Electromyographic Investigation of Free Weights and Thera-Band during Selected Shoulder Rehabilitation Exercises

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

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ABSTRACT

The purpose of this study was to compare average and peak muscle activation when using free weights and Thera-Band® in the completion of three selected shoulder rehabilitation exercises. More specifically the purpose was to compare the average and average peak normalized rms EMG of the anterior deltoid during shoulder flexion, the middle deltoid during shoulder abduction, and the biceps brachii during elbow flexion with a 10 pound dumbbell or with a black Thera- Band.® Eight male subjects voluntarily participated in this study. Each subject completed 2 sets of three repetitions each with a 10 pound weight and a black piece of Thera- Band®. Surface electromyography recorded the muscle activation of the anterior deltoid, middle deltoid, and biceps brachii muscles. A paired samples T-test was used to compare the level of muscle activation between the two rehabilitation tools. No significant differences were found between the paired samples test. Significant values were found for the paired samples correlation test for the middle deltoid average activity, biceps brachii average activity, and biceps brachii peak activity. It was concluded that neither device produced significantly higher muscle activation levels than the other, therefore leading to the assumption that both rehabilitation tools affect a working muscle in the same manner.

ACKNOWLEDGEMENTS

There have been a large number of people throughout this process that have helped me develop my ideas and contributed to my success in completing this study. It would be impossible to recognize them all, but I would like to take a second and point out a few who were instrumental along the way.

The faculty of the Exercise Science Department at SUNY Cortland, particularly Peter McGinnis, Joy Hendrick, and Jeff Bauer, through their support enabled this project to happen. I cannot express the appreciation I have for the hours that they have put into the processes of data collection, statistical analysis, and editing of this study.

I also need to thank my family for always being there to support whatever it was that I wanted to do; without that love and guidance I wouldn't be where I am today.

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CHAPTER 1

INTRODUCTION

Progressive resistance exercises, PREs, are commonly used by clinicians to increase muscular strength during a reconditioning program, usually following an injury. There are numerous techniques and a variety of equipment that can be utilized in resistance training, but all are governed by the same principle: allowing the muscles to become strengthened by contracting and overcoming some fixed resistance (Hughes, Hurd, Jones, & Sprigle, 1999; Prentice, 1999). Resistance training can be any type of resistance overload that is placed upon muscles to develop muscular power, strength, and endurance (Zachazewski, Magee, & Quillen, 1996). For the early stages of shoulder rehabilitation, some commonly employed methods include the use of elastic resistance devices and conventional dumbbells or free weights. The exercises performed with these types of devices can be categorized as isotonic, or isodynamic, where the muscle is changing in length while it generates a force. The components of the contraction include both a concentric, or shortening, and an eccentric or lengthening phase through which the muscle overcomes the resistance. Greater amounts of force can be produced during the lengthening or eccentric phase, therefore making it an important element that should not be ignored when performing shoulder rehabilitation exercises (Prentice, 1999). An eccentric contraction is easily attained using both free weights and Thera-Band® elastic resistance (The Hygenic Corporation, Akron, Ohio) for rehabilitation.

The problem with using elastic resistance for rehabilitation is the uncertainty of whether or not using these new techniques work as well as the accepted standards, such as using free weights. Is the resistance provided by the elastic devices similar to the resistance provided by free weights? Is the muscle activation during exercises with elastic resistance similar to that during the exercises with free weights? Muscle activation can be quantified using electromyography. Surface electromyography is an easy, noninvasive way to measure the electrical activity of a muscle as it contracts and does work (Cram & Kasman, 1998).

Statement of the Problem

The general purpose of this study was to compare muscle activation levels of the anterior deltoid, middle deltoid, and biceps brachii muscles when completing shoulder rehabilitation exercises using a 10 pound dumbbell versus a black Thera-Band®. More specifically the three purposes of the study were: 1) to compare the average and average peak normalized rms EMG of the anterior deltoid during a shoulder flexion exercise with a 10 pound dumbbell to the average and average peak normalized rms EMG of the anterior deltoid during a shoulder flexion exercise with a black Thera-Band®, 2) to compare the average and average peak normalized rms EMG of the middle deltoid during a shoulder abduction exercise with a 10 pound dumbbell to the average and average peak normalized rms EMG of the middle deltoid during a shoulder abduction exercise with a black Thera-Band®, and 3) to compare the average and average peak normalized rms EMG of the biceps brachii during an elbow flexion exercise with a 10 pound dumbbell to the average and average peak normalized rms EMG of the biceps brachii during an elbow flexion exercise with a black Thera-Band®.

Significance of Study

In most rehabilitation facilities, the availability of free weights and elastic resistance devices is prevalent. They are both available for use, but are the benefits from each equal in producing strength gains when used correctly? The significance of this question has much importance for a therapist. Knowing the advantages or drawbacks of the equipment they employ will allow them to best serve their patients and maximize the results they see from the rehabilitation. By comparing these two commonly used devices in shoulder rehabilitation, clinicians will have evidence to quantify how much work is being done by their patients and how much strength gain is occurring.

Hypothesis

The hypothesis of this study is that when used correctly, a 10 pound free weight and a black piece of Thera-Band® produce muscle activation levels that are similar when performing shoulder flexion, shoulder abduction, and elbow flexion.

Delimitations

There were a number of delimitations that were taken into account as a part of the project design. Only male subjects were tested, and all were of college-age. This was proposed as the population to decrease the differences that may have arisen if males and females were used, or if EMG or shoulder rehabilitation exercises are affected by a subject's age. The study was also restricted to just the two rehabilitation devices that were used, the 10 pound weight and the black Thera-Band®.

Limitations

The three shoulder exercises that were chosen impose a limited scope on this study. Every subject completed only these exercises under the same conditions to determine specifically if these exercises were affected by the device used; other muscles could have been examined with these movements, but only the prime movers throughout a particular range of motion were studied. Another limitation is the electrode placement, particularly that of the anterior deltoid muscle. The reference limited the site to 4cm below the clavicle (Cram & Kasman, 1998), however it didn’t take into account the difference in the sizes of the subjects. This could have affected the muscle activity that was detected by the EMG, if the electrode placement was off more or less of the actual activity may have been able to be detected, possibly affecting the overall results that were found. The most important limitation that is present in this study was the small sample size. There were only eight subjects that were tested due to time constraints and the length of the testing. A larger sample population may reveal more about the variables that were being tested in this study.

Definition of terms

Electromyography or EMG**:** a sum of the electrical energy from all the muscle action potentials detected by the recording electrode (Cram & Kasman, 1998).

Gain: how much larger an amplifier makes a biological signal; the amount of gain or amplification determines how large or small the EMG signal appears on a visual display (Cram & Kasman, 1998).

Maximum voluntary contraction or MVC: the greatest amount of effort and individual can put forth with the volitional activation of a particular muscle or muscle group (Prentice, 1999).

Progressive resistance exercise or PRE: exercises or a program of exercises that build physical strength through lifting progressively heavier weight (Prentice, 1999).

Root mean square or rms: the quantification of an EMG signal by squaring the data, summing the squares, dividing this sum by the number of observations, and taking the square root of that number to come up with the answer (Cram & Kasman, 1998).

CHAPTER 2

LITERATURE REVIEW

The purpose of this study was to compare muscle activation levels of the anterior deltoid, middle deltoid, and the biceps brachii when completing shoulder rehabilitation exercises using a 10 pound free weight and a black Thera-Band®. Progressive resistance exercises, along with the characteristics of elastic resistance and their use in shoulder rehabilitation, and surface electromyography will be further reviewed in this section as it relates to the study.

Progressive resistance exercises

Progressive resistance exercises, or PRE's, are a major component of any rehabilitation program. They are utilized to bring muscles and tissue back to a state of optimal functioning and strength following an injury or to condition a competing athlete. Strength refers to the ability of a muscle to produce a force against a resistance, and it is often used as a measure of one's physical ability (Prentice, 1999). Weakness in muscles will occur gradually over time if they are not used or following an injury; this is known as atrophy. As this occurs, changes in the mechanics of a person's movements may be noted, which can either cause them to sustain an injury or to aggravate an already existing one (Prentice, 1999).

Isotonic training, achieved by performing PREs, is thought to offer the greatest flexibility and variability in the design of the resistance program (Zachazewski et al., 1996). Isotonic training involves both concentric and eccentric contractions. It can be performed using such devices such as Thera-Band® elastic resistance bands and handheld free weights. These tools both allow for the introduction of sport- specific movements, which is important for rehabilitation. They also allow the athlete to control the speed at which the exercise is performed. There are advantages and disadvantages to using elastic resistance bands and handheld free weights in PRE's. Both have proven benefits for increasing a person's strength when used correctly in the rehabilitation setting (Prentice, 1999).

Use of elastic resistance bands in exercise

Thera-Band® elastic resistance devices have increased in popularity in the rehabilitation setting. There are six different colors of the band produced, each one varying from the others in the level of resistance offered. The least resistive band is yellow, and the next five colors gradually increase in resistive properties. The colors of the bands, from lowest to highest resistance are yellow, red, green, blue, black, and silver. Hughes et al (1999) showed the benefits to using Thera-Band® for strengthening include its ease of use, safety for all populations of people to employ, low cost, and portability. Its use can translate into increased functional performance by those who use it correctly. Anderson, Rush, Shearer, and Hughes (1992) reported a ten percent increase in the strength of the internal rotators of the shoulder of young subjects after six weeks of training with Thera-Band® (Anderson et al., 1992, as cited in Hughes et al., 1999). Ward, Paolizzi, Maloon, Stanard, and Bell (1997) compared the use of free weights and Thera-Band® on the external rotators of the shoulder for four weeks. Both methods were equally effective in producing gains in strength in the muscles that were exercised (Ward et al., 1997, as cited in Hughes et al., 1999).

The questions that arise when using Thera-Band® pertain to the fact that the resistance varies to some extent as it stretches. This phenomenon is known as the stress- strain relationship, which implies that the resistance from the material is relative to its change in length during use (Simoneau, Bereda, Sobush, & Starsky, 2001). The amount of resistance provided by a piece of elastic material is dependent on its stiffness (which is coded by color), its length, its initial deformation, and its final deformation (Simoneau et al., 2001). As the material is stretched more and more, the resistance increases, therefore the initial length will govern how much more stretch the material can undergo.

Another characteristic of elastic resistance is that over time the material begins to fatigue; upon being stretched countless times the elastic material will no longer be able to provide the same tension. A patient may be able to recognize the decrease in resistance of the material, but this dilemma can be avoided altogether by continually changing the material used after it has been stretched so many times. According to Simoneau et al. (2001) when the elastic bands were stretched to 100% of their initial length for 501 cycles, there was a decrease in tension of approximately 9-12% between the first and last cycle. They also found that the most fatigue will occur within the first 50 stretch cycles. They concluded that the tension in the material decreases slowly with repeated stretching, and would continue to decrease with an increased number of stretches (Simoneau et al., 2001).

Due to the fact that the resistance level is determined by the stretch and the resting length of the material, some questions as to just how much resistance the patient is receiving have arisen. Studies have quantified the amount of resistance provided by different colors of Thera-Band®. Results of these studies give a rough estimate as to how much work is actually being performed by a patient. The data in Table 1, provided by the Fitness Wholesale Online (2003) website regarding the use of Thera-Band®, quantify this resistance in relation to the deformation of the material. This allows clinicians to make comparisons with other rehabilitation tools, such as free weights, when making decisions about the intensity and frequency of exercises to be performed. If someone is unfamiliar with Thera-Band®, the quantification of the resistance will better clarify the amount of work being done by their patients.

Table 1. Average Force (pounds) for Thera-Band® Elastic Bands.

% Elongation	Yellow	Red	Green	Blue	Black	Silver	Gold
50%	2	2.5	3	4.5	6.5	8.5	14
100%	3	4	5	7	9.5	13	21.5
150%	4	5	6.5	9	12.5	17	27.5
200%	5	6	8	11	15	21	33.5
250%	6	7	9.5	13.5	17.5	25.5	40

Note: Data reprinted from Fitness Wholesale Online website, retrieved February, 24, 2003, from http://www.fitnesswholesale.com/tbbkit.htm

A drawback to using elastic resistance is that at the end range of motion, a greater force is needed to complete the exercise (Hughes et al., 1999). At the beginning of an exercise, the force needed by the muscle is relatively small, while using handheld weights the resistance remains constant throughout the movement. The torque that the muscles are able to exert does vary throughout the range of motion however. For example, during elbow flexion, the elbow flexors must exert a greater amount of force at the end ranges to generate the same torque that is needed in the midrange of the same movement (Baechle & Earle, 2000). This example does not hold true for all exercises and muscles however, the position in which the exercise is performed and the exercise itself will determine the torque needed to overcome the resistance of the band.

The choice of Thera-Band® versus handheld weights is a decision that rehabilitators are forced to make in their field. Handheld weights are familiar to patients and clinicians and often need no explanation as to their use. The benefits that Thera-Band® offers in terms of functional rehabilitation cannot be ignored. The gains in strength achieved by its use may be comparable to that of free weights, as well as the exercises which can be performed, but it allows for variations of these exercises in terms of the angle at which they are carried out. Thera-Band® elastic resistance provides the same beneficial strengthening effects as free weights, but this less common tool may cause some to be hesitant of its use.

Shoulder rehabilitation

In shoulder rehabilitation, a general overall strengthening of the shoulder complex and all the muscles surrounding it and the neighboring joints is desired. The rotator cuff muscles are the most common muscles rehabilitated for most injuries, and are major movers in the GH joint (Donatelli, 1997). The deltoid muscles however have also been tagged as prime movers of the GH joint. Two of the exercises chosen for this study, shoulder flexion and shoulder abduction, focus on the strength of the anterior and middle fibers of the deltoid muscle. The third exercise used in the present study is elbow flexion which involves the biceps brachii muscle. It plays a role in assisting the rotator cuff muscles in compressing the humeral head (Donatelli, 1997). The muscles being utilized in this study are common muscles that you would find included in many shoulder rehabilitation programs. The position and range of motion of the shoulder during these exercises coincide with rehabilitation programs, in that the humeral elevation should not exceed the level of 90º during the early stages of rehabilitation; this decreases the stress placed on the rotator cuff and other shoulder ligaments (Decker, Hintermeister, Faber, & Hawkins, 1999). McCann, Wootten, Kadaba, and Bigliani (1993), supported the notion that rotator cuff strengthening exercises done below shoulder level are a satisfactory way of increasing strength of the shoulder muscles whether someone is using resistive bands or light weights.

Surface electromyography

Resistive exercises performed with an elastic band below shoulder level consistently showed moderate levels of activity in the deltoid muscles as found by McCann et al. (1993). The signal obtained from an EMG represents an estimation of the muscle's level of activation (Wells & Patla, 1985). The motor units within a muscle are stimulated and the result is an action potential within the muscle. Multiple action potentials occur and these are added together, transmitted as an electrical signal, and produce values on the EMG that can be used as data. The overall activity of these action potentials affects the magnitude of the signal, and as the contraction becomes stronger, the amplitude of the signal also increases with the increased recruitment of active motor units (Wells & Patla, 1985).

The signal acquired by using surface electromyography appears to be heightened when testing under isometric conditions (Cram & Kasman, 1998). If testing an isotonic movement however, the concentric portion of the contraction appears to exceed the values obtained from the eccentric portion; this is thought to happen because of the work that is occurring within the muscle in breaking the already existing cross- bridges (Cram & Kasman, 1998).

Differences in EMG may also be due to differences in gender. Individuals each have different values that will be obtained from EMG testing, even if they are doing the same exercises, but differences can be generalized between men and women. In terms of physical performance, gender differences are almost always noted because of the variations in anthropometric factors (Ives, Kroll, & Bultman, 1993). Changes in neuromuscular coordination between men and women have also been discovered relating to the ability of the muscle to exert force. Ives et al (1993) found that men not only have larger EMG values recorded, but they are also faster at generating tension within their muscles. The mechanism for this was proposed to be because men have larger muscle mass and less subcutaneous fat (Ives et al., 1993). Anders, Bretschneider, Bernsdorf, Erler, and Schneider (2004) believed that the activation levels found in the male subjects may have been able to have been studied more precisely. They attributed this to higher levels of muscle activation in the male subject's muscles, as opposed to the female population that was tested.

Summary

Resistance training is used to rehabilitate the injured shoulder. Progressive resistance exercises are the exercises most often used in shoulder rehabilitation, where the muscles are being strengthened by overcoming a fixed resistance. There are many devices that can be used to accomplish strength gain. Two tools that have grown in popularity are free weights and Thera-Band®. Many studies have found that the use of resistance bands and free weights have both been shown to increase a person's strength when used as part of a training program. The resistance offered by a piece of Thera-Band varies as the material is stretched from its original resting length. Studies have quantified the amount of resistance of the material relative to its change in length from its original size in order to better compare it to other rehabilitation tools. Using surface electromyography, muscle activity levels can be measured in working muscles.

CHAPTER 3

METHODS AND PROCEDURES

The purpose of this study was to compare muscle activation levels in men when performing shoulder exercises with both Thera-Band® and free weights. Electromyography was used to measure average and leak muscle activation levels.

Subjects

Eight male subjects (age 23.62 ±2.83 yrs., 1.83 ±.11 meters, 90.17±11.7 kgs), were the population tested for this study. Each subject was required to give their informed consent to participate in the study, and be free of any previous shoulder pathologies or surgeries. Table 2 displays the descriptive data for each of the participants. The subjects each signed an approved SUNY Cortland- Human Subjects Research form and filled out an information sheet (found in Appendix A) after they read the procedures for the testing. They were required to perform three selected shoulder rehabilitation exercises using their dominant arm. These exercises were shoulder abduction, shoulder flexion, and elbow flexion, which work the middle deltoid, anterior deltoid, and biceps brachii respectively. The activity of each of these muscles was recorded using a Therapeutics Unlimited Model 544 Multichannel Electromyographic System (Therapeutics Unlimited Inc, Iowa City, IA).

Table 2. Participant's age, height, and weight.

Subject #	Age (years)	Height (meters)	Weight (kgs)
1	23	1.68	72.00
2	22	1.80	90.00
3	26	1.75	79.20
4	21	1.83	83.25
5	21	1.8	103.50
6	22	1.88	96.75
7	25	2.03	105.75
8	29	1.90	90.90
Average-	23.6 (± 2.83)	1.83 (±.11)	90.17 (± 11.7)

Instrumentation

A Therapeutics Unlimited Model 544 Multichannel Electromyographic System was used to record the electrical activity of the anterior deltoid, middle deltoid, and biceps brachii. Surface electrodes with built in preamplifiers detected the EMG signal and transmitted the analog signal by cable to the Therapeutics Unlimited Model 544 Multichannel EMG System. The analog signal was then amplified by a factor 2000 or 5000, depending on the subject being tested. A root mean square (rms) function rectified and filtered the raw analog signal using a 2 ms time period. The analog rms signal was then sampled at 1020 Hz and recorded by the Peak Motus® motion analysis system (Peak Performance Technologies, Inc., Centennial, CO) for nine seconds resulting in 9180 data points for each trial. A video camera was positioned in front of the subjects in the frontal plane, which was connected to the VCR, enabling the muscle activity to be recorded on the EMG, while the actual performance of these exercises was recorded on video. The test began by connecting the appropriate EMG lead to the muscle being tested, and the first rehabilitation device that the subject was to use was given to them. Each set of exercises with both devices were recorded, and each data file was saved separately in Peak Motus.® Each subject completed six sets of exercises with each device, or twelve sets of exercises. The subjects completed the study when they had performed the required number of repetitions with each device, and all their data was recorded.

Data collection procedures

Subjects were required to wear clothing in which the electrode sites could be properly exposed on their dominant arm and shoulder. The electrode positions on each of the muscles were referenced from Kram and Casman (1998). For the anterior deltoid, the electrode was placed on the anterior upper arm approximately 4 cm inferior to the clavicle. For the middle deltoid, the electrode was placed on the lateral aspect of the upper arm approximately 3 cm inferior to the acromion. For the biceps brachii, the electrode was placed on the center of the muscle belly. The electrode sites were initially marked with a non- permanent marker. The marked areas were cleaned with an alcohol pad, and conductive gel and double-sided tape were applied to the electrodes, and placed on the proper area parallel to the muscle's fibers. A reference electrode was also applied with conducting gel to the dorsal aspect of the forearm on the non- dominant arm. All of the electrodes were secured with athletic tape to insure contact.

The subjects were then instructed on the proper technique of the three exercises with each rehabilitation device; ample warm-up and practice time was given to each participant. The order of the exercises performed and the device that they would use first was predetermined to negate any possible influences of fatigue amongst the individuals tested. A video camera was used during the testing to ensure each subject was completing each exercise with the proper form and throughout the full range of motion.

Figure 1. Photograph of a subject set-up on the EMG.

Maximum voluntary contractions, MVCs, were performed for each of the three muscles tested. The MVCs were performed in the same sequence in which the muscles were to be tested with the devices, the order of these exercises can be found in Table 3. For each muscle, three MVCs were recorded for six seconds each. Each MVC was performed at the final angle in the range of motion of the exercise, except for elbow flexion. Each subject differed in the end angle of full elbow flexion, therefore to ensure consistency an angle on 90º was used. An isometric contraction was produced by pulling on a rope that acted as a fixed resistance. There was approximately 30 seconds of rest between each contraction. The first two subjects had their values recorded with the gain set at 5k on the EMG; the last six subjects used a gain of 2k.

Table 3. Testing order for shoulder muscles.

Subject	Device used first	Testing order for shoulder muscles
1	10 pound weight	MD, AD, BB
2	Thera-Band	MD, AD, BB
3	10 pound weight	AD, BB, MD
4	Thera-Band	AD, BB, MD
5	10 pound weight	BB, MD, AD
6	Thera-Band	BB, MD, AD
7	10 pound weight	MD, BB, AD
8	Thera-Band	MD, BB, AD

MD- Middle deltoid, AD- Anterior deltoid, BB- Biceps brachii

Approximately 5 minutes elapsed between the MVC and the shoulder exercise testing to set each subject up, which allowed them sometime to rest. Before the subjects performed the shoulder exercises using the Thera-Band®, measurements of the length of band used were taken. While the subject was standing the band was placed under the subject's foot, and then gripped in their dominant hand with their arm fully extended; marks were made on the band with chalk where it was under their foot, as well as at the location where they grabbed the band. The resting length of the band was then measured between these two marks and recorded. The band was then stretched to the final position in the range of motion of each exercise; its length was measured and recorded. These measurements were taken to verify that the band approximately doubled in length. According to the Fitness Wholesale Online chart (2003), at 100%, or when the black Thera-Band® doubles in length, the resistance is close to that of a ten pound weight.

A metronome, set to 60 beats per minute, timed the completion of the exercises. The subjects were instructed to use the beats to guide them through the appropriate movements. The shoulder flexion exercise, shown in Figure 2, began with the subject's arm fully extended at their side and their forearm pronated. The arm then moved to 90º of flexion at the shoulder with the arm fully extended and forearm still in pronation. The exercise ended with the arm extended at the shoulder and returning to its starting position with the arm at the side.

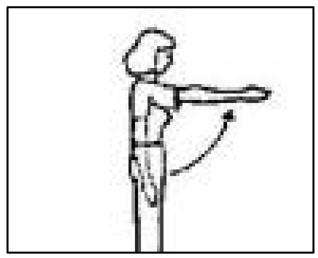

Figure 2. Shoulder flexion exercise.

The exercise of shoulder abduction, shown in Figure 3, began with the arm extended at their side with the forearm in a neutral position. The arm was raised into 90º of abduction at the shoulder and the exercise ended with the arm adducting at the shoulder and returning to its starting position at the side.

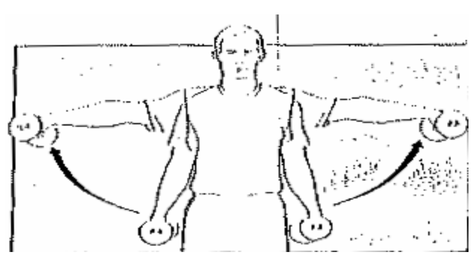

Figure 3. Shoulder abduction exercise.

Before elbow flexion was performed, the subjects were asked to bring their arm into full elbow flexion. This final angle was measured using a goniometer and recorded for each participant. The elbow flexion exercise, shown in Figure 4, began with the subject's arm at their side and their forearm supinated. In this position they performed elbow flexion through their full range of motion; the exercise finished with their arm in the starting position. When the subject's were completing the exercises with the Thera-Band®, the band was secured under their dominant foot, and held in their dominant hand; the 10 pound weight was simply placed in their dominant hand.

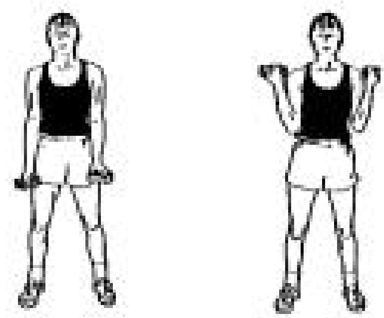

Figure 4. Elbow flexion exercise.

The subjects completed two sets of three repetitions of each exercise with both rehabilitation devices. EMG was recorded for nine seconds for each set, although the repetitions only required six seconds to be performed. The extra seconds of recording were needed because the subjects were instructed to listen to the beats on the metronome and begin when they heard a beat to make sure they were timing themselves properly. Each set was separated by one minute of rest. The electrodes were removed from their skin, and the conducting gel was removed with an alcohol pad.

Data reduction

The purpose of this study was to compare average and peak muscle activation when using free weights and Thera-Band in the completion of three selected shoulder rehabilitation exercises. Surface electromyography was used to measure the muscle activation in the anterior deltoid, middle deltoid, and biceps brachii. There were 21 different data files for each subject, which included the MVC contractions and the exercises with the band and the weight. These files were all stored in a file using Peak Motus®. and each of these files was then transferred to a CD, where each subject's files were stored separately. The first of the files that were analyzed were the MVC files. These files were presented graphically using Peak Motus®. The data presented as a graph allowed for the three seconds of muscle activity to be selected. The criteria for the selection was based upon the coordinates of the graph and the area in which maximum muscle contraction appeared to be obtained; a block of three seconds of data became the values used to compute the MVC. The data chosen was visually selected based upon the appearance of the graph. In general for all the subjects, the three seconds selected as the MVC data ranged from the first to the fifth second.

The entire data file stored from the trials of the MVCs was also transferred onto a spreadsheet in Microsoft Excel® (Microsoft Corporation, Redmond, WA, 2003). A time column was added to the spreadsheet, which broke time down into thousandths of a second intervals, and was displayed directly next to the values obtained from the EMG. Using functions of Microsoft Excel®, the average and peak activity levels were calculated for each of the three MVCs according to the three chosen seconds for each muscle. Means were calculated for the three average and three peak MVC values, and these means represented the average MVC and peak MVC for that particular muscle for each subject. In order to have the data be expressed in millivolts, mV, the gain used to collect the data had to be taken into account. The first two subject's data was multiplied by 200, and the last six needed their final values multiplied by 500 to convert to millivolts.

The next set of data analyzed, were the files recorded when the subjects performed the exercises with each rehabilitation device. Two sets of each exercise were performed, however when analyzing the data the first set was disregarded. The subjects were unaware of how the data would be processed; therefore the first set of repetitions was viewed as practice to ensure that the subjects were completing the exercises correctly and becoming acclimated to using the metronome for exercise timing. The second data file collected for each set of exercises was presented as a graph in Peak Motus®, an example of one such graph is presented in Figure 1.

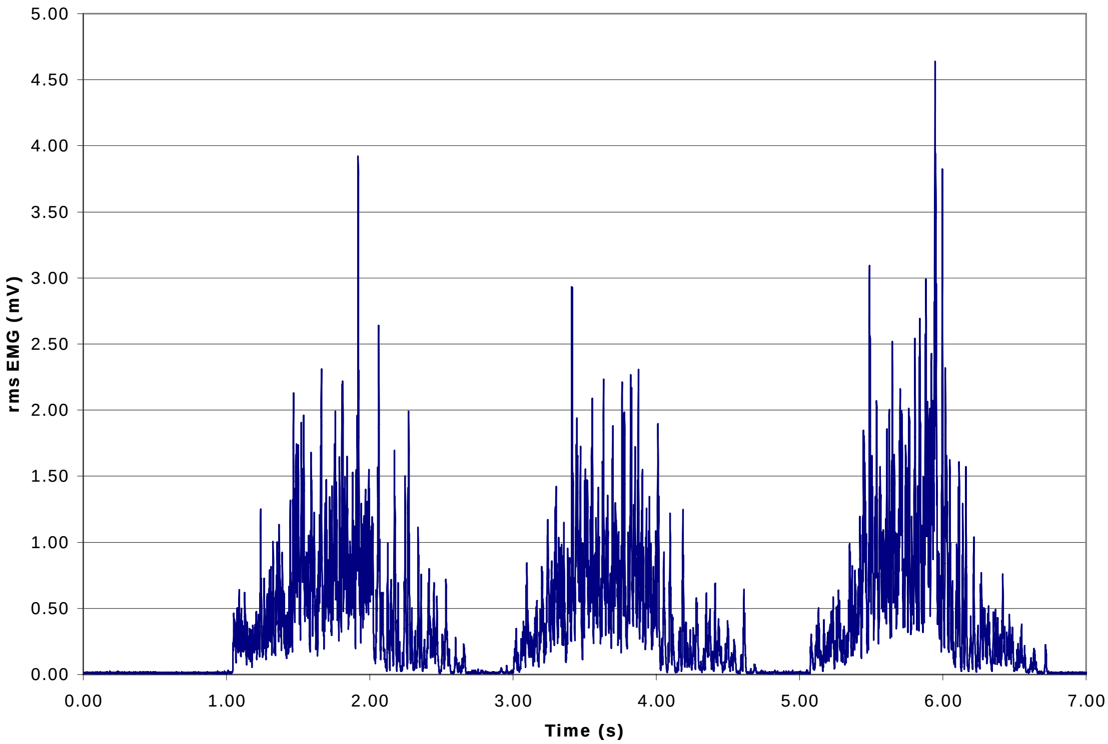

Figure 5. A sample of the EMG data represented graphically in Peak Motus.

Based upon the coordinates and the appearance of the data, it was possible to find where each repetition began and ended. The time at which the first repetition began was noted. The entire data file was then transferred onto a Microsoft Excel® spreadsheet. A time column was added to the spreadsheet, which again broke time down into thousandths of a second. The time when the first repetition started was found using the time column, and this allowed for the average and peak muscle activity from each repetition to be calculated. Average and maximum value functions were used in Microsoft Excel® to determine these values for every two seconds of data recorded, with two seconds being the time it took for each individual repetition. These calculations gave three average and three peak values for each subject. The mean of these average and peak values was used in the final calculations. Mean average and peak values were found when the participants were using the Thera-Band® and the weight.

The next set of data collected was calculated from the previously analyzed data. In order to compare the average and peak muscle activity for each person, the data was normalized. This was done by taking each individual's MVC values and the values found from the exercise repetitions, and averaging the two. The average and peak values for muscle activity were divided by the average and peak MVCs, giving a percent activation as compared with the maximum level that could be attained by each person. The average muscle activities were divided by the average MVC values, and the peak muscle activity levels were divided by the peak MVC values to give the normalized values of muscle activation.

SPSS, a program designed for statistical analysis (SPSS, Inc., Chicago, Illinois), was then used to run the statistical analysis. A paired samples T-test, as well as a paired samples correlation test, was run to compare each rehabilitation device, based on the muscle activation it elicited at both the average and the peak activity level. The results from this test identified differences between the two modes of exercise and the muscle activation generated from the use of each.

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this study is to compare muscle activation levels in men when performing shoulder exercises with both Thera-Band® and free weights. Electromyography was used to measure average and peak muscle activation levels. Average and peak muscle activation levels were calculated using Peak Motus® and Microsoft Excel®.

Table 4 shows the average and peak MVC values for each participant. These numbers varied throughout the subjects, and were used to determine the muscle activity levels generated from completing the exercises which were tested.

Table 4. Average and peak maximum voluntary contractions (MVCs) in µV.

Subject #	AA	AP	MA	MP	BA	BP
1	254.8	1143.8	297.8	1303.0	335.0	1315.8
2	204.2	1082.8	307.0	1524.2	236.0	1172.2
3	644.5	3366.5	573.0	2693.5	595.0	2601.0
4	951.5	3544.0	522.0	2335.0	1116.0	4073.0
5	413.5	2262.5	553.0	2652.0	481.0	2380.5
6	234.0	1083.0	433.5	1780.5	398.5	2235.5
7	264.0	1799.0	308.5	1715.0	129.0	733.0
8	289.5	1241.5	366.0	1556.0	441.5	1946.5

AA- Anterior deltoid, Average MVC
AP- Anterior deltoid, Peak MVC
MA- Middle deltoid, Average MVC
MP- Middle deltoid, Peak MVC
BA- Biceps brachii, Average MVC
BP- Biceps brachii, Peak MVC

In Table 5, the average and peak muscle activities are shown for each of the subjects when they completed the required exercises using either the Thera-Band® or the 10 pound weight. To compare these values, a paired samples T-test was run using SPSS (SPSS, Inc., Chicago, Illinois). The values, when tested at the $p \leq .05$ alpha level, displayed no significant results. The paired samples correlations did have values that were significant at this level. For the pairs of the middle deltoid average activity (MA) and both the average and peak values for the biceps brachii (BA and BP respectively), significant correlations were found. The correlation for the MA was .792. The r^2 value of this result was .627; which indicated that approximately 63% of the variation between the two devices tested was common, or shared among them. The correlation values for the BA and BP were .922 and .822. This indicated that about 85% and 68% of the variation respectively, was shared between the two groups.

Table 5. Average and peak muscle activity (average or peak EMG activity in μV).

Subject	AA	AP	MA	MP	BA	BP
10 lb Weight						
1	113.27	1030.00	134.13	861.53	129.53	894.87
2	99.53	748.40	89.00	603.87	244.67	1528.93
3	247.00	1889.00	274.33	3182.83	208.50	1908.17
4	417.67	3571.83	223.17	1493.17	231.83	1511.17
5	166.50	1260.67	226.00	1730.17	353.00	2510.83
6	141.00	1040.00	130.33	818.83	296.33	2003.50
7	252.50	1147.90	105.83	1128.00	135.67	1071.67
8	95.67	524.33	107.67	975.00	98.83	619.33
Thera-Band®						
1	138.73	965.53	141.67	1060.20	143.67	1227.20
2	170.33	1694.27	85.27	658.13	161.00	1156.33
3	178.00	1256.50	230.67	1781.50	220.30	1883.83
4	338.50	4650.00	216.67	2467.33	240.83	2188.33
5	212.83	1907.50	246.83	2287.67	348.67	2675.00
6	89.17	743.83	105.33	820.33	165.50	1357.50
7	138.00	1178.33	93.33	1121.33	132.50	1372.83
8	149.33	916.00	136.00	1376.83	123.83	1042.50

AA- Anterior deltoid, average muscle activity
MA- Middle deltoid, average muscle activity
BA- Biceps brachii, average muscle activity
AP- Anterior deltoid, peak muscle activity
MP- Middle deltoid, peak muscle activity
BP- Biceps brachii, peak muscle activity

A paired samples T-test was used to analyze the normalized data. The normalized data are presented in Appendix B. No significant differences were found in peak or average muscle activity between the shoulder exercise with the Thera- Band® or the free weight. Table 6 shows the results of this test. None of the six comparisons were significant at the $p \leq .05$ alpha level. If the muscle activation levels were similar, no significant differences would be expected.

Table 6. Paired samples T-test results.

		Mean	Std. Dev.	Std. error mean	t	df	Sig. (2-tailed)
Pair 1	AA10-AABAND	0.0125	0.2482	0.0877	0.142	7	0.891
Pair 2	AP10-APBAND	-0.1068	0.4185	0.1479	-0.722	7	0.494
Pair 3	MA10-MABAND	0.0074	0.0521	0.0184	0.4	7	0.701
Pair 4	MP10-MPBAND	-0.0688	0.2781	0.0983	-0.7	7	0.506
Pair 5	BA10-BABAND	0.0998	0.1746	0.0617	1.617	7	0.15
Pair 6	BP10-BPBAND	-0.0627	0.2575	0.0911	-0.689	7	0.513

Correlation coefficients were computed for the paired sets of normalized data. An examination of the correlations better explains the results. The correlations are shown in Table 7 and illustrated graphically in Figures 6 through 11. Significant correlations were found between the Thera- Band® and 10 pound weight for the middle deltoid average activity, biceps brachii average activity, and biceps brachii peak activity ($p \leq .05$). The correlation coefficients were .792, .922, and .822 respectively. By using r^2, or the coefficient of determination, the correlation can be interpreted. The coefficient of determination accounts for the total variance in one group that can be explained by the total variance in the other group. Therefore the r^2 values for the MA is 63%, for BA 85%, and for BP 68%. By taking the biceps brachii average activity as an example, the results indicated that 85% of the variation between the exercises being performed with the Thera-Band® and the 10 pound weight can be explained by commonalities between the two. That leaves approximately 15% of the data found to be uncommon between the two experimental groups, and this number allows for one to speculate as too what these differences may be.

Table 7. Paired samples correlations.

		N	Correlation	Sig.
Pair 1	AA10-AABAND	8	0.096	0.821
Pair 2	AP10-APBAND	8	0.161	0.703
Pair 3	MA10-MABAND	8	0.792	0.019
Pair 4	MP10-MPBAND	8	0.238	0.571
Pair 5	BA10-BABAND	8	0.922	0.001
Pair 6	BP10-BPBAND	8	0.822	0.012

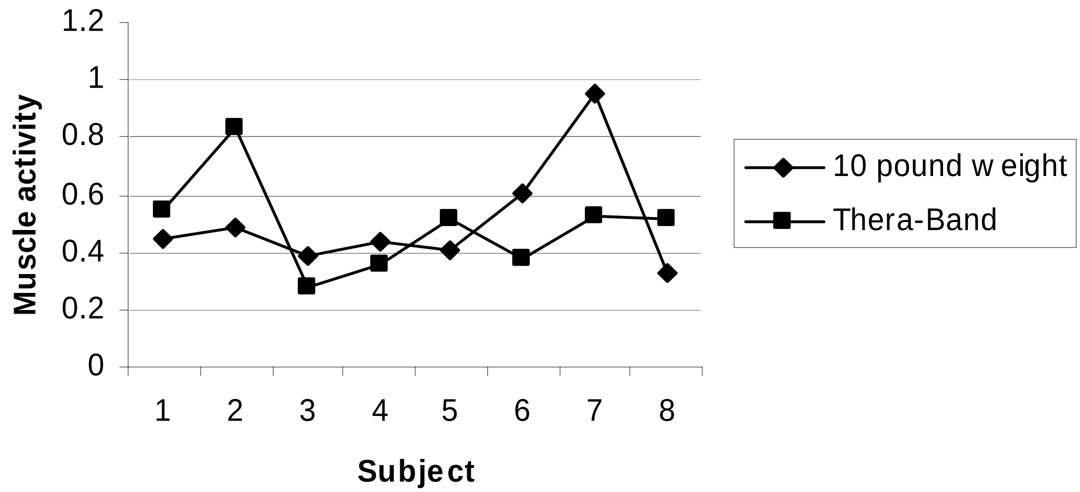

Figure 6. Comparison of average muscle activity of anterior deltoid.

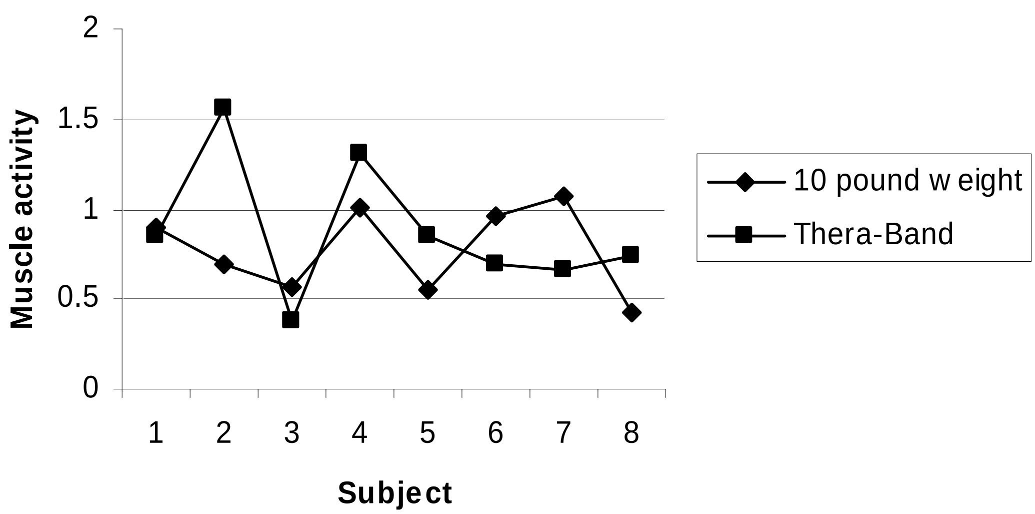

Figure 7. Comparison of peak muscle activity of anterior deltoid

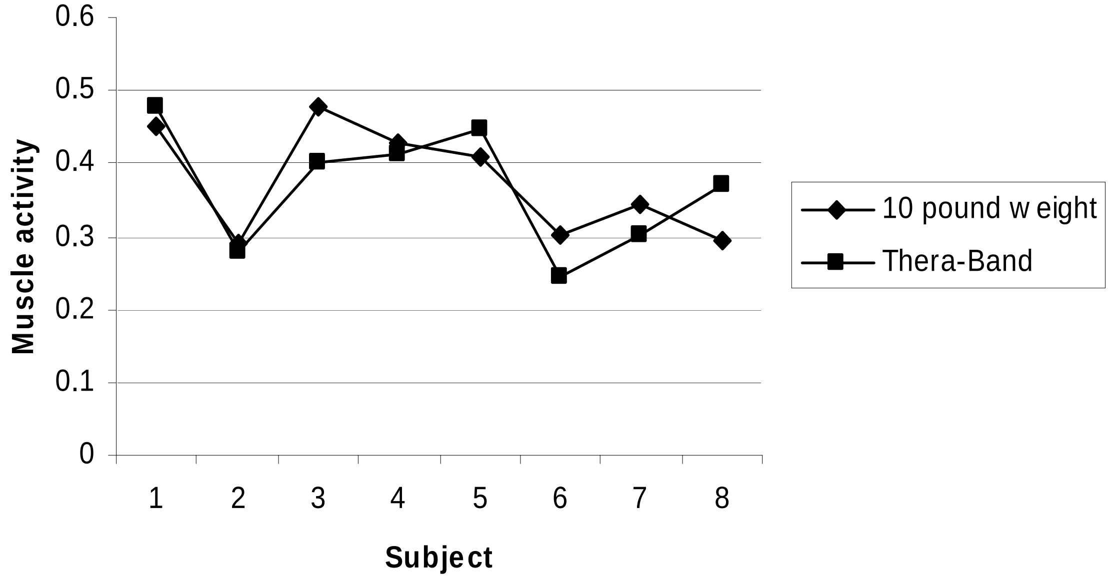

Figure 8. Comparison of average muscle activity of middle deltoid.

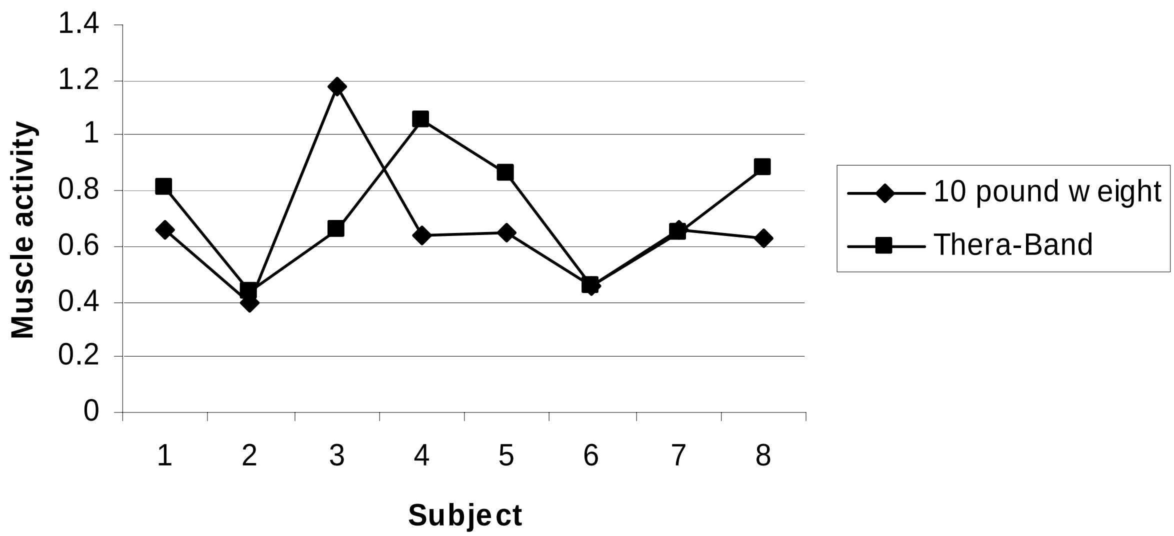

Figure 9. Comparison of peak muscle activity of middle deltoid.

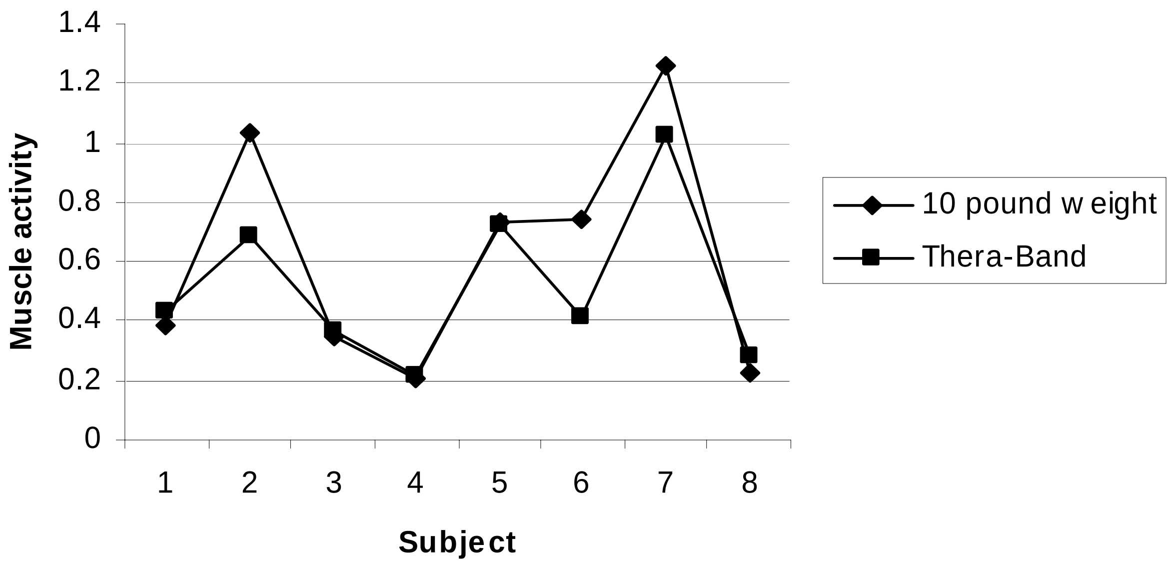

Figure 10. Comparison of average muscle activity of biceps brachii.

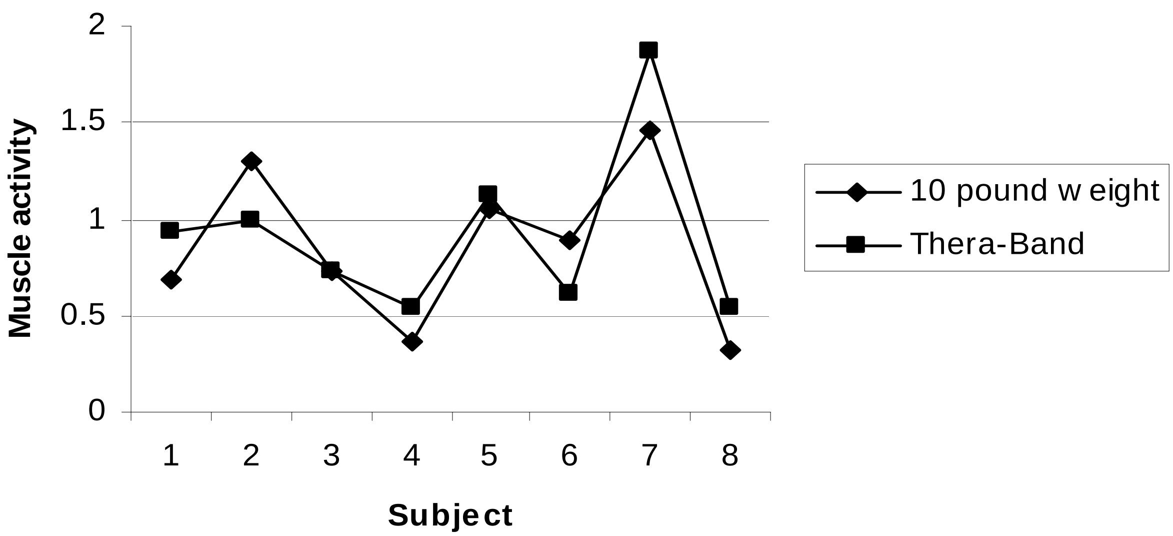

Figure 11. Comparison of average muscle activity of biceps brachii.

The large correlations for the three variables tested suggest that both devices produce similar effects on the muscles tested during these exercises. The range of motion and the angle at which the exercises were tested, elicited similar activation levels within the muscles. For application into the daily use of these devices for shoulder rehabilitation, a clinician could deduce that if both devices are available for use, there are no clear advantages or disadvantages as to why one should be chosen over the other.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The purpose of this study was to compare average and peak muscle activation when using free weights and Thera-Band in the completion of three selected shoulder rehabilitation exercises. The hypothesis for this study was that with the completion of the shoulder exercises and using surface electromyography to quantify the muscle activation levels, the use of either device would produce similar effects on muscle activation. Eight male subjects voluntarily participated in this study. Each subject completed two sets of three repetitions each with a 10-pound weight and a black piece of Thera- Band®. Surface electromyography recorded the muscle activation of the anterior deltoid, middle deltoid, and biceps brachii muscles. A paired samples T-test was used to compare the level of muscle activation between the two rehabilitation tools. No significant differences were found from the paired samples test. Significant values were found from the paired samples correlation test for the middle deltoid average activity, biceps brachii average activity, and biceps brachii peak activity. It was concluded that neither device produces significantly different muscle activation levels than the other, therefore leading to the assumption that both rehabilitation tools affect a working muscle in the same manner.

This study supports other literature which states that Thera-Band® can be used to strengthen the shoulder musculature. Anderson et al. (1992) and Ward et al. (1997) both used Thera-Band® and free weights to compare strength gains over time for selected shoulder muscles; they reported that there were significant strength gains made in the muscles tested. The results of this study showed that the muscle activity for the middle deltoid and the biceps brachii are correlated between the two rehabilitation devices. It can be inferred that from this finding that if someone were to use either device for a sustained period of time, they would see increases in strength in the muscles that were exercised with both tools.

There was no clear answer as too which device is better to use for shoulder rehabilitation of the three specific muscles. The limitations present in this study may also help to better examine the results that were found. The electrode placement references were generalized for all people. The middle deltoid and biceps brachii muscles in most individuals are fairly easy to discern, they are usually the largest muscles found in the shoulder region and are generally well developed. The anterior deltoid muscle however is not as easy to locate and the electrode reference from Cram and Kasman (1998) was generalized for the entire population. On the larger individuals in this study, the reference of 4 cm below the clavicle may not have been accurate, the same thing holds true for smaller individuals. If the electrode was not placed directly over the muscle, more or less activity may have been recorded. Also, activity from neighboring muscles may have also contributed to the overall activity recorded by the EMG. Significant correlations were found in the other two muscles, however no significant results were obtained from testing the anterior deltoid muscle. Poor electrode placement may have contributed to the unimpressive results obtained from testing the anterior deltoid muscle.

The sample size used in this study was also a limitation. A larger sample population could provide more knowledge, as well as increase the power of the results that are found. Also, if the aim of future studies was to determine if one device resulted in greater strength gains to be made after its use, studying more muscles within the shoulder or different exercises could produce different results. A study comparing multiple joints within the body may also provide clearer answers, if there are any to be found, as too which rehabilitation tool is superior.

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APPENDIX A

Document of Informed Consent

Department of Exercise Science and Sport Studies

State University College at Cortland

TITLE: An EMG comparison of shoulder rehabilitation exercises using free weights versus Thera-band.

STUDENT INVESTIGATOR: Lisa Barbasch, ATC, 753-5443

FACULTY SUPERVISORS: Peter McGinnis, Ph.D., 753-4909
Jeff Bauer, Ph.D., 753-5536

PURPOSE: The purpose of this study is to compare muscle activation, using surface electromyography, in the completion of selected shoulder rehabilitation exercises using both free weights and Thera-band.

PROCEDURES:

The data gathered from the completion of the activities, which are described below, will be used to determine if a difference exists between muscle activity generated using wither free weights or Thera-band to perform shoulder rehabilitation exercises. The data generated from the testing will be used to determine the average muscle activity and the peak muscle activity of each of the three muscles, using each of the two devices. Subjects will be considered for the project if they meet the following criteria: 1) must be a male undergraduate or graduate student and 2) be free of any previous shoulder pathology or surgeries.

As a test subject, you will be required to report once for an approximately two hour testing period, which will take place in the Biomechanics laboratory. You will be familiarized with using free weights and Thera-band to complete the selected shoulder exercises, as well as to the equipment that will be used pertaining to the EMG unit. Appropriate clothing must be worn that allows for proper exposure of your upper arm and shoulder on your dominant arm.

You will be required to perform three isometric voluntary contractions for each of the three muscles being tested, as well as perform two sets of three repetitions each with both the Thera-band and the free weight. In total, six sets of three repetitions each will be completed with the free weight, and six sets of three repetitions each will be completed using the Thera-band. Timing of the exercises will be controlled using a metronome.

RISKS: The proper precautions will be to taken to ensure that the testing area, as well as all of the equipment being used, is safe for all participants involved in the study. The possibility of injury in this study is minimal, and the exercises being performed have only a small potential of causing soreness because of the low level of resistance being used.

BENEFITS: The results of this study may indicate whether Thera-band exercises are similar enough to free weight exercises to be a convenient alternative.

CONFIDENTIALITY: All of the data from the experiment will be stored in a locked cabinet, and the data on the computer will be stored anonymously with your identity protected.

FREEDOM OF CONSENT: Participation in this study is completely voluntary, and you may withdraw from the project at any time. Individuals may withdraw in writing or by telephone (753-5443).

The student responsible for this research project is Lisa Barbasch, who will be working in conjunction with the faculty members of the SUNY Cortland ESSS Department. For questions concerning the rights of human subjects, please contact Amy Henderson-Harr, Designee, Human Subjects Committee at SUNY Cortland, (607) 753-2511.

I have read and understand the activities required for my involvement in this project, and I consent to participate.

Project Title: ____

Name: _________________________________ Telephone#: _______________________________

Signature: ______________________________________ Date: ____________________________

APPENDIX B

Table B1. Average and peak muscle activity normalized with MVC activity (raw EMG data/ MVC data). Six pairs as entered into SPSS for analysis

Average 10 lb	Average Thera-Band®	Peak 10 lb	Peak Thera-Band®
Anterior Deltoid			
0.445	0.545	0.900	0.844
0.487	0.834	0.691	1.565
0.383	0.276	0.561	0.373
0.439	0.356	1.008	1.312
0.403	0.515	0.557	0.843
0.603	0.381	0.960	0.687
0.956	0.523	1.063	0.655
0.330	0.516	0.422	0.738
Middle Deltoid			
0.450	0.476	0.661	0.814
0.290	0.278	0.396	0.432
0.479	0.403	1.181	0.661
0.428	0.414	0.640	1.057
0.409	0.446	0.653	0.863
0.301	0.243	0.460	0.461
0.343	0.302	0.658	0.654
0.293	0.372	0.627	0.885
Biceps Brachii			
0.387	0.429	0.680	0.933
1.037	0.682	1.304	0.987
0.350	0.370	0.733	0.724
0.208	0.216	0.371	0.537
0.734	0.725	1.055	1.124
0.743	0.415	0.896	0.608
1.260	1.027	1.462	1.873
0.224	0.280	0.318	0.535