Comparative Study of Grip Strength in Different Positions of Shoulder and Elbow with Wrist in Neutral and Extension Positions

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Abstract

This study investigated the effect of shoulder, elbow positions with respect to wrist positioned in neutral and in extension in 25 males and 25 females. A hydraulic dynamometer was used to measure the grip strength in six testing positions with respect to wrist positioned in neutral and in extension. The six grip strength tests consisted of three positions in which the elbow was maintained in full extension with varying degrees of shoulder flexion (0^0, 90^0 and 180^0) and other three positions where the elbow was maintained in 90^0 flexion combined with varying degrees of shoulder flexion (0^0, 90^0 and 180^0). Only the dominant hand was tested. The highest mean grip strength score was recorded when the shoulder was positioned in 180^0 of flexion with elbow in complete extension with respect to wrist being positioned in neutral (30.20 ± 8.74) and wrist in extension (25.44 ± 7.51), while the lowest mean grip strength score was recorded when shoulder was positioned in 180^0 flexion with elbow 900 flexion with respect to wrist being positioned in neutral (21.92 ± 7.45) and wrist in extension (19.40 ± 6.21). Finally grip strength differed significantly for both sexes and study showed males have greater grip strength than females with respect to wrist being positioned in neutral and in extension. In essence, our study affirms that various joint positions can affect grip strength, especially elbow and shoulder joints with respect to wrist positions (neutral and extension). Clinically useful information may be derived from these findings and are valuable in evaluation and rehabilitation training of hand injured patients

Key Words: Grip Strength, Hand Strength Testing, Shoulder Position, Elbow Position, Wrist Position

Introduction

Grip strength is frequently evaluated in clinical settings as an indicator of disease activity (*Rhind et al, 1980*). It is evaluated as a component of hand function. In addition to being an economical measure that is easy to administer, it is one of the best indicators of the overall strength of the limb (*Rice et al, 1989*). Grip strength is the integrated performances of muscles that can be produced in one muscular contraction (*Nwuga, 1975*). It is widely accepted that grip strength provides an objective index of the functional integrity of the upper extremity (*Myers et al, 1973; Mayers et al, 1982*).

To obtain an objective assessment of hand function there is a need for a standardized measure of hand strength. American society of hand therapist suggested a standardized testing protocol for handgrip strength in which subject is seated with the shoulder adducted and neutrally rotated, the elbow flexed at 90° and forearm in neutral and the wrist between 0 and 30 degrees extension and between 0 degrees and 15 degrees ulnar deviation (*Fess & Moran, 1981*). However, there may be clients who are unable to assume or hold this standardized testing position. Standardized grip strength testing procedures have been recommended to provide even greater objectivity of measurement. In a clinical setting, however, there are a number of reasons why it may be impossible to follow standardized testing procedures, such as patient’s inability to tolerate an upright position or the presence of contractures in upper extremity joints.

Alternative testing position may be useful, however, in identifying positions, which maximize biomechanical abilities and may assist in the design of environment and tools (*Richards et al, 1996*). Various reports have discussed the effect of testing posture and joint position on grip strength. Standing has been found to result in higher grip strengths than when sitting when using the same instrument. Differences of up to 2lb/in (140gm/cm) have been reported (*Balogun et al, 1991; Amosun et al, 1995*). Teraoka examined the effect of three body positions on grip strength: standing, sitting, and supine, with the elbow joint held in full extension in each test position. He found that grip strength was strongest with the subject in the standing position (*Teraoka, 1979*).

One study has directly examined the influence of the shoulder position on grip strength. *Su et al (1994)* compared the strength of the grip while the shoulder was in 0°, 90° and 180° of flexion. They found that the strongest grips were obtained while the shoulder was in 180° of flexion and the elbow extended. The weakest grips were found while the shoulder was in 0° and the elbow in 90° of flexion. In this study only the dominant hand was tested.

Studies on the effect of elbow position on grip strength remain controversial. *Mathiowetz et al (1985)* tested the grip strength of 29 female college students with the elbow joint flexed at 90° in one test and fully extended in another. Significantly higher grip strength was obtained in the 90° elbow flexed position than in the fully extended position. *Balogun et al (1991)* tested the grip strength of 61 college students in four positions: (i) sitting with elbow in 90° flexion; (ii) sitting with elbow in full extension; (iii) standing with elbow in 90° flexion; and (iv) standing with elbow in full extension. Lowest scores were recorded when the measurement was taken while the subject was sitting with the elbow joint in 90° flexion.

Wrist position is another variable that affects grip strength performance (*Kraft & Detels, 1972*; *Pryce, 1980*; *O'Driscoll et al, 1992*). Pryce found no significant difference in grip strength with test angles of (a) 0^0 and 15^0 ulnar deviation, (b) 0^0 and 15^0 wrist extension and (c) any combinations of these positions. *Kraft and Detels (1992)* found significant differences with wrist positioned at 0^0, 15^0 and 30^0 extensions. Both studies found grip strength to be significantly less than 15^0 of palmar flexion. Recently *O'Driscoll et al (1992)* investigated the relationship between the optimum wrist position and maximal grip strength in 20 healthy subjects. An electro-goniometer recorded the wrist position naturally assumed by the subjects during their maximal unconstrained grip. Maximal grip strength was consistently obtained for the dominant wrist in 35 ± 2^0 of extension and 7 ± 2^0 of ulnar deviation. Grip strength was significantly less in any positions of deviation from this natural or self-selected position. This finding was at variance with the finding of *Pryce (1980)* and *Kraft and Detels (1972).*

The position given by American society of Hand therapists (ASHT) accommodates range of wrist positions (0-30^0 wrist extension, 0-15^0 ulnar deviation) enabling the subjects to self-select a position of wrist comfort *(Fess & Moran, 1981).* And therefore, alternative testing positions may be useful, however in identifying positions which maximizes biomechanical abilities and may assist activities of daily living. The main objective of the current study is to establish the variation in grip strength in different positions of shoulder (0^0, 90^0 and 180^0 flexion) and elbow (90^0 flexion, 0^0 extension) with wrist in neutral and extension.

Material and Methods

A convenience sample of fifty healthy subjects from the student population of Padmashree Institute of Physiotherapy, Bangalore (25 males, 25 females) in age group of 18-25 years participated in the study. Subjects signed informed consent forms after being provided with a brief description of the study. The exclusion criteria for this study included any previous history of upper extremity abnormalities, inflammatory joint diseases, neurological disorder or injury to upper limb and other health conditions.

A standard adjustable hydraulic hand dynamometer which was manufactured in USA (Fabrication Enterprises Inc) was used for measuring grip strength. The device was set at second handle position (of the five positions available) and same dynamometer was used throughout the study.

All the subjects reported themselves to be in good health. By self report, majority of subjects were right hand dominant. Prior to the procedure subjects who met the inclusion criteria were assessed and evaluated thoroughly. Each subject's name, gender, age and BMI were recorded. Subjects in the standing position were instructed to adduct and neutrally rotate their shoulders while holding their forearm and wrist joints neutral for one set of six testing positions and also wrist in extension, while subjects were able to self-select their wrist position during testing in another set of the six testing positions:

1. 0° of shoulder flexion with elbow fully extended
2. 0° of shoulder flexion with elbow flexed to 90°.
3. 90° of shoulder flexion with elbow fully extended.
4. 90° of shoulder flexion with elbow flexed at 90°.
5. 180° of shoulder flexion with elbow fully extended.
6. 180° of shoulder flexion with elbow flexed at 90°.

Prior to the commencement of data collection, a practice trial was given to familiarize the subjects with the dynamometer. Before testing, the examiner demonstrated how to hold the handle of the dynamometer. The same instructions were given for each trial. After the subject was positioned with the dynamometer, the examiner instructed the subject to "squeeze as hard as possible … harder … harder. Relax". To control for the effects of fatigue, subjects were asked to rest for 2 minutes. For dominant hand, three trials were performed in each position. Mean of 3 trials were recorded for calculation purpose.

Data were computed with repeated measures of analysis of variance procedure (ANOVA) to determine the effects of gender and positions on grip strength, followed by use of the Newman Keul's post hoc test. In addition, multivariate analysis of variance procedure (MANOVA) was used to determine the effects of gender and all six different positions with respect to wrist positions (wrist in neutral and wrist in extension). In the above statistical analysis, a value equal to or less than 0.05 was considered evidence of statistically significant finding. These methods were applied to determine any significant grip strength differences among the total sample and different sexes for all the six hand strength tests and to identify specific group differences (positions of wrist in neutral or wrist in extension) between the six positions.

Results

Table 1 shows, the physical characteristics of the study population are summarized.

Table 1: Physical characteristics of the study population.

Measure		N	Mean	SD
Age, yr	**Male**	**25**	**20.56**	**1.04**
	Female	**25**	**20.28**	**4.13**
Height, cm	**Male**	**25**	**171.50**	**7.37**
	Female	**25**	**157.99**	**4.85**
Weight, kg	**Male**	**25**	**62.45**	**7.30**
	Female	**25**	**50.80**	**6.18**
Body Mass Index	**Male**	**25**	**21.23**	**2.05**
	Female	**25**	**20.34**	**2.36**

Table 2 & figure 1 shows means and standard deviations of grip strength scores for all six positions with respect to wrist position (neutral and extension). The highest mean grip strength was recorded; when the shoulder was positioned in 180^0 of flexion with elbow in complete extension with respect to wrist in neutral and in extension positions. While the lowest mean grip strength score was recorded when shoulder was positioned 180^0 of flexion with elbow in 90° flexion with respect to wrist in neutral and in extension positions. Also the mean grip strength scores were observed to be higher in all the six positions in neutral than the wrist positioned in extension.

TABLE 2: Means and Standard deviation of grip strength scores for all six positions with respect to wrist in neutral and in extension position.

	WRIST IN NEUTRAL (N=50)		WRIST IN EXTENSION (N=50)	
	Mean	**±SD**	**Mean**	**±SD**
PS 1	**28.32**	**8.76**	**24.76**	**8.07**
PS 2	**25.84**	**8.89**	**23.56**	**7.44**
PS 3	**26.20**	**8.68**	**23.72**	**8.02**
PS 4	**25.06**	**8.39**	**22.16**	**6.78**
PS 5	**30.20**	**8.74**	**25.44**	**7.51**
PS 6	**21.92**	**7.45**	**19.40**	**6.21**

PS 1: 0 degrees Shoulder flexion with Elbow in complete extension.
PS 2: 0 degrees Shoulder flexion with Elbow 90 degrees flexion.
PS 3: 90 degrees Shoulder flexion with Elbow in complete extension
PS 4: 90 degrees Shoulder flexion with Elbow 90 degrees flexion.
PS 5: 180 degrees Shoulder flexion with Elbow in complete extension
PS 6: 180 degrees Shoulder flexion with Elbow 90 degrees flexion.

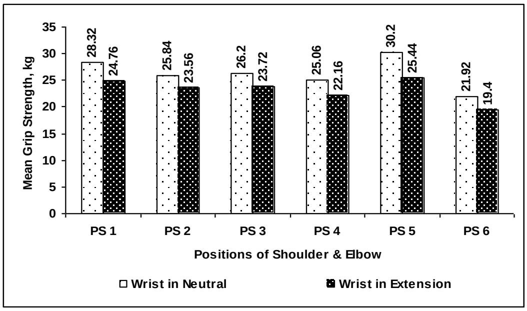

Figure 1: Comparisons of Mean grip strength for all six positions with respect to wrist in neutral and in extension positions.

Table 3 shows the means and standard deviation of grip strength scores for all six positions for different gender. The highest mean grip in females and males were recorded when the shoulder was positioned in 180^0 of flexion with elbow in complete extension with respect to wrist positioned in neutral. While the lowest mean grip strength scores in females and males was recorded when shoulder was positioned 180^0 of flexion with elbow in 90^0 flexion with respect to wrist being positioned in extension.

TABLE 3: Means and Standard deviation of grip strength scores for all six positions for different gender.

	WRIST IN NEUTRAL		WRIST IN EXTENSION	
	Males (N=25) Mean±SD	Females (N=25) Mean±SD	Males (N=25) Mean±SD	Females (N=25) Mean±SD
PS 1	36.00±4.58	20.64±3.59	31.84±4.16	17.68±3.35
PS 2	33.08±5.10	18.00±4.09	29.54±4.64	17.08±3.23
PS 3	33.31±5.18	18.50±3.50	30.15±4.16	16.75±3.86
PS 4	1.27±6.33	18.33±3.94	27.38±4.96	16.50±3.65
PS 5	37.15±5.75	22.67±3.62	31.38±4.92	19.00±3.23
PS 6	26.92±6.48	16.50±3.69	23.85±4.70	14.58±3.41

TABLE 4: Repeated measures of ANOVA determining grip strength differences in all the six positions with respect to wrist position.

Position of wrist	Source	D.F	S.S	M.S.S	F-value	P-value
Wrist in Neutral	Gender	1	14364.3	14364.3	621.9	0.00
	All six positions	5	2033.0	406.6	17.6	0.00
Wrist in extension	Gender	1	10951.3	10951.3	655.1	0.00
	All six positions	5	1180.8	236.2	14.1	0.00

[p<0.05, indicates significant finding]

Table 4 shows the repeated measures of ANOVA determining grip strength differences in all the six positions with respect to wrist position. The results of ANOVA findings indicated significant overall difference ($p<0.05$) in grip strength across six testing positions for the total sample with respect to wrist position (neutral and extension).

Consequently, The Newman Keuls post hoc analysis was done which indicated statistically significant differences existed across the six testing positions for the total sample and for both sexes with respect to wrist positions (wrist in neutral and wrist in extension position). The differences in mean grip strength scores for all six testing positions as well as for gender (male and female) with respect to wrist positions (neutral and extension) is evident from Tables 2 & 3).

TABLE 5: Summary of the MANOVA for the effects of different positions and gender with respect to wrist positions. (Wrist Positions*: Wrist in neutral, Wrist in extension)

Positions	Source	D.F	S.S	M.S.S	F-value	P-value
PS 1	Gender	1	5446.44	5446.44	348.91	0.000
	Wrist Positions*	1	316.840	316.84	20.30	0.000
PS 2	Gender	1	4928.04	4928.04	293.22	0.000
	Wrist Positions*	1	129.96	129.96	7.733	0.006
PS 3	Gender	1	5069.44	5069.44	276.57	0.000
	Wrist Positions*	1	153.76	153.76	8.39	0.005
PS 4	Gender	1	3660.25	3660.25	174.37	0.000
	Wrist Positions*	1	210.25	210.25	10.016	0.002
PS 5	Gender	1	4596.84	4596.84	235.86	0.000
	Wrist Positions*	1	566.44	566.44	29.06	0.000
PS 6	Gender	1	2601.00	2601.00	125.03	0.000
	Wrist Positions*	1	158.76	158.76	7.63	0.007

Table 5 shows, the summary of the MANOVA for the effects of different positions and gender, where the findings indicated significant overall difference ($p<0.05$) in grip strength across the six testing positions for the total sample and for both sexes with respect to the different wrist positions.

Discussion

Measurement of grip strength is an important component for hand rehabilitation. It assesses the client's initial limitation and provides a quick reassessment of client's progress throughout the treatment. This study has investigated comparative study of grip strength at different positions of shoulder and elbow with wrist in neutral and extension positions. The results reveal that the highest mean grip strength was recorded; when the shoulder was positioned in 180^0 of flexion with elbow in complete extension with respect to wrist positions (neutral and extension). While the lowest mean grip strength score was recorded when shoulder was positioned 180^0 of flexion with elbow in 90° flexion with respect to wrist positions. Grip strength decreased as shoulder was positioned in 0^0 flexion (Table no.2). These findings indicated that shoulder angle does affect grip strength performance and are similar to the results reported by *Kattel et al (1996).* He reported the effect of upper extremity posture of maximum grip strength revealed that the shoulder joint angle has influence on grip strength performance. It may be speculated that the synergistic muscles of the back and shoulder may be able to act to their best advantage, when the shoulder is elevated at 180^0 shoulder flexion during grip. This overhead position appears to allow those proximal muscles involved to be stretched beyond their normal resting length, which would theoretically increase their efficiency for optimum exertion according to the principle of length-tension relationship (*Lehmkuhl & Smith, 1985; Carlstedt et al, 1989*).

The mean grip strength scores were higher for all the six positions when wrist was positioned in neutral than in extension position (Table 2). This may be explained on the basis of the length–tension relationship of active contractile elements within a muscle (*Loren et al, 1996*). It may be that when the wrist is positioned at neutral with slight ulnar deviation the muscular compartments for individual fingers attain optimal length for maximum active force production. As the wrist moves in full extension the associated muscle compartment length for each finger exceeds the optimal range leading to decrease in grip force. This can occur can occur when musculo-tendinous units such as the extrinsic finger flexors (digitorum superficialis, flexor digitorum profundus) that are primarily responsible for powerful finger force production cross more than one joint. According to *Li (2002)* when an external force is applied at a distal phalanx during gripping, the profundus is the only flexor that balances the external extension torque at the distal interphalangeal joint and the torque balance at the proximal inter-phalangeal and metacarpophalangeal joints is progressively assisted by the flexor digitorium superficialis and intrinsic muscles. The flexor digitorum profundus originates outside the hand, inserts into the distal phalanx, and crosses many joints like the wrist, the metacarpophalangeal, proximal inter-phalangeal, and distal inter-phalangeal joints leading to increase in the length of its elements beyond optimum levels. Therefore, decreased grip force at a deviated wrist position may be primarily caused by the weakened force production capability of the flexor digitorum profundus.

In our study results were further analyzed in males and females in all six positions. Results showed existence of differences in the grip strength among males and females (Table No.3) with males exhibiting greater grip strengths than their female counterparts. Various authors have reported similar results (*Agnew & Mass, 1982; Crosby et al, 1994*). *Balogun et al (1991)* attributed the differences in strength between the genders to their physical characteristics rather than to the biological differences. Study conducted by *Su et al (1994)* reported that the highest mean grip strength was found when shoulder was positioned in 180^0 of flexion with elbow in full extension where as the position of 90^0 elbow flexion with shoulder in 0^0 flexion had the lowest grip strength scores. He also showed grip strength differed significantly for both sexes and for each age group. Though the results of our study was found to be similar to the study conducted by him, but the lowest mean grip strength was recorded when the shoulder was positioned in 180^0 of flexion with elbow 90^0 flexion with respect to wrist positions (neutral and extension). Explanation of this finding may lie in the length tension-property of muscle contraction. In our study grip strength was measured in combination of various shoulder and elbow positions with wrist in neutral or extension positions that might have produced different muscle lengths and thus grip strengths. Highest mean grip strength was recorded with 180^0 shoulder flexion and elbow fully extended with respect to wrist positions (neutral and extension). Grip strength with the elbow extension regardless of shoulder position was significantly higher than the elbow flexion position. It may be attributed to the fact that the length-tension relationship of the forearm muscles involved in producing grip strength is most favorable when the elbow is in an extension position (*Lehmkuhl & Smith,* 1985; *Su et al*, 1994). These results are in accordance with the study performed by *Su et al (1994).*

Previous studies have established that there is a relationship between handgrip strength with position of elbow (*Balogun et al*, *1991*; *Kuzala & Vargo, 1992*).

The results of the study indicate that using 0^0 shoulder flexion with elbow in fully extended position, significantly greater grip strength can be obtained as compared to any other combination of shoulder and elbow positions (Table No.2). But this result is in contrast to the standardized testing protocol given by *(Fess & Moran, 1981*). In standardized testing protocol the subject's shoulder is adducted and neutrally rotated, the elbow flexed at 90^0, and the forearm and wrist in neutral positions. These kind of alternative positions as suggested in the present study from standardized positions are useful in identifying positions which maximize biomechanical abilities and may assist in the design of environments and tools (*Richards et al*, *1996*).

In essence, our study affirms that various joint positions can affect grip strength, especially the elbow and shoulder joints with respect to wrist positions (neutral and extension). Some clinically useful information may be derived from these findings. For example, in the sports rehabilitation programmes, it would be feasible to evaluate the sports injured patients' grip strength using different combined elbow and shoulder positions to determine their maximal grip force. Later, with this knowledge, an individualized treatment program can be designed to train the athlete in the specific upper extremity positioning that provides the greatest efficiency to minimize the incidence of overuse disorders.

Our study was limited to symptomatic subjects as well as ambidextrous people. The use of convenience sample limits the generalization of the results of this study to the population at large. In our study majority of subjects were right-handed. These norms should be used with caution for left handed persons. During testing, we did not strictly control two wrist movements (neutral and extension). Another limiting factor is fatigue as there were large numbers of testing positions.

Conclusion

The changes in wrist position on grip strength are observed with variations in shoulder and elbow positions. It is vital that when measuring grip strength, one understands how small changes in body position can result in altered grip strengths. Hence the findings are valuable in evaluation and rehabilitation training of hand injured athletes or patients. Further studies are needed to find out how individual variables such as ambidexterity, work characteristics and as well as anthropometric measurements of subjects, can influence grip strength in combination of shoulder, elbow and wrist angles.

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