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REVIEWARTICLE

IMPACT OF POSITIONS OF SHOULDER, ELBOW, WRIST, BODY POSTURE AND HAND SPAN ON GRIP STRENGTH - A REVIEW STUDY

Manjula[1] , Kaur. J[2], Malik. M[3] , Joshi. S[4].

1)Teaching Associate, Department of Physiotherapy, Guru Jambheshwar University of Science & Technology, Hisar.
2)Assistant Professor, Department of Physiotherapy, Guru Jambheshwar University of Science & Technology, Hisar.
3)Assistant Professor, Department of Physiotherapy, Guru Jambheshwar University of Science & Technology, Hisar.
4)Assistant Professor, Department of Physiotherapy, Guru Jambheshwar University of Science & Technology, Hisar.

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***Corresponding Author**

Manjula

Abstract

Grasping and manipulating objects is one of the most pervasive and perhaps most important activity among all human physical activities. While grasping was necessary in early human development for handling tools and for accomplishing other basic necessities of life, today it is a precursor to more sophisticated tasks and especially in the work place. Activities of daily life like eating, bathing, brushing hair, ironing clothes, getting medicines primarily require holding of any tool in hand. Many daily functions and sporting events require high activity levels of the flexor musculature of the forearms and hands. These are the muscles involved in gripping strength. This review focuses on the relationship of grip strength with different positions of shoulder, elbow, wrist, body posture and hand span. The study was conducted with an objective to find which positions of shoulder, elbow, forearm and wrist yield maximum grip strength. It was concluded that positioning of upper limb, posture and hand span play an important role in measurement of grip strength.

Introduction

Man is capable of achieving an extremely wide variety of functions and skills with the hand. The baby learns to grasp a finger placed in his/her hand during first 6 months of life. At about 3 months, baby learns to extend fingers. At 4-5 months baby develops a primitive pincer grasp and can pick up small objects between finger and thumb. The skill of prehension is acquired during the following months with gradual improvement in the stability of the upper arm and in hand by coordination (Maureen & Lynn, 2000).

Hand Grip Strength is an easily obtainable measure of physical health & muscle function. Handgrip strength is measured in either kilograms or Newtons by squeezing a handgrip strength dynamometer with one's maximum strength (Kuzala & Vargo, 1991). The power of grip is the result of forceful flexion of all finger joints with a maximal voluntary force that the subject is able to exert under normal bio kinetic conditions (Richards et al. 1996 and Bohannon 1997). Grip strength is the force applied by the hand to pull on suspend from objects. The hand represents the most sophisticated and differentiated musculoskeletal tool in the human being, demanding the largest capacity of the nervous system in relation to its size. Full function and adequate strength of the hand are preconditions for dealing with the demands of daily life (Felix et al. 2010) . A Reliable and valid evaluation of hand strength can provide an objective index of general upper body strength (De S et. al. 2011). Grip strength is a useful tool for assessing a variety of sport and clinical conditions (Richards et. al. 1996).

It is recommended that grip forces, especially when applied repetitively, may produce significant muscular strains in the hand and should be avoided. Therefore, one needs to understand the nature of hand gripping in order to prevent manual muscle overexertion and enhance task performance. (Nurgul, 2002).

Variables affecting grip strength measurement are the position of shoulder, elbow, wrist, body posture and hand span (Su CY et. al., 1994, Methowetz et. al., 1985, Krafts & Detels, 1972, Watanabe et. al. 2005) as shown in figure 1.1. The information regarding the relationship of hand grip strength with the different variables viz position of shoulder, elbow, wrist, body posture and hand span is scanty so the present study was planned. The purpose of this literature review is to dissect the importance of grip strength and how it correlates to various variables like shoulder, elbow, wrist position, body posture and hand span .

Impact of Shoulder Position on Grip Strength

Position of shoulder plays a significant role on grip strength. Su et al (1994) conducted a study with an objective to evaluate the influence of shoulder position on gip strength. A total of 160 subjects were included in the study and their grip strength was measured with Jamar dynamometer (figure 1.2) in the four testing positions. The four hand strength tests consisted of three positions in which the elbow was maintained in full extension combined with varying degrees of shoulder flexion (i.e. 0º, 90º, and 180º) and of one position in which the elbow was flexed at 90º with the shoulder in 0º of flexion. Only the dominant hand was tested. It was concluded that the mean grip strength measurement was highest with shoulder positioned at 180º of flexion with elbow in full extension; whereas the lowest mean grip strength was recorded with elbow positioned at 90º of flexion with shoulder in 0º of flexion.

Parvatikar and Mukkannavar (2009) investigated the effect of shoulder, elbow positions on grip strength with respect to wrist positioned in neutral and in extension in 50 subjects. Grip strength of dominant hand was tested. The findings were that the highest mean grip strength score was recorded when the shoulder was positioned in 180º of flexion with elbow in complete extension with respect to wrist being positioned in neutral and wrist in extension, while the lowest mean grip strength score was recorded when shoulder was positioned in 180º flexion with elbow in 90º flexion with respect to wrist being positioned in neutral and wrist in extension.

These findings suggested that shoulder angle has a significant impact on grip strength performance. Kattel et al (1996) in their study reported the influence of upper extremity posture i.e. shoulder joint angle on grip strength performance. The synergistic action of muscles of the back and shoulder act to their best advantage and yield maximum grip strength, when the shoulder is elevated at 180º of flexion. 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). But Kong et. al. (2011) in their study found that shoulder angle should be between 45º and 135º for optimal grip strength and comfort. Therefore further investigation is needed with extended number of subjects to find the accurate angle of shoulder for grip strength measurement.

Effect of Elbow Position on Grip Strength

Various studies have been conducted to demonstrate the impact of elbow position on grip strength and their results vary significantly. Mathiowetz, Rennells, and Donahoe (1985) found that grip-strength scores were higher with the elbow positioned in 90° of flexion as compared with when the elbow was positioned in full extension.

Kuzala and Vargo (1992) also studied relationship of elbow position and grip strength in forty-six graduate students. Grip-strength measurements were taken with the elbow positioned at 0°, 45°, 90°, and 135º of flexion. The highest mean grip strength was recorded at 0º of flexion while 135º of elbow flexion was the position of weakest grip strength where as Fess & Moran (1981) advocated that the second handle position of the Jamar Dynamometer with elbow at 90º flexion be used for grip evaluation and that the mean of three successive trials be recorded as the measure of grip strength.

Su et al (1994). found significantly higher grip strength in 160 Chinese subjects with the elbow fully extended rather than flexed regardless of shoulder 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.

Shyam et. al. (2008) conducted a study of grip endurance and strength in different elbow positions with twofold aim i.e. to investigate the optimum position of the elbow while measuring grip endurance and to investigate the optimum position of the elbow while measuring peak grip strength. A total of 45 healthy adults participated in this study. Grip strength and endurance were measured using computerised handgrip analyser for the non dominant hand with 90° of flexion and then with full extension of the elbow for each participant. *T* test analysis showed no statistical significance for elbow positions for grip endurance ($P = 0.67$) and peak gip

strength (P = 0.93). This study shows that there is no statistically significant difference between different positions of the elbow (90° flexion and full extension) for peak grip endurance values.

Desrosiers J et al (1995) investigated impact of elbow position on grip strength of 49 elderly men. Grip strength was measured at two elbow positions i.e. full extension and 90° of flexion. Significantly higher grip strength was recorded in the non-dominant hand with the elbow flexed to 90° rather than fully extended but no such difference was documented for the dominant hand between 2 elbow positions.

Barut & Demirel (2012) examined the effect of testing posture and elbow position on grip strength in individuals aged between 9 and 18 years. A hand held dynamometer was used to measure grip strength of 546 subjects in two positions: (1) standing with elbow in full extension, forearm in full supination (anatomical position) and (2) sitting with elbow in 90° flexion, forearm in semi pronation lying on an arm rest. The subjects were asked to squeeze the dynamometer three times with each hand and for each testing positions with 1-minute resting period between each trial in order to overcome fatigue. Paired t test was used to evaluate the two testing positions. Only the right hand grip strength was significantly higher in anatomical position in girls ($p<0.05$). Besides this result, no statistically significant differences were reported for the left hand grip strength of girls and for both the hands of boys ($p>0.05$) when the two testing positions were considered.

The above mentioned studies showed conflicting results. Some support that grip strength is higher with elbow in full extension while other support position of elbow 90° flexion and remaining advocates that there is no statistical difference between the two positions. From a biomechanical perspective, one might consider length-tension relationships of the muscles involved. Flexor digirorum superficialis is the only primary finger flexor that crosses the elbow joint; therefore, elbow position may affecr the strength performance of this muscle. As a muscle is placed in a shortened position, it may become incapable of generating the tension necessary to achieve a functional contraction (Kendall & McCreary, 1983). As the elbow is placed in more degrees of flexion, flexor digitorum superficialis is progressively placed in a more shortened position, thereby placing it at a mechanical disadvantage. This may serve to explain the decrease in grip strength that resulted with varying degrees of elbow flexion.

Contrary to this two other studies support higher grip strength measurement with elbow in 90° flexion while one study demonstrated nill association of elbow position with grip strength. So there is further need to find the accurate relation of elbow position with grip strength.

Influence of Wrist Position on Grip Strength

Another variable wrist position also has a significant impact on grip strength performance (Kraft & Detels, 1972; Pryce, 1980; O'Driscoll et al, 1992). Pryce concluded with his study that there is no significant difference in grip strength with test angles of (i) 0° and 15° ulnar deviation, (ii) 0° and 15° wrist extension and (c) any combinations of these. Kraft and Detels (1992) also found grip strength to be significantly less with 15° of wrist flexion.

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 $35^o \pm 20^o$ of extension and $7^o \pm 20^o$ 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^o - 30^o wrist extension, 0^o -15^o ulnar deviation) enabling the subjects to self-select a position of wrist comfort (Fess & Moran, 1981).

Lomoreaux L & Hoffer (1995) conducted a study to examine the impact of wrist deviation on grip and pinch strength in 12 normal right handed adults. Wrist positions of neutral, maximal ulnar deviation (41^o) & maximal radial deviation (26^o) were held in short arm casts while grip and pinch strength were measured and grip strength was found to be less with radial deviation as compared to ulnar deviation. Wrist position was neutral with respect to flexion and extension.

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.

Effect of Testing Posture and Hand Span on Grip Strength

A change in testing posture and hand span may also alter grip strength measurement. Richard et.al. (1997) conducted a comparative study to examine whether grip strengths were different when measured in supine and sitting positions with seventy four healthy adults. Participants performed grips with each hand while sitting and standing. Shoulder was adducted and extended with the elbow flexed, and wrist and forearm in neutral. Three trials with each hand in each posture were performed. They concluded that grip strength measurements were equivalent when tested in the supine and sitting positions and posture had no significant impact on grip strength measurement.

Watanabe et.al. (2005) conducted a study to examine effect of posture i.e. standing, sitting and supine and grip span on grip strength. One hundred healthy subjects were evaluated. Grip strength was measured twice as a single set by using a dynamometer and the mean value for each hand was recorded. One set of measurements was performed in 3 postures: standing, sitting, and supine. They concluded that with regard to posture the minimum grip strength in both genders was obtained when the subject was supine, with no difference between standing and sitting. So posture should be considered for maximum grip strength measurement data accuracy.

Vanesa Espana Romero et. al. (2008) conducted a study with dual objectives . The first aim was to determine whether there is an optimal grip span for determining the maximum hand grip strength in boys and girls aged 6 to 12 years and whether the optimal grip span was related to hand span. A total of 123 boys and girls were evaluated. Each hand was randomly tested on 10 occasions using 5 different grip spans, allowing a 1-minute rest between attempts. The hand span was measured from the tip of the thumb to the tip of the little finger with the hand opened widely (figure 1.3) and grip span from the external base of the grip to the mark placed in the central strip of the dynamometer as shown in figure 1.4. The result of the study was that an optimal grip span to determine maximum hand grip strength was identified for both genders. Hand span and optimal grip span showed a significant linear association in the studied children. The equation relating grip span as a function of hand span in boys is formulated as $y \_ x/4 \_ 0.44$ and in girls as $y \_ 0.3x - 0.52$, where x is the hand span (maximal width between first and fifth fingers) and y is the optimal grip span. The results suggest that there is an optimal grip span to which the dynamometer should be adjusted when measuring hand grip strength in children. The optimal grip span was influenced by hand span in both genders.

Jonathan Ruiz-Ruiz et. al. (2002) investigated which position (grip span) on the standard grip dynamometer result in maximum grip strength. Seventy healthy subjects free of upper-limb lesions were evaluated. Hand size was measured in both hands at maximal width and by measuring the distance separating distal extremes of the first and fifth digits (Fig. 1.5) and grip strength was measured using hand held digital dynamometer. Each hand was randomly tested on 10 occasions using 5 different grip spans. The findings showed that (1) optimal grip span was identified for both genders and (2) hand size and optimal grip span correlated in women but not in men. Thus when measuring handgrip strength in women, hand size must be taken into consideration.

Teraoka (1979) 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.

Thus from the results of the above mentioned studies it is clear that grip strength is influenced by hand span. Different parts of hand as palm length, finger length especially the length of middle finger imparts biomechanical effects while measuring grip strength and it could be concluded that finger lengths may be more significant in handgrip strength than palm length and it is important to measure the perimeters of the hand for practical point. (Hager-Ross, Schieber (2002), (Visnapuu & Jurimae, 2007). Finger spans, finger lengths and hand perimeters are predictors of hand grip strength. So these parameters should be considered while measuring grip strength (Ali Asghar & Ali Akbar, 2011).

Comfortable postures are defined to be those that have a low biomechanical load (Mathilde et al, 1997). A difference in maximum handgrip force generation in different upper limb postures can be measured and the reason behind for changes in grip strength can be related to variation in muscle force capacity resulting from change in muscle length with different posture. Regarding impact of posture on grip strength the results of the above mentioned studies are very much ambiguous. In addition, measurement of grip strength is also influenced by specific experimental conditions such as testing protocols and the equipment used (Barut & Demirel, 2012). Thus a precise conclusion can not be drawn and the concerned should be explored further.

CONCLUSION

In summary, we found that the various variables like upper limb position, testing posture and hand span are significantly correlated with grip strength. The hand is considered as the most sophisticated musculoskeletal tool in the human being. Full function and adequate strength of the hand is basic necessity for dealing with the demands of daily life. Hand strength has been considered as an important factor predicting not only disability in musculoskeletal diseases but also generalized strength of a human being. It also predicts complications after surgical interventions and general disability in elderly people. Hand grip strength is also considered as an objective parameter to quantify outcome after orthopedic interventions. Measurement of handgrip strength using a hand held dynamometer is a simple and economical test that gives practical information on muscle, nerve, bone, or joint strength and that is why it is currently used worldwide . Levels of physical activity are directly correlated with the differences in grip strength. Grip strength is also measured in several sport disciplines and on the admission tests for different types of work as police, army or fire brigade. Therefore, from a public health perspective it is important to standardize the procedure and increase the reliability to minimise the measurement error otherwise measurement error may be too large to detect actual changes in strength. It must be borne in mind that different variables may affect grip strength accordingly. Many daily functions and sporting events require high activity levels of the flexor musculature of the forearms and hands and these are the muscles involved in gripping strength. Whether it's sports or daily activities, some degree of grip strength is necessary to be successful. Often overlooked but the strength of one's grip plays a key role in injury prevention and overall strength more than an individual's handgrip strength. Hand grip strength is a cost effective, non-invasive screening tool to evaluate a person's general well being. The knowledge of relationship of above mentioned variables with grip-strength scores can be incorporated into treatment techniques and functional activities and an effective rehabilitation as well as training programme can be designed to help achieve an individual's optimized level of performance. With the knowledge of above mentioned grip strength, the evaluation of an individual's strength can be done with much more precision and a more valid, reliable and standardized protocol can be designed. The findings of this review literature may also be useful in the process of sports talent identification in grip sports such as handball, basketball, volleyball, baseball, wrestling, judo, rock climbing and rowing etc. The findings are of utmost importance in designing a rehabilitation protocol for sportspersons, hand injured athletes or patients.

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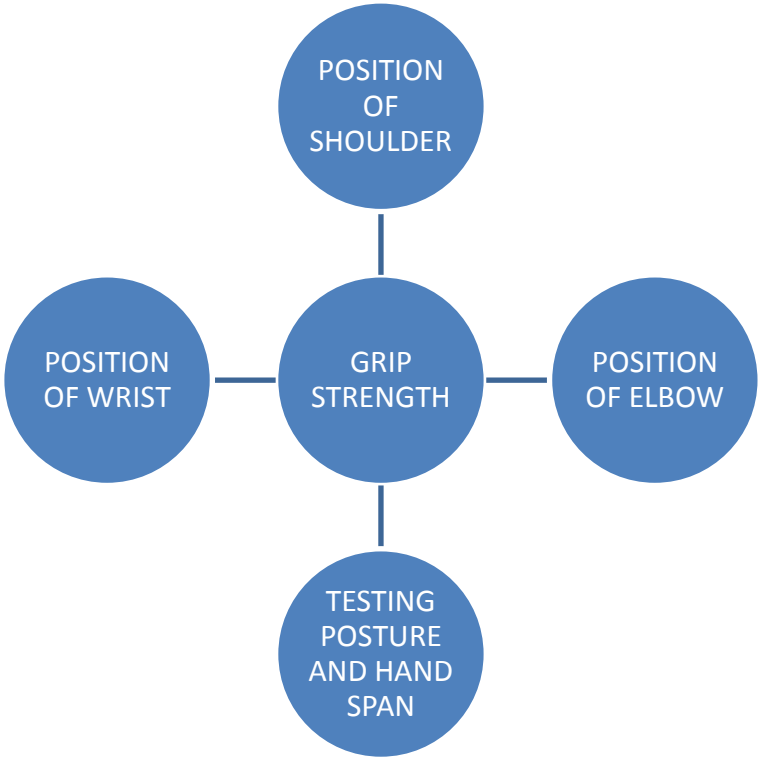

Figure 1.1 showing variables affecting measurement of Grip Strength

Figure 1.2 Jamar Dynamometer

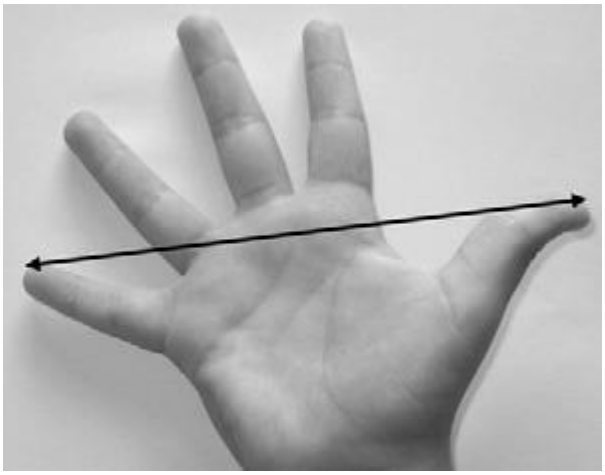

Figure 1.3 : Measurement of Hand Span

Figure 1.4 : Hand Held Dynamometer for measurement of Grip Span

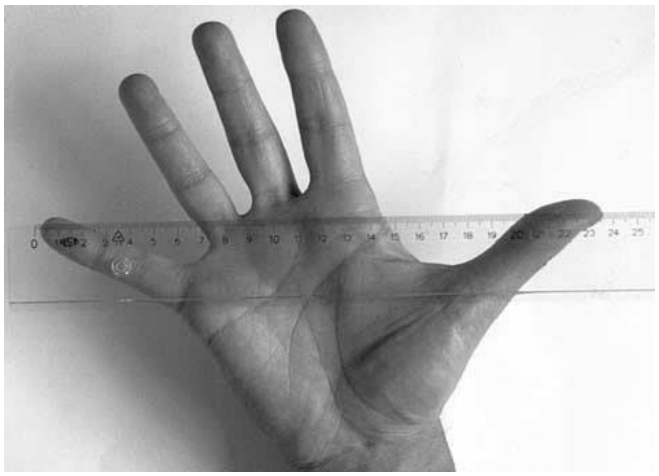

Figure 1.5 Measurement of Hand Size