 (left hand). KF: kiloforce.

Comparison among grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended of right hand. Presented in table 4 is the summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended of the right hand. The grip strength is significantly (F= 15.12, p< 0.001) stronger at 0^0 shoulder flexion, 90^0 and 180^0 shoulder flexion elbow fully extended

Table 4. Summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended of the right hand (n=400)

Variables (KF)	Mean±SD	F	p
OSFEFEr	57.37±29.64		
NDSFEFEr	55.31±26.69	7.83	0.006
OESFEFEr	53.42±24.82		

KEY: OSFEFEr (0^0 shoulder flexion, elbow fully extended (right hand), NDSFEFEr: 90^0 shoulder flexion, elbow fully extended (right hand), OESFEFEr: 180^0 shoulder flexion, elbow fully extended (right hand). KF (kilo-force).

Comparison among grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended of left hand. Shown in table 5 is the summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended for the left hand. It was observed that grip strength is significantly (14.89) (p<0.002) stronger at 0^0 shoulder flexion, elbow fully extended than 90^0 and 180^0 shoulder flexion, elbow fully extended left hand.

Table 5. Summary of ANOVA comparing values of grip strength at 0^0, 90^0, and 180^0 shoulder flexion at elbow fully extended for the left hand N=100

Variables (KF)	Mean±SD	F	p
OSFEFEI	43.21±22.60		
NDSFEFEl	41.40±20.67		
OESFEFEl	40.53±19.03	14.89	0.001

KEY: *OSFEFEl: 0^0 shoulder flexion, elbow fully extended (left hand), NDSFEFEl: 90^0 shoulder flexion, elbow fully extended (left hand) , OESFEFEl: 180^0 shoulder flexion, elbow fully extended (left hand).KF: kilo-force.*

Comparison between male and female hand grip strength. Presented in table 6 is the summary of comparison between male and female grip strengths at various shoulder and elbow angles. Grip strength of male in all the various angles of shoulder and elbow was significantly (p<0.001) higher than that of female.

Table 6. Summary of Independent t-Test comparing male and female grip strengths at various shoulder and elbow angles (n=400)

Variables(KF)	Male (N=57) Mean+ SD	Female(N=43) Mean+ SD	T	p
OSFERAr	80.65±23.02	32.63±11.50	4.256	0.001
OSFEFEr	78.19±21.06	29.77±10.50	3.799	0.001
NDSFEFEr	73.60±19.26	31.07±11.36	4.120	0.001
NDSFE90r	67.93±20.46	29.26±10.79	3.453	0.001
OESFEFEr	69.14±20.40	32.58±10.84	4.121	0.001
OESFERAr	57.23±14.94	29.40±11.52	3.602	0.001
OSFERAl	56.68±18.65	28.42±8.91	9.171	0.001
OSFEFEl	56.42±20.51	25.70±9.62	9.090	0.001
NDSFEFEl	53.74±18.14	25.05±9.41	9.449	0.001
NDSFERAl	51.91±15.47	25.02±9.03	10.157	0.001
OESFEFEl	51.51±16.96	25.97±9.46	8.877	0.001
OESFERAl	45.16±15.18	23.58±9.49	8.185	0.001

KEY: OSFERAr: 0^0 shoulder flexion,elbow at right angle(right hand); OSFEFEr(0^0 shoulder flexion, elbow fully extended (right hand); NDSFEFEr: 90^0 shoulder flexion, elbow fully extended (right hand); NDSFE90r: 90^0 shoulder flexion, elbow at 90^0 (right hand); OESFEFEr: 180^0 shoulder flexion, elbow fully extended (right hand); OESFERAr: 180^0 shoulder flexion, elbow at 90^0 (right hand); OSFERAl: 0^0 shoulder flexion,elbow at right angle (left hand); OSFEFEl: 0^0 shoulder flexion, elbow fully extended (left hand); NDSFEFEl:90^0 shoulder flexion, elbow fully extended (left hand) ;NDSFERAl:90^0 shoulder flexion, elbow at 90^0 (left hand); OESFEFEl: 180^0 shoulder flexion, elbow fully extended (left hand); OESFERAl: 180^0 shoulder flexion, elbow at 90^0 (left hand). KF: kiloforce.

Comparison between left and right hand grip strength. Presented in table 7 is the summary of comparison between left and right grip strengths at various shoulder and elbow angles. The right grip strength was significantly (p< 0,001) stronger in all the shoulder angles than the left.

Table 7. Summary of Dependent t-Test comparing left and right hand grip strengths at various shoulder and elbow angles (n=400)

Variables (KF)	Right hand (r) Mean±SD	Left hand (l) Mean ± SD	T	p
OSFERA	60.00±30.44	44.53 ±20.70	6.256	0.001
OSFEFE	57.30±29.64	43.21 ±22.60	5.799	0.001
NDSFEFE	55.31±26.69	41.40 ±20.67	5.120	0.001
NDSFE90	51.30±25.62	40.35 ±18.68	4.453	0.001
OESFEFE	53.42±24.82	40.53 ±19.03	5.121	0.001
OESFERA	45.11±19.26	35.88 ±16.85	4.602	0.001

KEY: OSFERA: 0^0 shoulder flexion, elbow at right angle; OSFEFE (0^0 shoulder flexion, elbow fully extended, NDSFEFE: 90^0 shoulder flexion, elbow fully extended; NDSFE90: 90^0 shoulder flexion, elbow at 90^0, OESFEFE: 180^0 shoulder flexion, elbow fully extended; OESFERA: 180^0 shoulder flexion, elbow at 90^0. KF: kilo-force.

Discussion

This study investigated the effect of angle variation at the elbow and shoulder joints on the grip strength in apparently healthy undergraduates as well as examined the difference between male and female and right and left grip strength.

Our study observed that grip strength was strongest at zero degree of shoulder flexion when elbow is at right angle compared with when shoulder was at 90^0 and 180^0 of flexion.

The finding in our study was in line with the study of Mukkannavar, Mohanty (27) and Su et al (28). Mukkannavar and Mohanty compared the right and left grip strength at various angles of elbow and shoulder joints and they found that grip strength was strongest at zero degree of shoulder joint when elbow was at either full extension or at right angle which was in agreement to our study (27). Our study was at variance with the report of Kong where he found a higher grip strength at shoulder angle of 90^0 flexion than that at 0^0 and $45^0$of shoulder flexion (1). The variation in the strength could be associated with the posture when the measurement was carried out. Our study was in sitting position while his own was in standing position. The point of consideration in our study was that sitting posture is more comfortable than standing, especially when considering an elderly and individuals with health challenges. Sitting posture provokes muscle to relax, but in standing, cortical and peripheral stimulation are energized (29).

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This was explained by Åstrand and Rodahl (30) that during standing, there is continuous interaction of central commands with the muscles and joint of lower extremities using sensory feedback with assertion that there was a minimal joint and muscle sensory feedback in sitting posture. Our study found a stronger grip strength in shoulder angle of 0^0 and elbow joint at 90^0 which was in line with the study of Kattel et al (11). In addition America Society of Hand Therapy (ASHT) recommended that grip strength should be measured while sitting with shoulder joint at 0^0 and elbow at right angle (31), positions which was in tandem with our study.

The extensors of the forearm are the stabilizers of the wrist while the flexors of the forearm and the hand are the major muscles involved in grip strength (32). Roman-Liu and Tokarski (33) reported that the two major muscles involved in hand grip were flexor carpi ulnaris (FCU) and extensor carpi radialis (ECR), while biceps brachii is very important in flexion of the elbow and shoulder elevation being a single muscle that crosses both the shoulder and elbow joints (34). Considering the muscle responsible for the shoulder movement, the anterior and middle fibers of the deltoid muscles with infraspinatus perform a greater role especially in flexion of the shoulder joint Kronberg, et al (35). At zero degree of shoulder flexion, muscles responsible for the shoulder movement are relaxing, this enables the FCU and ECR to exert maximum contraction on the wrist and fingers. This leads to increase in grip strength compared to others shoulder angles in which there is movement of shoulder joint.

The 90^0 flexion of elbow joint was in agreement with the study of Mathiowetz et al (24), in which grip strength was evaluated with the elbow in 90^0 and full extension, it was stated that grip strength scores were significantly higher when the elbow was in a 90^0 flexion position. According to Kong (1) the activities of flexor carpill ulnaries FCU), biceps brachii (BB) and anterior deltoid (AD) tended to increase, whereas those of extensors carpill radilis (ECR) and triceps brachii (TB) decrease in activities as the elbow angle increased in their study. FCU and BB acted as agonist muscles, while ECR and TB acted as antagonist muscles during grip exertions at flexed elbow postures. Despite the fact that AD are more active during the flexion of shoulder joint (35), the muscle group display more activities when the elbow was flexed at 90^0 than when it was flexed at 0^0 , therefore the grip strength is more at 90^0 flexion of elbow joint that 0 degree of elbow joint.

The study observed further that male grip strength was significantly stronger than female grip strength in all angles of elbow and shoulder. Nicolay and Walker (36) reported in their study that males produced greater average grip force than did females, which is in tandem with our findings. In addition Leyk et al (37) in their study which examined hand grip strength of young male and female athletes affirmed that grip strength of male athletes were significantly stronger than that of the female counterpart. In a study by Vivian et al (38), they reported a general increase in the strength of male compared with female. Also Sinaki et al (39) reported that men are relatively stronger than women with respect to muscle strength. The significant difference between men and women strength especially the grip strength in our study was explained with a study conducted by Miller et al (40) in which they investigated the strength of men and women biceps and vastus lateralis. They found that muscle mass of men had relatively enlarged type I fiber cross sectional areas than women in biceps brachii and significantly larger type II fiber areas and mean fiber areas in vastus lateralis than women. They concluded that greater gender difference in upper body strength can probably be attributed to the fact that women tend to have a lower proportion of their lean tissue distributed in the upper body. Therefore women grip strength may be generally lower than that of men.

Conclusion

It can be concluded from the study that grip strength is at maximum when the elbow is at angle 90^0 and shoulder is at angle 0^0 in sitting position and the grip strength is lowest at 180^0 shoulder flexion, elbow at 90^0. It is then recommended that for maximum performance of grip strength in sitting position, elbow should be placed at 90^0 flexion and shoulder at 0^0.

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Received: August 10, 2017
Accepted: October 30, 2017