How Forearm Position Affects Grip Strength

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Objective. Several studies have indicated that changing body positions results in altered grip strengths. Although one might expect that grip strength would be influenced by the position of the forearm during gripping due to the biomechanical properties of the forearm and hand muscles, no investigations of this variable have been undertaken.

Method. This study examined the effect on grip strength of moving the forearm among supinated, neutral, and pronated positions while maintaining the standard position recommended by the American Society of Hand Therapists. The mean of three grip trials in each position was recorded for each of 106 subjects.

Results. Grips in forearm supination were the strongest, followed by grips in the neutral position. Grips in pronation were the weakest.

Conclusions. The changes in grip strength observed with variations in forearm position further support the necessity of a standard position for testing grip strength. The knowledge of how changes in body position affect the strength of the grip can be used to design environments and tools to maximize biomechanical abilities.

Grip strength is correlated with upper extremity function (Hyatt, Whitelaw, Bhat, Scott, & Maxwell, 1990; Shiffman, 1992), overall strength (Niebuhr & Marion, 1990), biological growth (Jones, 1949), and the amount of protein reserves in the body (Windsor & Hill, 1988). Because of these correlations, grip strength has been used as an objective clinical measure in a variety of situations. For example, grip strength has been used to assess general strength in order to determine work capacity (Gilbert & Knowlton, 1983), to determine the extent of injury and disease processes and the potential for and progress in rehabilitation (Petersen, Petrick, Conter, & Conklin, 1989), and to indicate the likelihood of postoperative complications (Griffith, Whyman, Bassey, Hopkinson, & Makin, 1989).

The quality of the information gained from grip strength measurement and its interpretation depends on established reliability of the instruments, the consistency of test administration, and the use of appropriate normative data against which to compare a person's grip strength (Fess, 1986). The development of hydraulic dynamometers, such as the Jamar1, has led to relative reliability in instrumentation. However, there is often little consistency in test administration—either in the instructions given to the client, in the number of grip trials measured, or in the body positions used when testing grip strength (Kritz-Silverstein & Barrett-Connor, 1994; MacDermid, Kramer, Woodbury, McFarlane, & Roth, 1994; Smith & Benge, 1985; Sunderland, Tinson, Bradley, & Hewer, 1989; Tsuji et al., 1995). Such inconsistencies are problematic when comparing client performance with normative data. Deviations from the protocols used in collecting the normative data may invalidate the use of such norms.

In an attempt to establish more rigorous grip strength testing procedures, the American Society of Hand Therapists suggested that grip strengths be measured with the client seated in a straight-backed chair with feet flat on the floor (Fess & Moran, 1981). The tested extremity should be held adducted against the body in neutral rotation, the elbow flexed to 90°, and the forearm in neutral rotation (the standard position, according to Fess and Moran). However, there may be clients who are unable to assume or hold this standard position. There are also numerous daily tasks that require gripping in positions other than this standard position. Thus, for clinical and ergonomic reasons, it is necessary
to understand how deviations from this standard position affect grip strength. The study reported here was concerned with how changes in forearm position affect the strength of the grip.

Several investigators have examined how deviations in the position of the whole body and the shoulder, elbow, and wrist joints influence grip strength. Three studies have investigated the effects of changing whole body position on grip strength. Tetakoa (1979) found that grip strengths measured while subjects were standing were stronger than those measured when subjects were either sitting or lying supine. Grips in the seated position were stronger than those in the supine position. The elbow was extended in each of these positions. Balogun, Akomolafe, and Amusa (1991) compared grip strength while sitting and standing with the elbow either flexed to 90° or fully extended. They also found stronger grips when subjects were standing with the elbow extended.

Only one study has directly examined the influence of the shoulder position on grip strength. Su, Lin, Chien, Cheng, and Sung (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 addition to the studies by Balogun et al. (1991) and Su et al. (1994), two other studies have found grips to be strongest when the elbow was extended. Kazala and Vargo (1992) found no difference in grip strengths between 0° and 45° or between 90° and 135° of flexion but found that grip strengths at 0° and 45° were stronger than those in the more flexed positions. Araujo, Oliveira, Ferraz, Ciconelli, and Atra (1992) also found a similar but insignificant pattern of results. They found that the grip strengths of persons with rheumatoid arthritis decreased with increases in elbow flexion from 30° to 90° to 130°. Only Mathiowetz, Rennells, and Donahoe (1985) have obtained contradictory findings. They found that grip strengths measured with the elbow in 90° of flexion were stronger than grip strengths measured with the elbow in extension. It is not readily apparent why Mathiowetz et al. found results opposite to the four previously discussed studies; there may be other factors operating in his study that have not yet been delineated.

Varying wrist position has also been found to affect grip strength. Pryce (1980) compared the strength of grip across six positions of wrist ulnar deviation and flexion–extension. The greatest grip strength was obtained when the wrist was positioned from 0° to 15° of ulnar deviation and from 0° to 15° of extension. Although grip strengths in these positions did not differ from each other, strengths were greater than when the wrist was positioned in either flexion or 30° of ulnar deviation.

It is apparent that changing body positions can lead to changes in grip strength. However, there is not consensus as to the exact nature of these changes. In addition, it is not known whether changes in all limb positions will lead to altered grip strengths. For example, how changes in forearm position affect grip strength has not been investigated.

Changes in forearm position have the potential to change the length of the extrinsic muscles of the hand. It is these extrinsic muscles that determine most of the strength and stamina (Motamed, 1982; Tubiana, 1981) of the cylindrical type of power grip (Harrison, 1981; Long, 1981), the fist grasp (Luhmkuhla & Smith, 1983), or whole hand grip (Malek, 1981). The power grip involves the long flexor and extensor muscles of the fingers and thumb that originate from the radius and ulna in the forearm and from the medical and lateral epicondyles of the humerus. These muscles cross the wrist and finger joints, and some cross the elbow joint. The long flexors and extensors work synergistically to stabilize the intermediate joints, such as the wrist, while allowing maximal contraction at the joint doing the work (Norkin & Levangie, 1992). Because all muscles have an optimal length at which they produce maximal contraction, any external shortening or lengthening of the muscle fibers of the long flexors and extensors of the fingers and thumb could decrease their ability to contract maximally (Brand, 1993; Norkin & Levangie, 1992). Changing the position of the upper extremity mechanically changes the spatial relationships among these extrinsic hand muscles. Thus, their interaction is potentially affected by elbow, wrist, and even shoulder position, as well as forearm and hand position. The purpose of this study was to determine whether varying forearm position would result in varying grip strength.

Method

Subjects

The subjects were 51 men and 55 women aged 18 to 84 years. Mean age was 37.85 years. By self-report, subjects had no history of neurological disorder, no fracture of the upper extremity since the age of 18, no diagnosed arthritis, and no other condition limiting strength in their upper extremities. Subjects' hand dominance was measured via a handedness questionnaire that asks about hand use in five common activities (Bryden, 1972). Scores on the questionnaire range from -1.0, indicating
extreme left handedness, to +1.0, indicating extreme right handedness. Subjects demonstrated the full range of handedness scores, with a mean of +.74.

Tests

Nine occupational therapy undergraduate students tested the subjects over the course of 2 years. Because Fess and Moran (1981) have indicated that there is high interrater reliability among testers when using a standard position and the Jamar dynamometer to measure grip strength, we did not establish interrater reliability among the testers. Instead, each tester established criterion performance before data collection.

Instrument

Grip strengths were measured with a Jamar dynamometer at the second handle position. We did not check the calibration of the dynamometer during the first year of data collection. Instead, the dynamometer was checked for similarity of measurement against two other in-house Jamar dynamometers. During the second year of data collection, the calibration of the dynamometer was checked by placing the dynamometer dial up in a vise and laying a 5-lb weight across the handle. Although full calibration was not performed, potential errors by the dynamometer in measuring strength did not affect our primary results.

Procedure

Each subject’s name, gender, and age was recorded. As part of a larger study, each subject’s height, weight, and hand size were also recorded. Each subject was then seated in a straight-backed chair in the standard position. Grip strengths in each hand were measured with the forearm in neutral, supinated, and pronated positions. The order of the starting hand and the order of positions tested were counterbalanced across subjects. The dynamometer was placed in one of the subject’s hands with the tester lightly holding the instrument around the readout dial and supporting it under the bottom to prevent accidental dropping. The tester told the subject to squeeze as hard as possible, adding “harder...harder.” The subject was then told to relax. For each hand, three trials were performed in each position with the mean being recorded. To control for the effects of fatigue, trials on each hand alternated so that there was approximately a 2-min rest between trials for each hand.

Results

Mean grip strengths in each condition for each subject were entered into a 2(hand) x 3(position) x 2(gender) split plot analysis of variance. Consistent with previous research (Balogun et al., 1991; Mathiowetz et al., 1985), men tested stronger than women, \( F(1, 104) = 339.05, p < .0001 \). This finding was most likely attributed to the generally larger physiques of men (Balogun et al., 1991). Right-hand grips were stronger than left-hand grips, \( F(1, 104) = 44.26, p < .0001 \), probably because most of our sample was right-handed.

Our main interest was in the effect of varying forearm position on the strength of the grip. The mean grip strengths obtained when the forearm was in supination, neutral position, and pronation can be found in Figure 1. Changing forearm position resulted in altered grip strengths, \( F(2, 208) = 103.20, p < .0001 \). Grip strength in each position was significantly different from grip strength in each of the other positions (supination vs. pronation: \( t(105) = 11.27, p < .0001 \); supination vs. neutral position: \( t(105) = 2.62, p < .01 \); pronation vs. neutral position: \( t(105) = 11.63, p < .0001 \)), with supination being the strongest and pronation being the weakest. Although they differed, grip strengths in each of the forearm positions were highly correlated (see Table 1), indicating that the amounts of strength in each of the positions were associated with each other.

For both men and women and for both hands, mean grip strengths in supination were always the strongest, and mean grip strengths in pronation were always the weakest. However, significant gender X position, \( F(2, 208) = 9.47, p < .0001 \), and hand X position, \( F(2, 208) = 3.46, p < .04 \), interactions indicated that grip strengths in each position were not always significantly different across both gender and hands. The gender X hand X position interaction was not significant (\( F < 1 \)).

Figure 2 displays the mean grip strengths for each position in each hand. Using a significance level of .0087 (Dunn’s procedure: Kirk, 1982), we found that for the left hand, grips varied in strength among all three fore-
Table 1

Correlation Coefficients for Supination, Neutral Position, and Pronation of Forearm

<table>
<thead>
<tr>
<th></th>
<th>Supination</th>
<th>Neutral</th>
<th>Pronation</th>
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</thead>
<tbody>
<tr>
<td>Supination</td>
<td>1.0000</td>
<td>0.9659</td>
<td>0.9523</td>
</tr>
<tr>
<td>Neutral</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.9673</td>
</tr>
<tr>
<td>Pronation</td>
<td>1.0000</td>
<td>0.9523</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

arm positions (supination vs. pronation: $t_{105} = 10.29$, $p < .0001$; supination vs. neutral position: $t_{105} = 2.84$, $p < .006$; neutral position vs. pronation: $t_{105} = 8.88$, $p < .0001$). In the right hand, grips in neutral position were stronger than grips in pronation ($t_{105} = 10.75$, $p < .0001$), and grips in supination were stronger than grips in pronation ($t_{105} = 9.96$, $p < .0001$). However, grips in supination were not significantly stronger than grips in neutral position ($t_{105} = 1.83$, $p > .06$).

For both men and women, the difference in strength between supination and neutral position was minimal (men, 2 lbs; women, 1 lb) and insignificant (alpha = .0087 by Dunn’s procedure: Kirk, 1982) (men: $t_{50} = 2.28$, $p > .02$; women: $t_{54} = 1.31$, $p > .1$). For men, grip strength in pronation was significantly weaker than in both supination and neutral position (supination vs. pronation: $t_{51} = 9.32$, $p < .0001$; neutral position vs. pronation: $t_{51} = 8.83$, $p < .0001$). This was also the pattern for the women (supination vs. pronation: $t_{54} = 7.56$, $p < .0001$; neutral position vs. pronation: $t_{54} = 8.94$, $p < .0001$). However, the difference in strength between pronation and both supination and neutral position was larger for men than it was for women (see Figure 3).

Discussion

Varying the position of the forearm altered the strength of the grip. Grips in both hands were strongest when the forearm was supinated and weakest when pronated. Grip strength with the forearm positioned in the neutral position was either similar to grip strength in supination or fell between the strength of grip in supination and pronation. This was true for both men and women, although the difference in grip strength among the positions was greater for men than for women.

Our finding that forearm supination produced the strongest grips is probably directly related to the anatomy of the forearm and hand. The power grip is a result of forceful flexion of all finger joints (Cailliet, 1994; Norkin & Levangie, 1992). Under normal biokinetic conditions, the power of the grip is primarily attributed to the action of the long flexor tendons (Motamed, 1982; Tubiana, 1981). However, power grip also involves the long and short flexor muscles of the thumb and of the little finger because the object to be gripped is held in place or steadied by these muscles (Cailliet, 1994; Harrison, 1981). In addition, the wrist must be stabilized to obtain a forceful grip. Thus, the synergistic action of flexors and extensor muscles and the interplay of muscle groups is an important factor in the strength of the resulting grip.

As stated previously, all muscles have an optimal length at which they produce maximal contraction. Any external shortening or lengthening of a muscle changes the length–tension relationship of its fibers and impairs that muscle’s ability to contract maximally (Brand, 1993; Norkin & Levangie, 1992). Supination and pronation take place around the superior and inferior radioulnar joints. As the hand moves from supination to pronation, the direction of pull of the muscles in the anterior or flexor compartment is changed, especially in those muscles that originate from the radius as it rotates around the stationary ulna (Valentin, 1981).

During supination, the long flexors of the fingers

![Figure 2](http://ajot.aota.org/pdfaccess.ashx?url=/data/journals/ajot/930010/)  
**Figure 2.** Mean grip strengths for the right and left hand with the forearm in supination, neutral position, and pronation.

![Figure 3](http://ajot.aota.org/pdfaccess.ashx?url=/data/journals/ajot/930010/)  
**Figure 3.** Mean grip strengths for men and women with the forearm in supination, neutral position, and pronation.
that originate in the forearm are in a position to contract maximally. These muscles include the flexor digitorum superficialis, which arises primarily from the anterior oblique line of the radius; the flexor digitorum profundus, which originates from the radial side of the interosseous; and the flexor pollicis longus, which originates from the anterior surface of the radius (Valentin, 1981). Moving the hand from a supinated to a pronated position rotates the radius over the ulna, and these muscles “wrap” around the radius as it rotates. The resulting change in length of these muscles may alter the optimal length-tension relationship and impair their ability to achieve maximum contraction, to act as a synergist, or to act as a stabilizer of a joint (Brand, 1993). The brachioradialis and the extensor carpi radialis longus and brevis muscles in the posterior compartment of the forearm would also potentially be affected because they originate from the posterior surface of the lateral epicondyle of the humerus and insert on the radius and bases of the second and third metacarpals, respectively (Brand, 1993). On the basis of these potential changes in the length-tension relationships, one would predict a weaker grip in the pronated position than in the supinated position. The change in length of the long flexor muscles from supination to pronation also potentially changes the synergistic relationships among the long extensors of the fingers and the flexor and extensor muscles that stabilize the wrist joint. The potential result is a decreased ability to stabilize the wrist, which could lead to decreased grip strength (Brand, 1993).

Our finding that the strongest grip strengths occurred when the forearm was in supination and the weakest when the forearm was in pronation supports both of the hypotheses stated earlier. However, the high correlations among the grip strengths in each of the forearm positions suggests that the possible change in length of these muscles was not enough to cause a severely weakened grip in the pronated position when measured at the second handle position of the Jamar dynamometer. It is likely that even greater differences in strength among forearm positions would have been obtained had we tested the subjects’ grip strength at handle position five. Although grip strength at position two is determined by both the extrinsic and intrinsic muscles of the hand, grip strength at position five is primarily determined by the extrinsic muscles (Bear-Lehman & Abreu, 1989). Further investigation, including electromyographic studies, need to be done before we can definitively state that the change from supination to pronation causes enough of a change in the length or synergistic relationships of the long flexor muscles to significantly weaken the grip.

The finding that grip strength varies with alterations in forearm position adds further support to the recommendation of the American Society of Hand Therapists that clinicians and researchers should use a standard position when measuring grip strength (Fess & Moran, 1981). It also indicates that one should only compare a person’s grip strength with normative data when the grip is measured in the identical position to that used when collecting the normative data. Should the use of a standard position not be feasible for a person, the most one should do is compare that client’s grip strength on one occasion with his or her grip on subsequent occasions, being meticulous in using the identical body positions to measure grip each time.

Limitations
The use of a convenience sample limits the generalization of the results of this study to the population at large. In addition, the study was conducted on persons without a history of conditions that might limit upper extremity strength. Although it is important to understand how changes in body position affect grip strength in persons without impairments, both for comparative and ergonomic reasons, the relationships between grip strength and body positions may not be identical for populations with upper extremity weakness of various etiologies.

Another potential limitation of the study is that we did not establish interrater reliability among all the testers. However, as stated earlier, the testers did establish criterion performance before data collection. Fess and Moran (1981) indicated that there is high interrater reliability among testers when using a standard position and the Jamar dynamometer to measure grip strength.

During the first year of the study, we did not definitively check the calibration of the dynamometer. However, when the calibration was checked in the second year of data collection, the calibration was accurate. Because it is unlikely that during year one the calibration had become inaccurate, only to return to accuracy during year two, we are confident that the calibration was accurate during year one.

Conclusion
This study compared the strength of the grip among three forearm positions: pronation, supination, and neutral position. We found that changes in forearm position resulted in changes in grip strength, even though the rest of the body remained in the standard position recommended by the American Society of Hand Therapists. It is likely that this is due to the changing mechanical relationships between the muscles involved in grip as the forearm is rotated from supination to pronation.

It is vital that when measuring grip strength, one
underscores how small changes in body position can result in altered grip strengths. The findings of multiple studies that changes in body positioning results in altered grip strength means that any retesting of a person’s grip must take place when the person’s position is identical to that of the first assessment. There are also ergonomic ramifications. Knowledge of body positions that afford the strongest grips is needed when designing and spatially orienting equipment that requires a maximum grip to operate. Our results suggest that equipment requiring such a grip should be designed to allow gripping to occur with the forearm in the supinated position.

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References


