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Differences in Muscle Activation while
Gripping a Sandbag versus an Olympic Weightlifting Bar

by

Todd Luther

Submitted in Partial Fulfillment of the
Requirements for the Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

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Approved:

Date

Peter M. McGinnis, Ph.D.
Thesis Advisor

Date

James Hokanson, Ph.D.
Thesis Committee Member

Date

John Foley, Ph.D.
Thesis Committee Member

Date

Eileen Gravani, Ph.D.
Associate Dean, School of Professional Studies

ABSTRACT

The purpose of this study was to compare the myoelectric activity of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles while gripping a 50 lb Olympic weightlifting bar to the myoelectric activity of the same muscles while gripping a sandbag of the same weight. Myoelectric activity was measured as the average root mean square (RMS) of the surface electromyography (sEMG) values. The hypothesis was that gripping a sandbag would result in greater muscle activation of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles than gripping an Olympic weightlifting bar of the same weight. The participants were seven healthy males who performed a six second lift with the sandbag as well as a six second lift with the Olympic weightlifting bar. The order of the lifts was random. The Olympic weightlifting bar was lifted using a traditional overhand grip and the sandbag was lifted using an overhand pinching grip. In both trials the bar or sandbag was positioned at thigh height and the participant then leaned over and gripped it with both hands in front of the body. The participant then lifted the implement off its support and assumed an upright position while holding the implement in a position so that it did not touch the body other than the hands. Surface EMG electrodes detected the myoelectric activity of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles. The electrodes preamplified the myoelectric signals by a factor of 35. The sEMG signals of the four muscles were treated with a 20 Hz low cut/high pass filter, amplified by a factor of 2000, and the RMS of the filtered signals were derived using a 2.5 ms time window. The analog RMS sEMG was sampled at 1000 Hz and converted to digital form. Each muscle's RMS sEMG was averaged over a six second period of the lift. The results of a within-subject one-tailed t-test

indicated that the means of the subjects' RMS sEMG for each of the four muscles were significantly larger for the sandbag lift than the Olympic bar lift. This result supported the hypothesis that gripping a sandbag produces significantly higher myoelectric activity in the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles than gripping an Olympic bar of the same weight. Athletic trainers, physical therapists, strength and conditioning coaches, fitness professionals, and other health professionals can use this information to improve grip strength when designing and implementing training programs for their clients, athletes, or patients.

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CHAPTER 1

INTRODUCTION

Grip strength has long been viewed as an important component of muscular fitness (Ratames, Faigenbaum, Mangine, Hoffman, & Jie, 2007). Ertem et al. (2003) suggested that grip strength could even be indicative of overall muscle strength. However, grip strength is often neglected during training. This can lead to sub-maximal performances. Grip strength is influenced by the number of motor units recruited in the forearm and hand muscles and the firing rate of these motor units. Previous research (Blackwell, Kornatz, & Heath, 1999; Ertem et al. 2003; Edgren, Radwin, & Irwin; 2004; Hagg & Milerad, 1997; Lee, Kong, Lowe, & Song, 1999; Mathiowetz et al. 1985; Ruiz-Ruiz, Mesa, Gutierrez, & Castillo, 2002) determined that such things such as age, gender, hand size, grip duration, implement shape, body position, mental state and previous training can directly influence the number of motor units recruited and the firing rate of these motor units. Few researchers have looked at how the thickness of the implement lifted affects the activity of the flexor and extensor muscles of the fingers and wrist. Ratames et al. (2007) looked at the actual differences in muscle activation when using bars of different thickness. However, their study only looked at performance outcomes of the agonists being trained while gripping bars of different diameters. The authors did not examine the activation of the gripping muscles. Many coaches recommended using implements of different shapes and sizes such as sand bags in their grip training programs, but no studies have determined the effectiveness of their use (Dudley, 2004; Hedrick, 2003; Mannie, 2004). The research question that this study sets out to answer is does gripping a sandbag require greater myoelectric activity

in the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles than gripping an Olympic bar?

Statement of the Problem

The purpose of this study was to compare the myoelectric activity of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles while gripping an Olympic bar to the myoelectric activity of the same muscles while gripping a sandbag of the same weight. Myoelectric activity was measured using surface electromyography (sEMG). The average root mean square (RMS) of sEMG signals from each muscle over a six second trial period were used as the basis for comparison.

Significance of the Study

This study may provide evidence of the complementary benefits of using non-traditional implements, such as sandbags, in addition to traditional weight training methods to increase grip strength. The results of this study may show that sandbags are a more effective lifting implement compared to the Olympic bar if improvements in grip strength are desired.

Hypothesis

The research hypothesis was that gripping a sandbag results in greater muscle activation, as measured by sEMG activity over six seconds, of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles than gripping an Olympic bar of the same weight.

Delimitations

The study was delimited by the following:

1. sEMG was used to measure myoelectric activity

2. only male participants were used.
3. the myoelectric activity of only four muscles, the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis, was measured.

Limitations

The major limitation in this study was the lack of previous research on this topic. Secondly, the unfamiliarity of the participants with lifting the sandbag used in this study may have been a limitation. The unique shape of the sandbag may have made it difficult for the participants to grip the sandbag in the same exact manner.

Assumptions

It was assumed that the procedures used to measure the sEMG were valid and reliable. It was also assumed that subjects were familiar with both gripping an Olympic bar and a sandbag. The subjects were allowed to grip the Olympic bar and the sandbag prior to the actual test session. Finally, it was assumed that all participants executed all trials with the same effort.

Definition of Terms

Crushing grip. The grip style that one would use when shaking hands, using a dynamometer, or using a gripper (a tool designed to specifically train the muscles of the hand and forearm). Specifically it is the flexion of the thumb and four fingers in opposition and simultaneously in order to grasp an object. This style of grip is important to anyone who uses tools for manual labor or to an athlete who holds on to an opponent or sports implement.

Electromyography (EMG). A technique for evaluating and recording the myoelectrical activity of muscles. EMG uses an instrument called an electromyograph, to produce a record called an electromyogram. An electromyograph detects the electrical potential generated by

muscle cells when these cells contract, and also when the cells are at rest. In this study surface EMG (sEMG) was used.

Pinch Grip. The grip used to grasp an object between the thumb and one or more fingers such as used when pulling a book off a shelf or holding a sheet of plywood by one of its ends.

Olympic bar. A weight lifting bar with rotating sleeves. The standard Olympic bar is 2.2 meters long, 28 mm in diameter at the grip location, and weighs 20 kg.

Raw EMG. An unfiltered (exception: amplifier band pass) and unprocessed signal detecting the muscle activation.

Root mean square. A method for quantifying sEMG in which each sEMG value is first squared, then the squared sEMG values over a specified time interval are averaged, and finally the square root of the average is computed as the root mean square value (RMS). “The RMS reflects the mean power of the signal (also called RMS EMG) and is the preferred recommendation for smoothing” (Konrad p. 11, 2006).

Strength. Amount of force a muscle can exert during a single contraction (Bompa et al., 1998).

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this study was to compare the average RMS sEMG over a six second period of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles while gripping an Olympic bar to the average sEMG RMS value of the same muscles while gripping a sandbag of the same weight. This chapter reviews research pertaining to grip strength, factors affecting muscle activation, grip strength of the dominant versus non-dominant hand, resistance training effects on grip strength, EMG use, EMG validity and reliability, testing procedures, and common uses of sandbags for training.

Grip Strength

To gain an understanding why grip strength is important it is first appropriate to understand what grip is. Hagg and Milerad (1997) explain that gripping is basically the concentric activation of the finger flexors in the forearm and the isometric activation of extensors in the wrist. Therefore, grip strength is the amount of concentric torque that can be produced by the finger flexors and the amount of isometric force that can be produced by the wrist extensors at the same time to counteract the flexors concentric torque.

There are many variations of grip, but they all stem from three main types: individual finger, pinch grip and crushing grip. Brookfield (1995) explains that individual finger grip is basically being able to flex all or individual fingers against a resistance. This type of grip is vital for athletes such as rock climbers and any mixed martial artists. Pinch grip is defined as the ability to use the thumb and fingers to grasp an object between them. This method of gripping would benefit athletes who rely on holding onto an opponent or implement. Brookfield (1995)

also explains that the thumb is often neglected which leads to decreased grip strength. Lastly, a crushing grip is described as what one would think of when shaking hands or using a gripper and is important to anyone who uses their hands to do anything in everyday life. Gripping an Olympic bar is considered a form of the overhand crushing grip and although gripping a sandbag can be classified as any combination of all three grips based on how the bag is held, it was assumed to be a pinch grip in this study.

Muscle Physiology

A skeletal muscle consists of muscle fibers that range in length from inches to feet (Bompa et al., 1998). These muscle fibers are bundled and wrapped in sheaths that hold them together. Contraction of a muscle fiber is initiated by the motor neuron that innervates that fiber. When the motor neuron is excited, the electrical potential across the motor neuron's cell membrane changes polarity. This change is electrical potential, or action potential, travels away from the cell body along the axon of the motor neuron to the motor endplate. The action potential is transmitted to the muscle fiber across the synapse between the motor endplate and muscle fiber membrane, the sarcolemma. The action potential then becomes a muscle action potential and the muscle action potential moves along the muscle fiber away from the synapse. The muscle action potential triggers cross-bridge formation between the actin and myosin filaments within the sarcomeres of the muscle fiber, and the muscle contracts. The absence of the action potential results in relaxation of the muscle fiber. Surface EMG signals are measures of the superposed action potentials produced by multiple motor units.

Factors that Influence Muscle Activation

The amount of force produced by a muscle is based on the number of motor units

recruited and the level of muscle activation in those motor units. Bompa et al., (1998) describes a motor unit as a single motor nerve and the muscle fibers that it activates. However, there are a number of different factors that will influence the ability of those motor units to activate. The first of those factors is age.

Mathiowetz et al. (1985) and Ertem et al. (2003) drew attention to the fact that grip strength increases from early childhood through adulthood, with the largest measurements in grip strength commonly being generated from people between the ages of 25-39 years old and gradually declining after that. This seems to be reasonable according to Ruiz-Ruiz et al. (2002), considering this is the time period when people are most likely to be engaged in activities where they use their hands. There is a direct correlation between handgrip strength, physical activity and health and subsequent to this period is when most people stop being as active. Like all muscles in our bodies, they must first mature to be able to produce maximal efforts from them. Mathiowetz et al. (1985) serves as the litmus of grip strength for norms for people older than 20 years old. Volunteers were tested on grip strength; tip strength, key pinch and palmar pinch. The mean score for right hand (dominant hand for majority of the population) grip strength for males in the age bracket between 25-39 years of age was approximately 120 lbs opposed to left hand grip strength of approximately 107 lbs. Furthermore, the pinch grip average for males in the same age bracket was 18.15 lbs and 17.25 lbs respectively. In addition, males demonstrated higher grip and pinch strength over females.

A second factor that influences grip is the actual span of the grip. Optimal grip span for producing peak grip strength has been examined by numerous researchers (Blackwell, Kornatz, & Heath, 1999; Edgren et al., 2004; Lee, Kong, Lowe, & Song, 2009; Ruiz-Ruiz et al., 2002;

and). Ruiz-Ruiz et al. (2002) investigated the influence of grip span when testing maximum hand strength as it relates to hand size. The purpose of their study was to determine if there was an optimal grip span for grip strength, if grip span was related to hand size and if so, could an equation be produced to determine optimal grip span for testing grip strength. The hand size and grip strength of seventy subjects (30 males and 40 females) with a mean age of 40 years old (ranging from 20 – 80 years old) were measured. To determine the optimal grip span for grip strength, the grip dynamometer was set to six different widths from 4.5 – 7.0 cm. Once all data were collected, the span at which the highest score was produced was identified as the optimal grip span. Ruiz-Ruiz et al. (2002) concluded that there was a linear relationship between hand size and grip strength for women, but not for men. It was concluded that 5.5 cm was an optimal grip span for men, regardless of hand size. This was intriguing due to that fact that men and women were very similar in average hand size, 20 cm and 19 cm respectively. However, in this particular study, the majority of men tested were employed in a field of work that was manual labor intensive. Therefore, grip strength could negate the influence of a possible “optimal” grip span correlation when producing maximum grip forces.

Lee et al. (2009) conducted a similar study of 46 men between the age of 20 and 39 years old. Once again, 5.5 cm was shown to not only produce the greatest mean grip strength values with a dynamometer, but was described as the most comfortable grip span. An additional factor that was examined was the contribution of each individual finger to total grip strength. The results coincided with the results of previous studies and indicated that the third phalange contributes the largest force (~ 37%) followed by the fourth phalange (~29%), the second phalange (~20%), and lastly the fifth phalange (~14%).

Shivers et al. (2002) attempted to determine the optimal lateral pinch grip span. Based upon two previous studies, Dempsey and Ayoub (1996) and Imrhan and Rahman (1995) (as cited in Shivers et al., 2002, p. 569), no true interpretation could be made based on contradicting results between the studies. However, Shivers et al. (2002) produced similar results to Dempsey and Ayoub (1996) (as cited in Shivers et al., 2002, p. 571), which indicated that maximum lateral pinch grip was achieved from 80% to 100% of a maximum lateral pinch span.

A third factor that influences grip is muscle fatigue. In racket sports, any mixed martial art and other sports that require an extended grip period, it is important to understand how fatigue affects gripping muscles. Blackwell et al. (1999) investigated the effect of grip span on isometric grip force and fatigue of the prime finger flexor muscle, the flexor digitorum superficialis. They determined that if a defined fraction of a maximal contraction were required, fatigue would materialize in similar time frames, regardless of grip span. In addition to these findings, the researchers also confirmed the findings of previous studies, that the optimum grip span is between 5.0 cm and 5.5 cm, (Blackwell et al., 1999)

Edgren et al. (2004) observed that most grip research studied grip in a fixed length for all fingers, assuming that all fingers produced forces only in one direction. To overcome this assumption, Edgren et al. (2004) used a cylindrical shaped handle to more accurately assess grip forces as vectors having a magnitude and direction and not just unilateral measurement. Edgren et al. (2004) provided evidence that in previous studies in which a JAMER dynamometer was used, accurate evaluation of grip strength as a vector did not occur, nor did it eliminate the possibility of inflated values due to leverage. By using a cylindrical shaped dynamometer that more accurately resembled a single handled tool, Edgren et al. were able to determine that a

diameter of 3.8 cm more accurately represents the optimum span for both maximum magnitude and direction of grip forces.

Dominant Hand Rule

The differences between right and left hand dominance are often overlooked. Mathiowetz et al. (1985), Ertem et al. (2003), and Thomas, Sahlberg, and Svantesson (2008) all discussed the so-called hand dominance rule. Thomas et al. (2008) stated that this rule says there is a difference in strength between the dominant and non-dominant hands. It is thought that the dominant hand is about 10% stronger than the non-dominant hand. Thomas et al., (2008, p. 324) cited Peterson et al. (1989) and Crosby et al. (1994), to support this conclusion. To examine this rule Thomas et al. (2008) used the Grippit dynamometer to test the grip strength of 41 subjects, 27 females and 14 males. “The Grippit device is a portable instrument with a grip device and arm support that enables standardized arm and grip position” (Thomas et al. 2008, p. 127). There was a 6-9% difference in handgrip strength between the right and the left hand. Furthermore, when hand dominance was taken into consideration, an 8-11% difference was seen between the dominant hand and the non-dominant hand. These results concur with the results of Peterson et al. (1989) and Crosby et al. (1994) (as cited in Thomas et al., 2008, p 325). However, Ertem et al. (2003) discovered that although grip strength was 2.4% higher in the dominant hand when the dominant hand was the right hand; a significantly higher difference (11.2%) was found when the dominant hand was the left hand.

Non-Strength Related Effects on Grip Strength

There are many possible reasons why one person, who has never lifted weights, may have stronger grip strength than another person. Some explanations could include genetics, lifestyle or

occupation. An explanation that is often overlooked is the use of imagery to produce increases in strength. Hale, Wiest, and Russell (2007) looked at the effects of imagery on grip strength. Hale et al. (2007) cited Ranganathan et al. (2004) and Smith et al. (2003) whose studies showed that finger strength can be improved with mental imagery practices alone. For their study, Hale et al. (2007) looked at the use of response-oriented imagery and stimulus-oriented imagery to produce increases in non-dominant handgrip strength. Twenty-one participants were split into three groups (response-oriented imagery, stimulus-oriented imagery, and actual strength task). Maximum voluntary contraction grip strengths were tested on the first, fifth and eighth week of the study. Throughout the study participants in the test groups were told to imagine the gripping movement for six sessions, twenty times per session with their assignment. The results of a 3x2 mixed-design ANOVA showed that there was a significant change from start to finish in all three groups. No significant differences were found between the three groups. Consequentially, Hale et al. (2007) reported that imagery practices could be just as effective as a strength-training task in increasing maximum voluntary contraction grip strength.

Prior to Hale et al. (2007), Smith et al. (1989) looked at the possibility of subjects not being truly sincere while performing the grip test. A sub-maximal trial in a study could affect the outcome of the study. Specifically, when testing people who may have sustained a hand injury they may receive compensation until they are able to go back to work. If they would provide a sub maximal effort on a grip test they could continue to remain out of work indefinitely. They found that there was five such tell tale signs that set a sincere and fake trial apart: the ratio, the coefficient variation, ratio difference, peak-average difference and the peak-average root difference. By using two or more of these discriminators, researchers could

accurately predict whether or not the subject was providing a sincere effort (Smith et al., 1989).

Resistance Training Effects on Grip Strength

In addition to looking at the hand dominance rule, Thomas et al. (2008) also looked at the possible effects that resistance training may have on grip strength. Based on the same subjects that revealed the possible accuracy of the hand dominance rule, an intervention group was formed from the initial 27 females that performed a home-based upper body resistance-training program three times a week for eight weeks. At the initial grip strength measurement session, no significant difference was shown between the training group and the control group. The home-based resistance-training program consisted of three sets of ten repetitions for the first four weeks and three sets of fifteen repetitions for the last four weeks. Participants performed three exercises: push-ups from the prone position, dips from the supine position, and shoulder stabilization in the prone position. All exercises were chosen with the lack of focus on the training of the hands in mind. Thomas et al. (2008) concluded that an eight-week resistance-training program increased grip strength in the trained group since the muscles of the forearm are still used to some extent in the exercises. However, this study revealed that this was only true for the right hand and not the left. The reason for this could not be determined, but it was thought that hand dominance may be a factor in this outcome (Thomas et al., 2008).

Electromyography

According to Konrad (2006, p. 5), electromyography is “an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes.”

Furthermore, Konrad (2006) describes kinesiological EMG as the study of intentional muscle

activation. This activation can be a result of postural control, everyday movements, or movements performed in the work environment

Electromyography Measurement

There are a number of different ways to measure the strength of the hands but most common tools used to do so are dynamometers and surface electromyography (sEMG). There are some major differences between the two; dynamometers are used to test actual strength, where as sEMG is used to measure the electrical activation of the motor units used to perform a task. Although widely used due to it's non-invasive functionality, its relative ease of use, its safety, and its ability to provide objective quantification of the motor unit activation (Cram et al., 1998) there are some disadvantages to sEMG. These include the level of palpation skills possessed by the practitioner to identify the placement location of the EMG electrodes, the actual muscles being tested, the number of muscles examined at one time, and the age and condition of the equipment. But as shown by examining the differences in the spectral parameters of specific sEMG leads, it is possible to discover which muscle contributes the most to a specific movement or exercise (Ebenbicher et al., 2002).

It is unclear for the most part if sEMG and dynamometer results are related. Duque, Masset, and Malchaire (1995) aimed to determine if handgrip force could be accurately estimated using an EMG and a mathematical equation, though no equation had ever been previously produced. Handgrip forces from 20 individuals between the ages of 18 and 30, in good health were examined. The subjects were tested using 11 different grip positions at both 30% and 70% of their maximum voluntary contraction (MVC); measurements were taken using a JAMAR dynamometer and an ambulatory MEGA ME 3000 EMG. The researchers developed

a mathematical model that successfully predicted grip force from the EMG. There were some limitations to this method. For one, surface electrodes and not fine wire electrodes had to be used with the EMG. Additionally, this mathematical model was only accurate when EMG was measured at 11 specific hand positions, and is not practical in a working environment where there is a constant movement of the wrist. In keeping with information provided by Hagg and Milerad (1997), hand strength is a combination of both finger flexion and wrist extension, making it seemingly impossible to use this formula in a practical setting.

EMG Validity and Reliability

In order for a device to be acceptable for use, it must produce valid and reliable results. Iacono (2004) agrees that measurement techniques and instruments must be valid and reliable for one to continue to use them. Reliability is defined by Iacono (2004) as the functional consistency of a device. To determine an instrument's reliability, many methods can be employed, but one of the most common is the test-retest method. This method is utilized by performing an initial test, followed by the same test once again. This method does have its limiting factors though. Iacono (2004) states that there are factors that can affect the results of this method; the length of the measurement encounter, the heterogeneity of the object being measured and the measurement interval. He included explanations for each of these factors as well. The longer the duration of the test or the more samples that are taken, the more reliable the study. The greater the similarity of the objects being measured, the lower the reliability. Lastly, the shorter the interval between test periods, the more reliable the results will be.

Due to the high reliability of the test-retest method, Iacono (2004) used it to determine the reliability of a static EMG. Before Iacono (2004) attempted the study, any additional factors

that could affect the test-retest method when using an EMG needed to be determined. Iacono (2004) discusses four factors that can affect sEMG. First are morphological factors. These include: age, which increases the muscle action potential duration; electrode location, which is affected by body size and type; adipose tissue, which interferes with the EMG signal; and muscle depth, which affects signal strength. A second factor is muscle cross talk and volume conduction. Iacono (2004) characterizes this as the fact that we are unsure exactly what we are looking at under the skin, so it is possible that we are getting other muscles' signals. A third factor was stated as administrative. This simply means the EMG test could be conducting poorly. For example, the testing area could be loud and drafty, which in turn would result in ambiguous outcomes due to involuntary muscle contractions. Lastly, there are hardware factors that could be detrimental to the study. Although not a significant concern with improved EMG technology, electrical appliances such as overhead lights and 60-Hz line voltages can influence reliability as well.

To investigate the test-retest method on the EMG Iacono (2004) took 64 participants who experienced chronic pain and scanned them using an EMG. Following the initial scan, patients were enrolled in a program to show exactly how to adjust their pain dilemma responsibility from their doctors to themselves using a psychological intervention. The program lasted five weeks with the patients meeting for six hours, three days per week. After the five weeks, the subjects were scanned once again. The results of the study showed the over all correlation coefficients ranged from .551 to .807 signifying that the EMG results were fairly similar. This is evidence for the case that the EMG is a reliable tool (Iacono 2004).

Correa, Correa, Martinelli, de Oliveria, and Olivera (2006) also wanted to determine the

reliability and validity of EMG using the test-retest method. They looked at continuous contractions to exhaustion for the rectus femoris, vastus lateralis and vastus medialis. They tested ten subjects, five males and five females, for two days, one week apart. Participants were asked to isometrically contract their quadriceps at 80% of their MVC until fatigue. The results revealed an intra-class correlation coefficient (ICC) between .6 and .85 for all three-muscle groups for this level of contraction. This led the investigators to agree that at least for their study, the use of the EMG has appropriate reliability and dependability for testing muscle contractions.

Protocols

When estimating grip forces with an EMG based model it is important to understand what muscles are being used and what function those muscles serve in gripping. Hoozemans and van Dieen (2005) explored the use of sEMG on different combinations of six muscles (medial carpi radialis longus, medial extensor carpi radialis brevis, medial extensor digitorum, medial extensor carpi ulnaris, medial flexor digitorum superficialis, and medial flexor carpi radialis) that are either involved in flexion or extension in the fingers or wrists during gripping. They found that their estimates of grip force were just as valid using the combination of three muscles involved in gripping as using six muscles. It was irrelevant which three muscles were tested as long as three were used.

When testing grip strength, not only are the muscles being tested important, but the reliability of the test is as well. Coldham et al. (2006) looked at the possibility of using the mean of three trials or the peak of three trials compared to the peak of only one trial to determine its reliability. They found that all three methods displayed clinically acceptable levels of reliability (>0.91), which therefore would suggest that only one maximal trial is necessary to determine

maximal hand grip strength.

When examining peak grip forces it is important to know exactly when those forces tend to occur. Kamimura and Ikuta (2001) studied the force time curves of 50 subjects trying to determine if a 6 s or 10 s trial is needed to discover the peak force. They found that the peak in the force time curve usually happens in the first or second seconds of the test and from there on, the force slowly diminishes. Therefore, for the purpose of finding peak forces it is only necessary to perform 6 second trials (Kamimura & Ikuta, 2001).

Dynamic Grip Strength

LaStayo and Hartzel (1999) observed that all grip strength tests were being performed as a static test, which allowed no movement at the wrist. This was seen as a problem since very few real life situations are performed in a static manner. Their subjects were 29 men and women between the ages of 21 and 43 years old. A new dynamic grip strength device was designed with two different optical encoded gyro engines to measure movement. One measured flexion/extension and ulnar/radial deviation of the hand at the wrist. The other measured supination/pronation of the forearm. What LaStay and Hartzel (1998) discovered was that the dynamic grip trial produced 14% weaker maximum grip strength compared to the static trial. This however was to be expected due to the decrease in joint and tendon stabilization, leading to a decrease in force production. Although the maximum voluntary contraction was weaker, using a dynamic grip test would be beneficial in both a clinical and field study.

Sandbags

Although little to no research is available on the subject, sandbag training has become a more common practice for training athletes. Even-Esh (2007) states that using sandbags is a

great way to incorporate grip training in to your workouts, especially when executing pulling movements due to the fact that pushing movements tend to have lower levels of muscle activation in the forearms and hands. Examples of training exercises using sandbags that would incorporate grip would be upright rows, bent rows, and cleans. Although you could assume that using sandbags would accomplish the goal of grip strength training, this method has not yet been backed up by scientific evidence. These beliefs are further supported by a number of coaches. Although scarcely studied, many coaches around the world are readily using these tools. What appears to make these tools so effective in building grip is their ability to promote the use of a dynamic grip.

Summary

In summary, electromyography is a safe and effective way to measure muscle recruitment for grip strength. The most reliable results are produced when using at least three or more muscles involved in gripping and when using one or more trials lasting a duration of 6 seconds. Additionally, muscle activation is affected by many different factors such as age, gender, hand size, grip duration, implement shape, body position, mental state and training, all of which can have a profound effect on grip strength. However, what is more important is that handgrip strength has been shown to be trainable using resistance training and mental imagery methods. Nevertheless, due to the lack of evidence on the use of sandbags as a tool for resistance training for grip strength, further investigation is needed to determine the specific performance outcomes.

CHAPTER 3

METHODS

The purpose of this study was to compare the average RMS sEMG value over a six second period of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles while gripping an Olympic bar to the average RMS sEMG value over a six second period of the same muscles while gripping a sandbag of the same weight. This chapter describes the participants, the instruments used, the procedures used to collect the data, and the data analysis.

Participants

Seven male participants were recruited from SUNY Cortland students and employees on a voluntary basis. Individuals who volunteered were not required to have any previous lifting experience, although most did, since the test was strictly isometric and did not require a specific lifting technique. Volunteers had to be over the age of 18 and not had any upper limb injuries in the past year. Injuries that excluded volunteers from being participants included, but were not limited to, broken bones, torn ligaments or tendons, and any lacerations that required stitches. Lastly, volunteers were required to be able to hold a 50 lb sand bag in front of them with two hands using an overhand pinching grip without resting it against their bodies for a minimum of six seconds. None of the volunteers met any of the exclusion criteria so all seven volunteers became participants in the study. All volunteers were required to sign an informed consent form prior to their participation in the study (appendix A).

Instruments

To improve the reliability of the study, a manufactured 50 lb sand bag from Gilman Gear

was used. Gilman Gear manufactures and sells sand bags and throw dummies for combat sports. Additionally a standard 45-pound Olympic weightlifting barbell was used with two, two and a half pound plates so both implements weighed the same.

A Therapeutics Unlimited Model 544 Multichannel Electromyographic System with four amplifier/processor modules and a Peak Motus® motion analysis system (Peak Performance Technologies, Inc., Centennial, CO) were used to measure and record the electrical activity of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles. Bi-polar silver-silver chloride electrodes with built-in preamplifiers were used. The built in preamplifier in each electrode assembly amplified the myoelectric signal by a factor of 35. Cables from the electrodes transmitted the four analog sEMG signals to the Therapeutics Unlimited Model 544 Multichannel Electromyographic System that then amplified each analog signal by a factor of 2000. The analog signals were then treated with a 20 Hz low cut, high pass filter. The RMS of the filtered signal was then computed with a 2.5 ms moving time window using the following equation:

$$f_{rms}(t) = \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} [f(t)]^2 dt}$$

where, $f(t)$ = myoelectric signal at time, t

$$f_{rms}(t) = \text{RMS of the myoelectric signal at time, } t$$

$$T_2 - T_1 = 2.5 \text{ ms, the size of the moving time window}$$

$$T_2 = t + \frac{(T_2 - T_1)}{2} = t + \frac{2.5 \text{ ms}}{2} = t + 1.25 \text{ ms}$$

$$T_1 = t - \frac{(T_2 - T_1)}{2} = t - \frac{2.5 \text{ ms}}{2} = t - 1.25 \text{ ms}$$

The four RMS analog signals were then transmitted by cable to the Peak Motus® motion

analysis system where each signal was sampled at a rate of 1000 Hz and converted to a digital signal. The digital data were then stored on the Peak Motus system. The averages of the RMS values over six seconds of the lift were used as the measure of the muscle activation of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles.

Design and Procedures

Data collection took place in the biomechanics lab at SUNY Cortland. The testing area was free of any possible external influences such as cold drafts, extreme lighting, and multiple subjects. Participants were given written and verbal instructions describing the testing, what was required of them, the benefits of the research, and any risks that might have been involved. They were then be asked to read and sign an informed consent if they wished to participate in the study (appendix A).

Once consent was given, a participant was screened to determine if he was able to hold the 50 lb sand bag and Olympic bar for the required six seconds. During this time each participant became familiar with the two implements and the grips used to lift the implements. All seven participants were capable of lifting and holding the 50 lb sand bag and Olympic bar for the required six seconds. Each participant then had his dominant arm shaved and swabbed with alcohol pads in the areas where the electrodes were to be attached, superficial to the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles (see Figure 1). The sEMG electrodes were attached on the skin of the shaved areas with double stick mounting tape and a conducting gel was used to improve contact conductivity. The electrodes were placed so that their cables would not interfere with the lift. The electrodes and the cables were then secured on the forearm with pre-tape and athletic tape. A reference electrode was

placed on the participant's forehead and fixed in place by a headband or knit cap. The quality of the each sEMG signal was checked by instructing the participant to flex and extend his wrist and fingers. The researcher then evaluated each signal on the monitor of the Peak Motus System. If the signal to noise ratio of a sEMG signal was observed to be too small, the electrode which measured that signal and its cable were adjusted until it produced an acceptable signal to noise ratio. Once each signal had an acceptable signal to noise ratio, the data collection trials began.

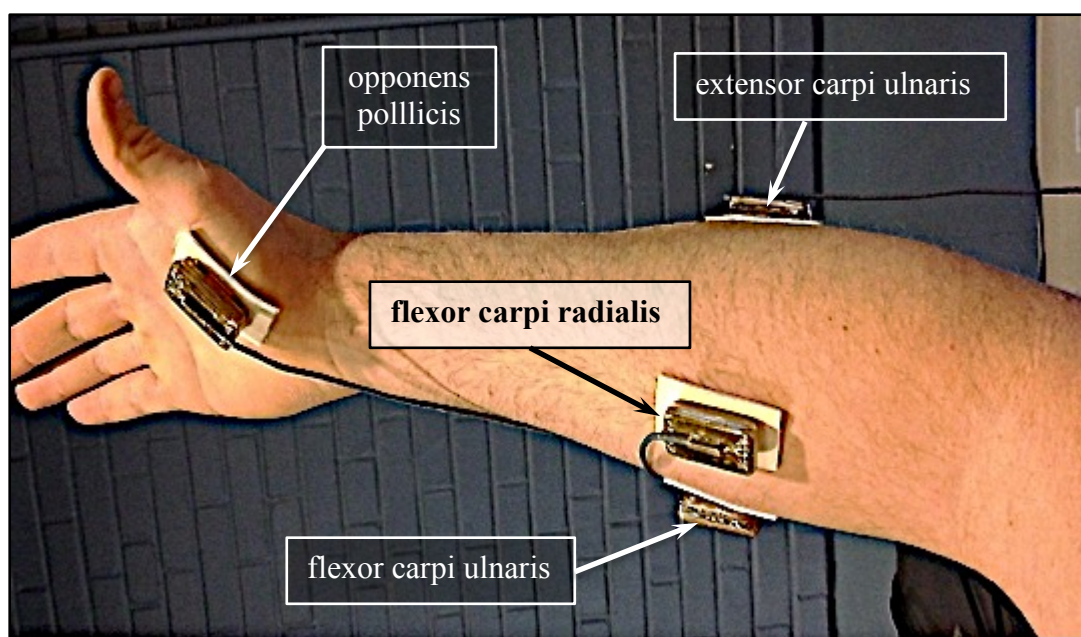


Figure 1. Placement of sEMG electrodes.

The sandbag or Olympic bar was supported in front of the participant at approximately thigh height. The implement lifted first was randomly determined for each participant. The participant stood in an upright position his feet positioned shoulder width apart. The participant then leaned forward and established overhand crushing or pinch style grips on the implement with both hands. Once the grips were established, the researcher instructed the subject to lift the implement, The participant then lifted the implement off its support and resumed an upright

position while holding the implement in a position so that it did not touch the body. The participants achieved this by flexing their arms at the shoulder joint and/or elbow joint (see Figure 2.). If the participant were lifting the sandbag, he was required to grip it with an overhand crushing grip in which the material inside the bag was held, not just the fabric. The participant maintained an upright posture while holding the implement away from his body for at least 8.5 s, starting when the support for the implement was taken away. After 8.5 s had elapsed, the researcher instructed the subject to lower the implement back to its support and the trial ended. Participants were given a one-minute recovery period before the next trial begun.



Figure 2. Participant with electrodes in place gripping the Olympic weightlifting bar.

The RMS EMG data were automatically digitally recorded using Peak Motus software. After the researcher instructed the subject to lift the implement, the researcher pushed a trigger when he observed the implement lifted off of the support. This trigger was detected by the Peak Motus software. In the Peak Motus software, the pre-trigger time was set at 0.5 s and post trigger time was set at 8 s. The Peak Motus system thus began recording the RMS sEMG data 0.5 s before the trigger was pushed. The total recording time for each trial was 8.5 s or 8500 samples for each of the four RMS sEMG signals.

After the data were collected, the researcher examined the RMS sEMG data files and identified when muscle activation began for each trial. This starting point was identified for each RMS sEMG history as the point when the participant's average myoelectric activity began to continually increase for a duration longer than 0.5 s, signifying muscle activation. Beginning with the data point corresponding to the start of muscle activation, the next six seconds of data or 6000 data points were used in the analysis.

Data Analysis

Fifty-six files (4 muscles x 2 implements x 7 participants) containing the RMS sEMG data were transferred from the Peak Motus system and analyzed using Microsoft Excel. The average RMS sEMG was computed for each muscle and for each trial by computing the average of the 6000 RMS sEMG values for each muscle, trial, and participant. Fifty-six average RMS sEMG values were computed using Excel. These RMS sEMG values were then statistically analyzed to determine if significant differences existed between the average RMS sEMG values of each muscles when lifting the sandbag versus the average RMS sEMG values of the corresponding muscles when lifting the Olympic barbell. The statistical differences were

identified using a one-tailed paired t-test with Excel where factor A was the Olympic bar and factor B was the sandbag. The decision to use a one tailed t-test was based on pilot study results which indicated that greater myoelectric activity should be seen while gripping the sandbag. Significance was set at $p < .05$.

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this study was to compare the average RMS sEMG values of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles over a six second period while gripping an Olympic bar to the average RMS sEMG value of the same muscles while gripping a sandbag of the same weight. Using an overhand crushing style of grip, participants performed one trial with each implement while holding the implements. RMS sEMG values were recorded for each muscle for each trial and the average of the RMS sEMG was computed for each muscle for each six second trial.

Results

There were a total of seven participants. The participants were all male and over the age of 21. Every participant had some previous experience weight training. Each participant lifted the sandbag or the Olympic weightlifting bar in random order and RMS sEMG was measured and recorded for the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles during the lift. Following the data collection a one-tailed paired t-test was computed to determine any significant differences between the mean RMS sEMG for the sandbag lifts compared to the Olympic bar lifts for extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles of the seven participants.

Significant differences between the Olympic bar lift and the sandbag lift for the mean RMS sEMG of each muscle (extensor carpi ulnaris, $p = 0.04$; flexor carpi ulnaris, $p = 0.01$; flexor carpi radialis, $p = 0.02$; and opponens pollicis, $p < 0.01$) for the seven participants were found. Additionally, the means and standard deviations of the RMS sEMG were greater in all

muscles while gripping the sandbag compared to the bar. The values for means and standard deviations of the RMS sEMG for the seven participants are shown in Table 1.

Table 1. *Means and Standard Deviations of RMS sEMG in Volts for the Seven Participants.*

	extensor carpi ulnaris		flexor carpi ulnaris		opponens pollicis		flexor carpi radialis	
	<i>Bar</i>	<i>Sandbag</i>	<i>Bar</i>	<i>Sandbag</i>	<i>Bar</i>	<i>Sandbag</i>	<i>Bar</i>	<i>Sandbag</i>
RMS	0.18	0.33	0.10	0.17	0.07	0.35	0.05	0.09
SD	0.11	0.13	0.07	0.13	0.07	0.32	0.04	0.06
<i>p</i>	0.04		0.01		0.02		$p < 0.01$	

These results indicate that a greater activation of these muscles was required to grip the sandbag, compared to gripping the Olympic bar. In fact of the 28 average RMS sEMG comparisons (4 muscles x 7 subjects), higher average RMS sEMG values were recorded for all participants when lifting the sandbag except for the average RMS sEMG of the extensor carpi ulnaris muscle of participant #6, whose average RMS sEMG was .16 v for the sandbag lift and .33 v for the Olympic bar lift.

The mean RMS sEMG for the extensor carpi ulnaris, flexor carpi ulnaris, opponens pollicis, and flexor carpi radialis for the seven participants are illustrated in Figure 3. While values were significantly higher for all muscles tested using a sand bag compared to the bar, differences in the RMS sEMG was largest for the opponens pollicis (.35 v vs .07 v). This was expected since the thumb is not particularly used while gripping an Olympic bar, due to the use of the traditional finger wrap around the bar. This finger wrap cannot be utilized when lifting a sand bag.

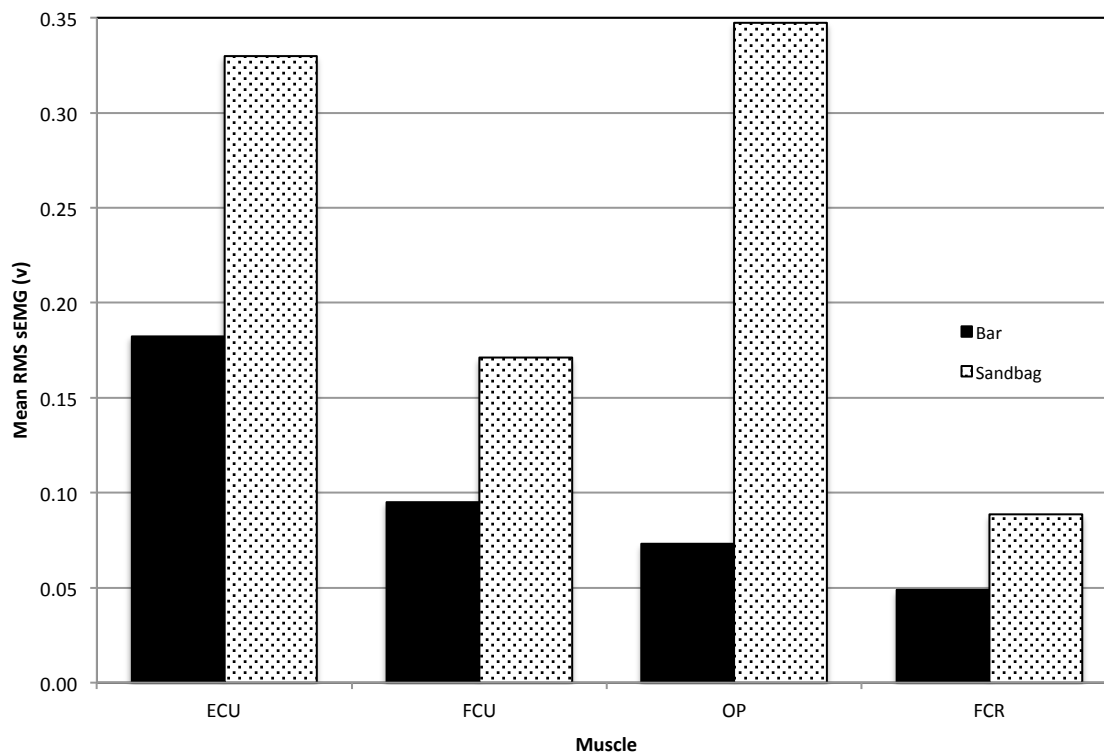


Figure 3. Mean RMS sEMG of the seven participants for extensor carpi ulnaris (ECU), flexor carpi ulnaris (FCU), opponens pollicis (OP), and flexor carpi radialis (FCR) muscles.

The standard deviations of the means of the RMS sEMG of the seven participants for the extensor carpi ulnaris, flexor carpi ulnaris, opponens pollicis, and flexor carpi radialis are illustrated in Figure 4. The standard deviations of the means of the RMS sEMG of the seven participants for the sandbag lift were higher for all muscles tested than for the Olympic bar lift. The largest difference in standard deviation was recorded for the opponens pollicis muscle (.07 v vs. .32 v). The opponens pollicis recorded the highest mean RMS sEMG in the test. This could be attributed to the location and placement of the opponens pollicis sEMG electrode and possibility of movement or pressure applied to the electrode as the sandbag was lifted (see Figure 5).

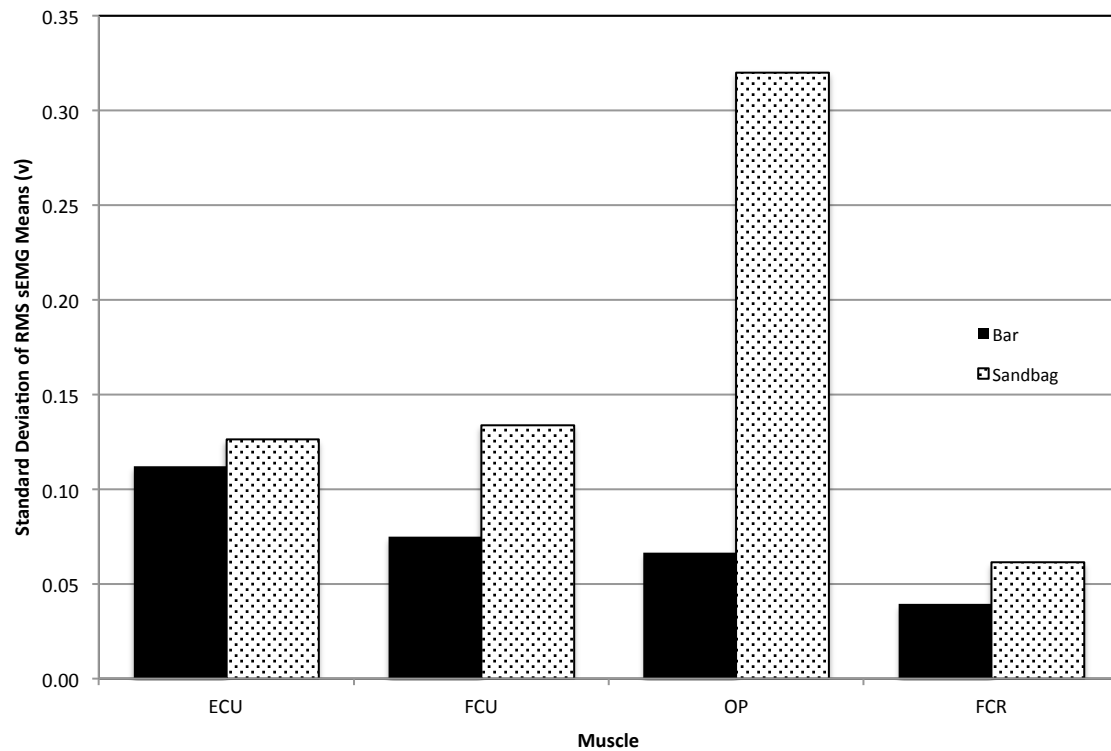


Figure 4. Standard Deviations of the RMS sEMG means of the seven participants for the extensor carpi ulnaris (ECU), flexor carpi ulnaris (FCU), opponens pollicis (OP), and flexor carpi radialis (FCR) muscles.



Figure 5. Electrode placement for opponens pollicis sEMG.

DISCUSSION

The results of this study support the hypothesis that gripping a sandbag elicits a higher demand on the muscles involved with grip compared to lifting a traditional Olympic bar.

Although no previous research has been completed regarding sandbag training and its effect on grip strength, the benefits of sandbag training on grip strength could be inferred from the conclusions of other studies that gripping implements of varying shapes and diameters yielded greater activation in the muscles responsible for grip strength. For example, the conclusion of several researchers (Blackwell et al., 1999; Edgren et al., 2004; Lee et al., 2009; Ruiz-Ruiz et al., 2002; and Shivers et al., 2002) that 5.5 cm is an optimal grip span for men, supports the use of sandbag training to improve grip strength since the sandbag allows a lifter to optimize grip span by gripping more or less of the sandbag. In this study, the sandbag provided the participants with the opportunity to use a grip span that was closer to optimal for producing maximal gripping force, unlike the Olympic bar with its fixed 1.1 inch diameter.

Another possible explanation for why lifting the sandbag required larger mean RMS sEMG of the muscles tested versus the Olympic bar has to do with friction. Unlike the grip used to hold the Olympic bar, the grip used to hold the sandbag did not allow the fingers to wrap completely around and beneath the fabric of the pinched sandbag material. Friction force between the sandbag and the fingers was thus required to provide a large enough upward force to hold the weight of the sandbag. To produce this larger upward directed friction force required greater horizontal pinching force on the sandbag. The grip used to hold the Olympic bar allowed the fingers and thumb to wrap around and beneath the bar. The upward directed normal contact force provided by the fingers and thumb at their contact with the underside of the bar provided

much of the upward force required to hold the weight of the Olympic bar. A large upward directed friction force was not required to lift the bar, so the bar did not have to be pinched with as much force as the sandbag.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

The purpose of this study was to compare the average RMS sEMG over a six second period of the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis muscles while gripping an Olympic bar to the average RMS sEMG of the same muscles while gripping a sandbag of the same weight. The hypothesis was that gripping the sandbag would produce higher muscle activation compared to gripping a Olympic bar of the same weight, therefore placing a higher training effect on the muscles involved in grip when training with the sandbag. The participants were all healthy individuals 21 years old or older. Surface EMG data were collected using a Therapeutics Unlimited Model 544 Multichannel Electromyographic System in conjunction with a Peak Motus® motion analysis system (Peak Performance Technologies, Inc., Centennial, CO). These systems recorded the frequency and amplitude of the myoelectric activity and derived the RMS sEMG from this data. The RMS sEMG of each of the four muscles (extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens pollicis) was then averaged over six seconds of the lift.. Means and standard deviations of the average RMS sEMG of each of the seven participants were computed for each of the muscles and lifts. A within-subjects one-tailed t-test was used to determine any significant differences between the average RMS sEMG between the two lifting implements.

Conclusion

It was concluded from this study that lifting a sandbag elicited significantly higher RMS sEMG in the extensor carpi ulnaris, flexor carpi ulnaris, flexor carpi radialis, and opponens

pollicis muscles than lifting an Olympic bar of the same weight.

Implications

The results of this study are relevant to professionals who work in the field of strength and conditioning, fitness, or coaching. Specifically, this information could be used by coaches and athletes while bracketing exercises as well as cycling phases of a training program. For instance, if an athlete wishes to develop more grip strength the athlete could use a sand bag while performing exercises such as bent over rows, farmer's carries, or cleans.

The results of this study are also relevant to clinical professionals such as physical therapists and occupational therapists or others who work in health related fields. Prescribed exercises to develop or rehabilitate grip strength may be made more effective if sandbags or similar implements are used.

Recommendations

Future research should be conducted to more accurately determine muscle activation using intramuscular EMG in the gripping muscles. This method of testing would further eliminate muscle cross talk. Furthermore, any future studies should examine more muscles to determine if the conclusions of this study apply to all the muscles typically used for gripping.

Additionally, at the time of this study, it was the only study to compare gripping a sandbag to gripping an Olympic bar. Therefore, further comparisons of gripping these implements would help confirm the results of this study.

Repeating the study with a larger number of participants would further confirm the results of this study. Also, repeating the study and comparing different groups of subjects may lead to interesting conclusions regarding athlete vs. non- athletes, hand dominant sports vs. non-

hand dominant sports, or strength athletes vs. endurance athletes.

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Appendix A

State University of New York College at Cortland Informed Consent

You are invited to participate in a research project conducted by graduate student Todd Luther of the Kinesiology Department at SUNY Cortland. He requests your informed consent to be a participant in the research project described below. The purpose of the research is to compare the activity of specific arm and hand flexor and extensor muscles while gripping an Olympic bar and while gripping a sandbag of the same weight. Please feel free to ask about the project, its procedures, or objectives.

You will be lifting a 50 pound Olympic bar and a 50 pound sandbag. The lead researcher will place four electrodes on the skin of your forearm and hand at four different locations to measure the electrical activity of four specific muscles in your forearm and hand. This electrical activity will be recorded using a Therapeutics Unlimited Model 544 Multichannel Electromyographic System as well as the Peak Motus® motion analysis system. This will take place in one session that will last approximately an hour. You will be asked to hold each implement in an overhand manner at separate times for 6 seconds. During each trial, the electrical signals detected by the electrodes will be recorded and stored for further analysis. Once both trials are completed the participants are free to leave.

The risks associated with your participation in this study are minimal. However, there is always a risk of injury associated with engaging in physical activity. Only the researcher will have access to your data. Your data will be stored on a flash drive containing your subject ID #. The data on the flash drive will be erased immediately following the completion of the study. Your data will also be stored on the hard drive of a desktop computer in the locked Biomechanics Lab (1163 Professional Studies Building). This data will be deleted 3 years after the completion of the study, upon which all files will be deleted. At no time will your name be associated with your data.

You are free to withdraw consent and stop your participation in the project at any time without penalty. Additionally, at any time, you may ask the researcher to destroy all records of your performances, as well as any other data or information collected.

By participating in this study, you should expect to better understand the way in which research is conducted. No other incentives will be offered.

If you have any questions concerning the purpose or results of this study, you may contact Todd Luther at (315) 723-0400 or at todd_luther@yahoo.com. Other contacts include: Dr. Peter McGinnis, Professor of Kinesiology at 1158 Professional Studies Building, or peter.mcginis@cortland.edu. For questions about research at SUNY Cortland or questions/concerns about participant rights and welfare, you may contact **the Institutional Review Board at SUNY Cortland**, PO Box 2000, Cortland, NY, 13045 (phone (607) 753-2511 or email irb@cortland.edu).

I (print name) _____ have read the description of the project for which this consent is requested, understand my rights, and I hereby consent to participate in this study.

Signature: _____ Date: _____

Appendix B
Average RMS sEMG in Volts

Olympic Bar

Participant	ECU Bar	FCU Bar	OP Bar	FCR Bar
1	0.140230404	0.015877154	0.013828012	0.012466446
2	0.075878142	0.030107733	0.034202118	0.045922485
3	0.061628339	0.029268858	0.00145206	0.057958216
4	0.217214747	0.144727394	0.1476939	0.113024343
5	0.122964462	0.092629389	0.084375038	0.08445589
6	0.332141745	0.138410161	0.175227362	0.018753999
7	0.325404264	0.215268834	0.055760149	0.009126995
AVERAGE	0.182208872	0.095184218	0.073219805	0.048815482
SD	0.112047742	0.074854575	0.06656023	0.039338481

Sandbag

Participant	ECU SB	FCU SB	OP SB	FCR SB
1	0.342634188	0.032277782	0.230060545	0.018166476
2	0.495860043	0.073802555	0.269680967	0.065634654
3	0.301598549	0.094395209	0.133109502	0.132429909
4	0.438968882	0.264042523	0.216676837	0.191371864
5	0.180301482	0.148040504	0.173521579	0.11826736
6	0.159460688	0.162058184	1.055484789	0.06453321
7	0.391165343	0.423452745	0.353600505	0.031080309
AVERAGE	0.329998454	0.171152786	0.347447818	0.088783397
SD	0.126217101	0.13388784	0.320019261	0.061561686
<i>p</i>	0.040416995	0.012259446	0.020496483	0.004479632