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MUSCLE ACTIVATION DURING BATTLE ROPE EXERCISES

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We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

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ABSTRACT

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The purpose of this study was to 1) compare electromyographic (EMG) responses in the vastus medialis (VM), gluteus maximus (GM), erector spinae (ES), external oblique (EO), rectus abdominis (RA), upper trapezius (UT), anterior deltoid (AD), and palmaris longus (PL) during five battle rope (BR) exercises to determine which exercises produced the greatest muscle activation, and 2) determine if the muscles tested were activated to a sufficient degree (greater than 40% MVIC) to increase in muscle strength. Twelve males completed 10 seconds of the following exercises in a random order: Double Arm Slams, Double Arm Waves, Double Alternating Waves, Single Arm Waves, and Double Outside Circles. Surface EMG was measured and represented as a percent of the maximal voluntary isometric contraction (MVIC). A one-way ANOVA with repeated measures was used to compare EMG for each muscle between exercises. Overall, Double Arm Slams elicited the highest EMG for all of the muscles tested. All of the muscles tested were contracting at greater than 40% MVIC for Double Arm Slams and Double Arm Waves. The VM, GM, and RA were contracting at greater than 40% MVIC for all of the exercises except for Double Alternating Waves and Single Arm Waves. All the muscles were contracting at greater than 40% MVIC for Double Outside Circles, except for the RA and AD. Based on these results, all of the BR exercises tested activated the muscles sufficiently to increase strength, with the exceptions of the VM, GM, RA, and AD.

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INTRODUCTION

New fitness products and training regimes are regularly introduced into the market in attempts to add variety to people's workouts and increase exercise adherence. Battle ropes (BR) have been used as part of exercise programs for the past several years (Stanforth, Brumitt, Ratamess, Atkins, & Keteyian, 2015). Battle ropes are thick ropes that come in a wide variety of lengths (i.e., 10 to 100 feet) and are generally 1 to 2 inches in diameter (Stanforth et al., 2015). The ropes are anchored at one end and the user performs a wide range of wave type motions, either unilaterally or bilaterally. There are numerous exercises that can be conducted with BR and they can purportedly be used for cardiorespiratory conditioning and muscle strengthening (Stanforth et al., 2015). Due to the large variety of exercises that can be performed using BR, they are suitable for any experience level, whether beginners looking for new exercises, or professional athletes trying to advance themselves over their competition.

Battle rope exercises are typically integrated into a high intensity interval training (HIIT) program. A workout usually consists of several alternating bouts of high-intensity exercise followed by either low-intensity exercise or complete rest. Factors contributing to the popularity of HIIT are that it takes a short period of time, yet helps to maximize caloric expenditure, while potentially improving body composition, cardiovascular fitness, and muscle strength (Meier, Quednow, & Sedlak, 2015). With BR, intensity can be altered by changing the rope size, wave velocity, amplitude, anchor position, and the amount of muscle mass used (Stanforth et al., 2015).

Fry (2004) reported that in order to improve muscle strength, muscles must be contracting in excess of 40% of one repetition maximum (RM). When performing resistance training, weights are usually assigned based on percentages of 1 RM. Because BR are not really “lifted,” it is difficult to assess how hard the muscles are being taxed. An alternate way to assess how hard the muscles are working is with electromyography (EMG). Electromyography is used to determine the electrical activity within the muscle. As a muscle is signaled to contract by the nervous system, action potentials are created, which are proportional to the force being produced by the muscle (Kraemer et al., 2002).

Research by Calatayud et al. (2015) evaluated the muscular responses during unilateral and bilateral BR exercises. With the use of EMG, it was found that both unilateral and bilateral wave movements can be used to provide a moderate to high level of muscle activity in the anterior deltoid, external oblique, and lumbar erector spinae. The study also found that unilateral exercises recruited the oblique muscles to a greater extent compared to bilateral exercises. Meier et al. (2015) found that 5 weeks of HIIT using kettlebells and BR only showed slight improvements in body composition and grip strength. Marin, Garcia-Gutierrez, Da Silva- Grigoletto, and Hazell (2015) found that whole-body vibration increased muscle activation while using BR, compared to exercising on stable ground. Because there is relatively little research on BR exercise, the purpose of this study was to measure muscle activity during several different BR exercises to determine which exercises may activate select muscles sufficiently to improve muscular strength.

Methods

Subjects

Twelve apparently healthy volunteers between the ages of 20 to 24 were used as subjects. Each subject was required to have previous resistance training experience and preferably experience using BR. This study was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects. Before participation, each subject was informed of the purpose, procedures, potential risks, and benefits of the study and provided written informed consent.

Procedure

Each subject participated in one practice session and one testing session, both lasting approximately 1 hour. On the practice day, the subjects were shown the BR exercises that were being used in the study and were allowed time to practice those exercises. On a separate day, each subject was tested. Subjects completed an active warm-up consisting of 5 minutes on a stationary bike and 3 minutes of warm-up with the BR. Subjects then performed a maximum voluntary isometric contraction (MVIC) for each muscle of interest using manual muscle techniques.

The eight muscles evaluated were the vastus medialis (VM), gluteus maximus (GM), erector spinae (ES), external oblique (EO), rectus abdominis (RA), upper trapezius (UT), anterior deltoid (AD), and palmaris longus (PL). Electrode placement was made using SENIAM (Sensor Locations, n.d.). Prior to MVIC testing, subjects had electrodes placed on the respective muscle. Electrode sites were shaven and cleaned with alcohol to improve the quality of the EMG signals. Subjects were advised to not use lotion or oil on the skin prior to testing (Electromyography (EMG), n.d.).

Subjects then performed five BR exercises. The BR used was 50 feet in length and 1.5 inches in width. The anchor stabilized the center of the BR. For each BR exercise, the subject stood with their feet shoulder width apart with slight knee bend. The subject had their back straight with a slight forward lean of the torso, elbows extended so their hands were waist high, and held the BR handles with a handshake grip. Elbow flexion was allowed during the exercise. The subjects were instructed to do the exercises at a self-selected pace but were encouraged to do the exercises as vigorously as possible. A description of the five exercises that were used in the study are presented below.

1. Double Arm Slams: The subject brought both ends of the BR near or above their head with shoulder flexion. Forceful shoulder extension occurred to cause the BR to hit the ground as hard and fast as possible.
2. Double Arm Waves: The subject held both ends of the BR. The subject kept their arms in front of their torso by flexing the shoulders until the BR handles were approximately shoulder height and extended the shoulders until the handles were even with the waist. Both arms moved up and down in unison.
3. Double Alternating Arm Waves: The subject held both ends of the BR. The subject kept their arms in front of their torso by flexing the shoulders until the BR handles were approximately shoulder height and extended the shoulders until the handles were even with the waist. The subject alternated the extension and flexion of each shoulder with each arm, so the arms moved in opposite directions.
4. Single Arm Waves: The subject held one end of the BR with a single arm. The subject flexed their shoulder until the BR handle was approximately shoulder

height, and then extended the shoulder so the BR handle was approximately waist height.

5. Double Outside Circles: The subject held both ends of the BR, and the BR handles stayed near the abdomen region throughout the exercise. The subject slightly raised and externally rotated both shoulders in a circular motion and then internally rotated both in a posterior position. The circles from each arm being made were going in opposite directions.

EMG ANALYSIS

Electrical activity of the VM, GM, ES, EO, RA, UT, AD, and PL were recorded and stored on a personal computer. The EMG signal was preamplified using a differential amplifier (Delsys Trigno Wireless Systems, Boston, MA; bandwidth 20-450 Hz). Raw EMG signals were digitized at 2000 Hz. For each trial, the EMG amplitude (microvolts root mean square [µVrms]) was calculated and represented as a percentage of the maximum RMS value recorded during the MVIC trial. Subjects completed 10 seconds of each exercise with three representative movements averaged for each muscle.

STATISTICAL ANALYSIS

For each muscle tested, normalized EMG activity between the different exercises were compared using a one-way ANOVA with repeated measures. If there were significant differences between exercises, pairwise comparisons were made using Fisher's LSD tests. To achieve statistical significance, alpha was set at 0.05. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 25.0, SPSS, Chicago, IL).

RESULTS

Twelve apparently healthy men completed the current study. Descriptive characteristics of the subjects are presented in Table 1. Muscle activation for each of the eight muscles, for each exercise, are presented in Figures 1-8, respectively.

Table 1. Descriptive characteristics of subjects (N=12)

	Mean ± SD	Range
Age (yrs)	22.8 ± 1.27	20-24
Height (cm)	177.6 ± 6.35	167.6-190.5
Weight (kg)	80.8 ± 11.06	59.0-95.3

Values represent mean ± standard deviation.

It was found that EMG for Double Arm Slams was significantly greater than all of the other exercises for the VM (Figure 1), GM (Figure 2), ES (Figure 3), and RA (Figure 5). For the EO (Figure 4), Double Arm Slams, Double Alternating Waves, and Single Arm Waves were all significantly different than Double Arm Waves and Double Outside Circles. For the AD (Figure 7), Double Arm Slams, Double Arm Waves, Double Alternating Waves, and Single Arm Waves were all significantly different than Double Outside Circles. For the UT (Figure 6) and PL (Figure 8), there were no significant differences between exercises. It should be noted that for the ES, data were only available for nine subjects due to technical difficulties.

Another finding from the data was that all eight muscles tested during Double Arm Slams and Double Arm Waves were contracting above 40% MVIC. According to Fry (2004), muscles must contract at an intensity of at least 40% of 1RM in order to improve muscle strength. During Double Alternating Waves and Single Arm Waves the muscles were contracting above 40% MVIC for all muscles except the VM (Figure 1), GM (Figure 2), and the RA (Figure 5). During Double Outside Circles, all the muscles except for the RA (Figure 5) and AD (Figure 7) were contracting above 40% MVIC.

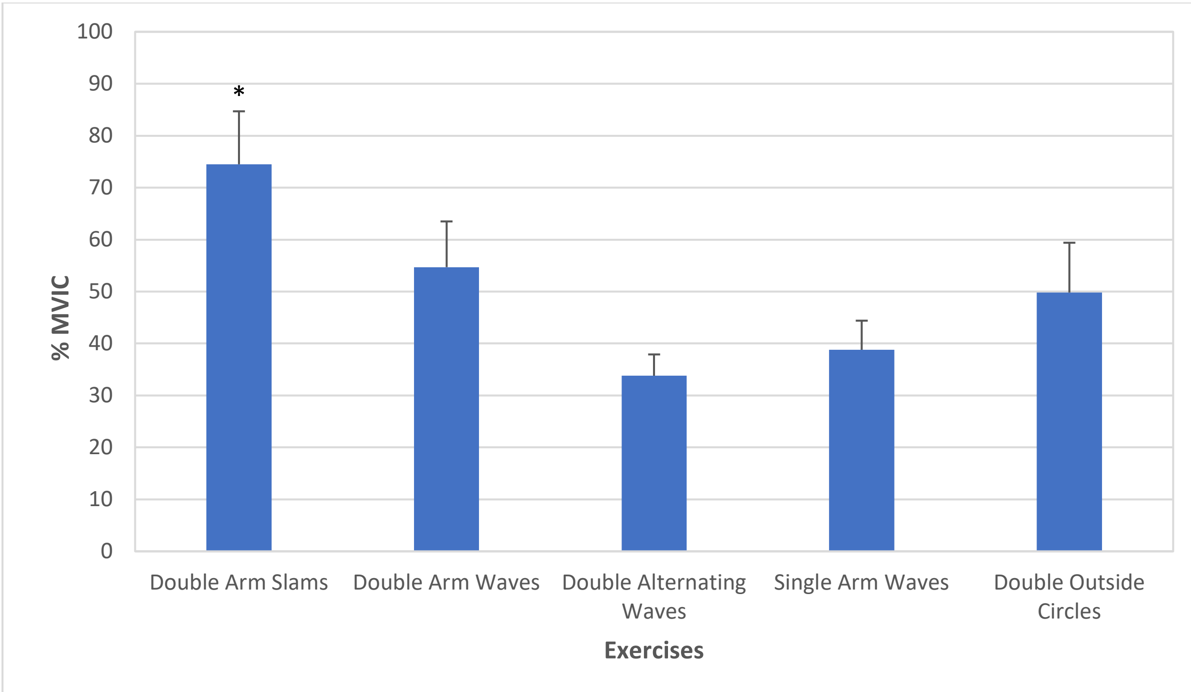

Figure 1. Activation of the vastus medialis for the five battle rope exercises.
*Significantly greater than all other exercises (p<.05).

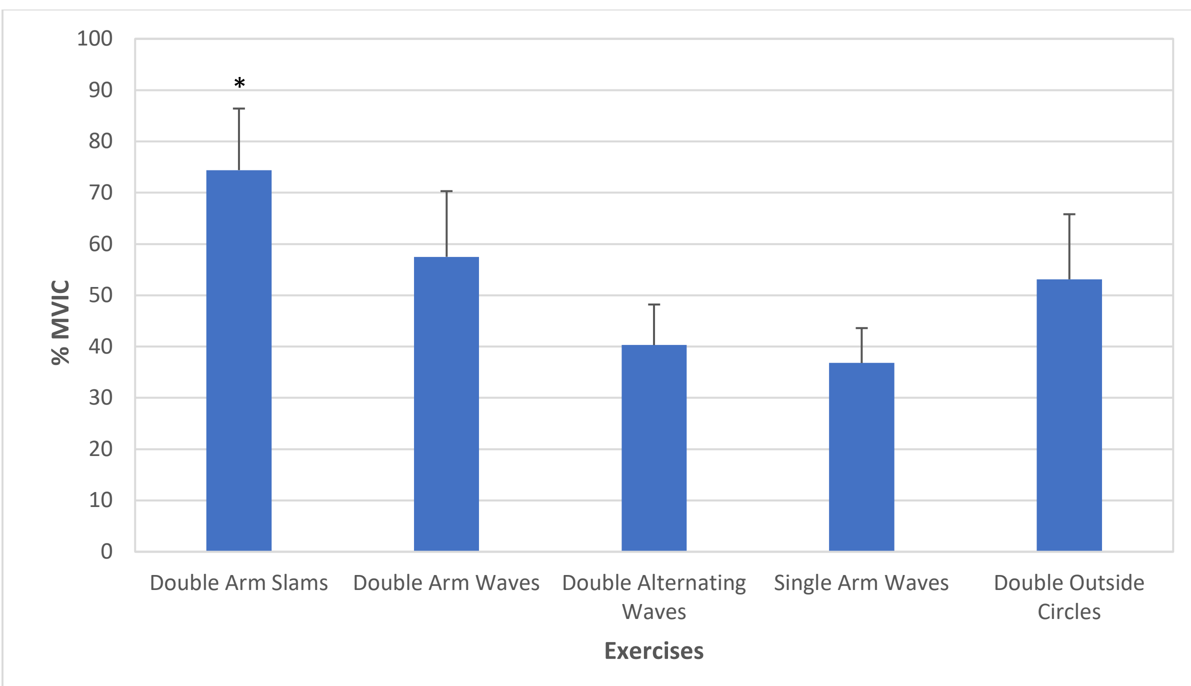

Figure 2. Activation of the gluteus maximus for the five battle rope exercises.
*Significantly greater than all other exercises (p<.05).

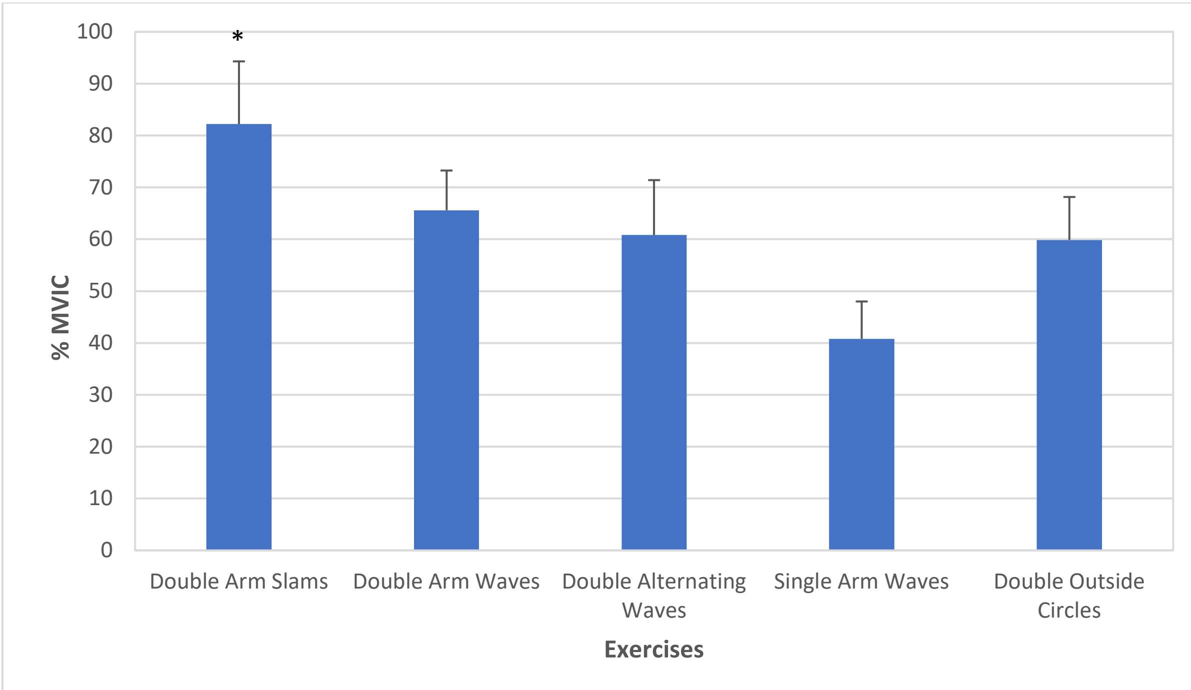

Figure 3. Activation of the erector spinae for the five battle rope exercises.
*Significantly greater than all other exercises ($p<.05$).
Note: Data only for nine subjects.

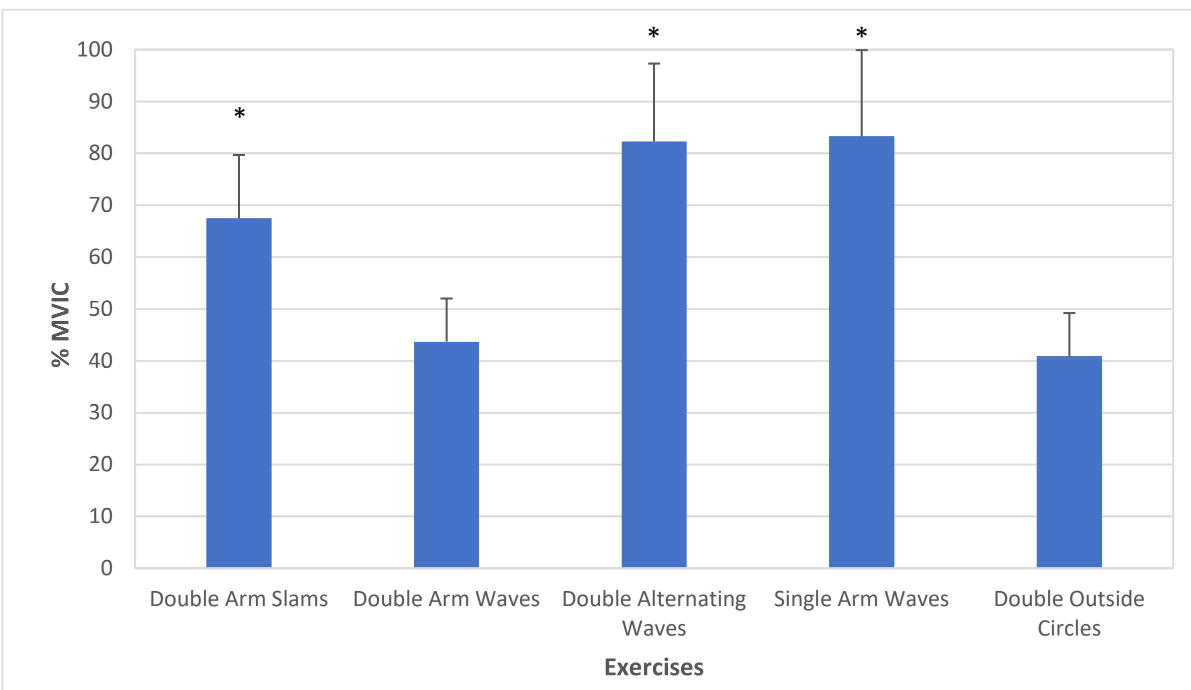

Figure 4. Activation of the external oblique for the five battle rope exercises.
*Significantly different than Double Arm Waves and Double Outside Circles ($p<.05$).

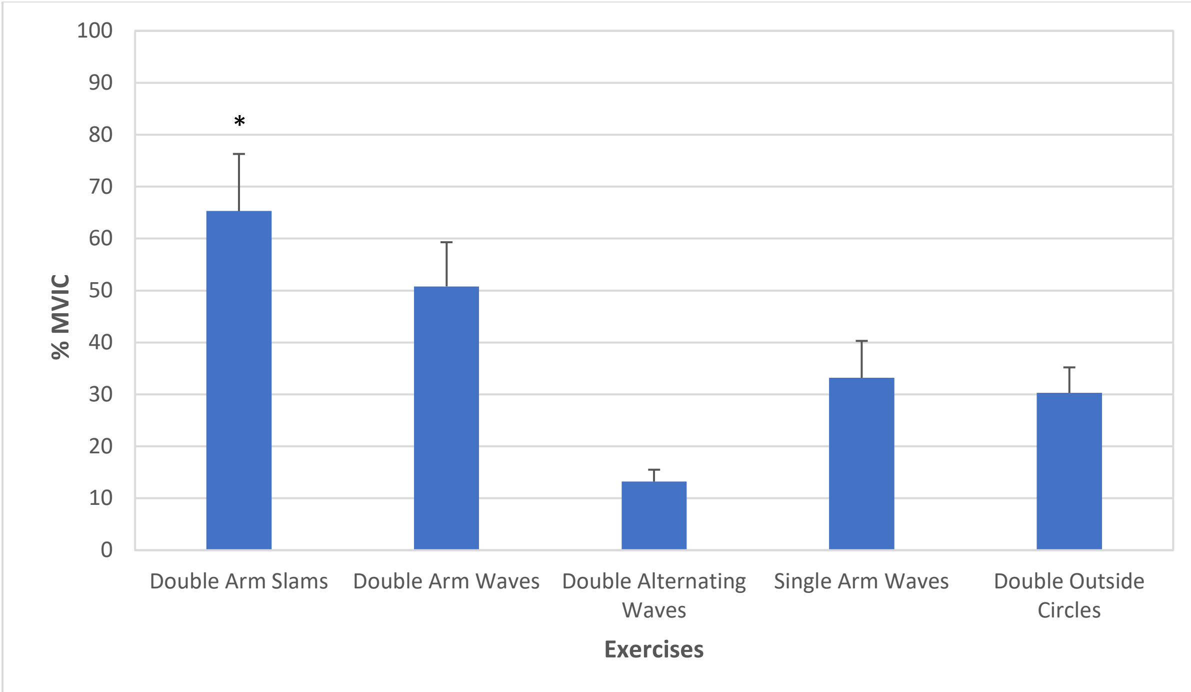

Figure 5. Activation of the rectus abdominis for the five battle rope exercises.
*Significantly greater than all other exercises (p<.05).

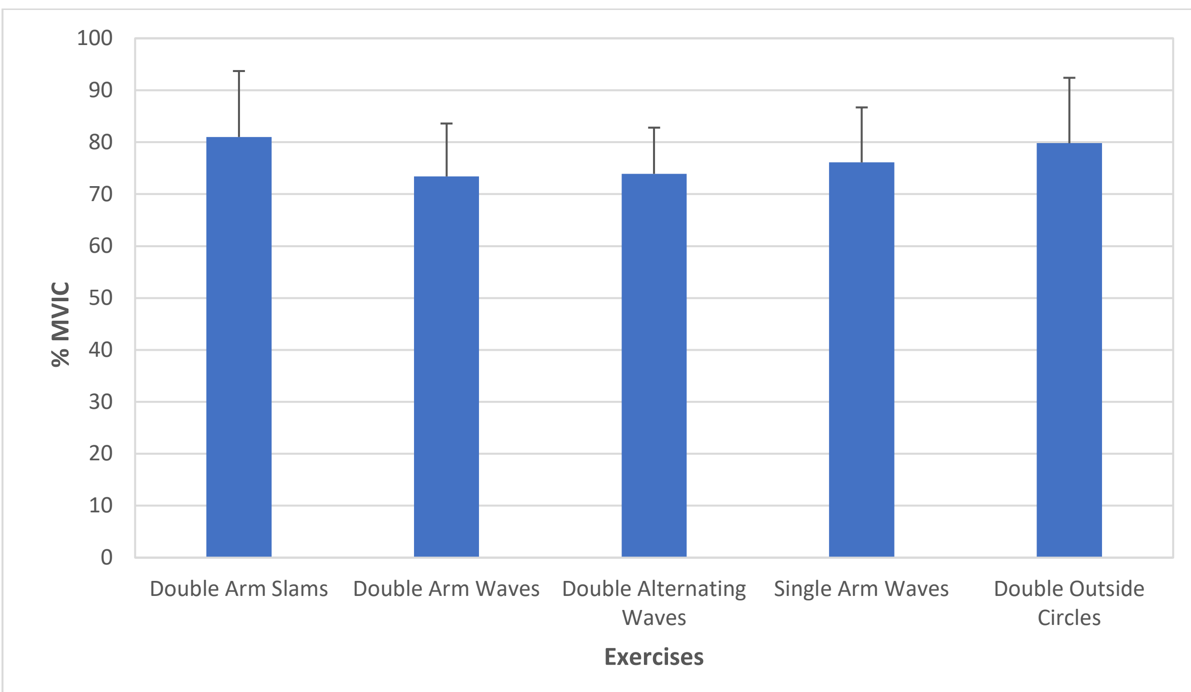

Figure 6. Activation of the upper trapezius for the five battle rope exercises.

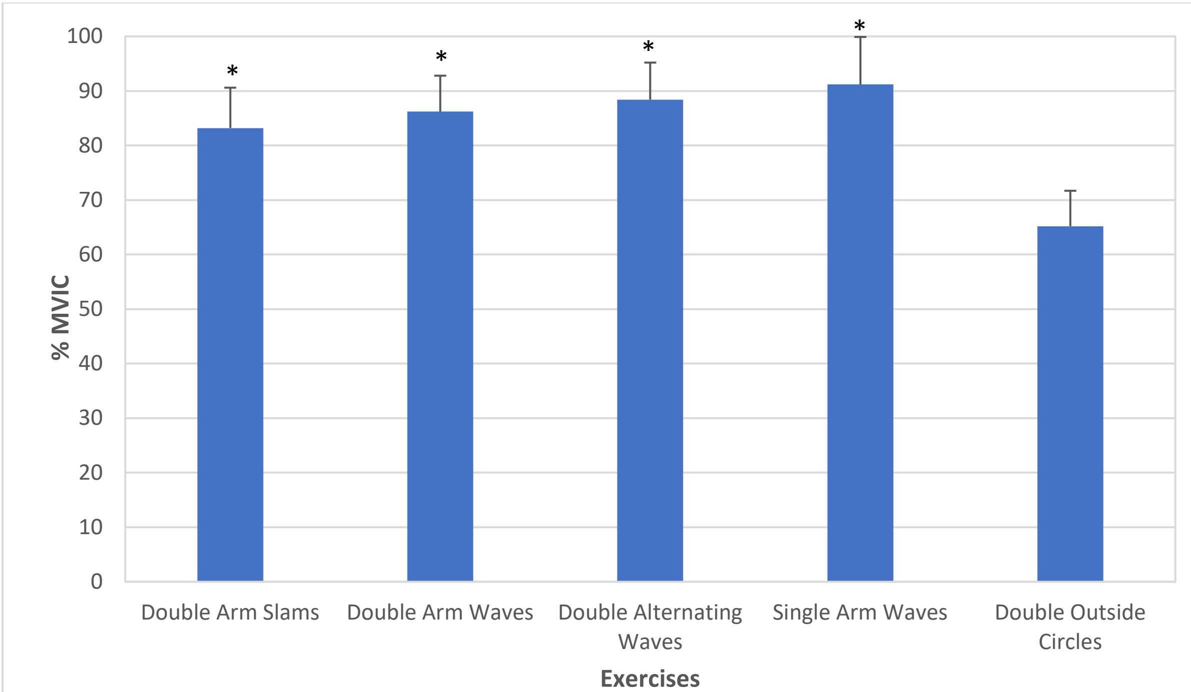

Figure 7. Activation of the anterior deltoid for the five battle rope exercises.
*Significantly greater than Double Outside Circles (p<.05).

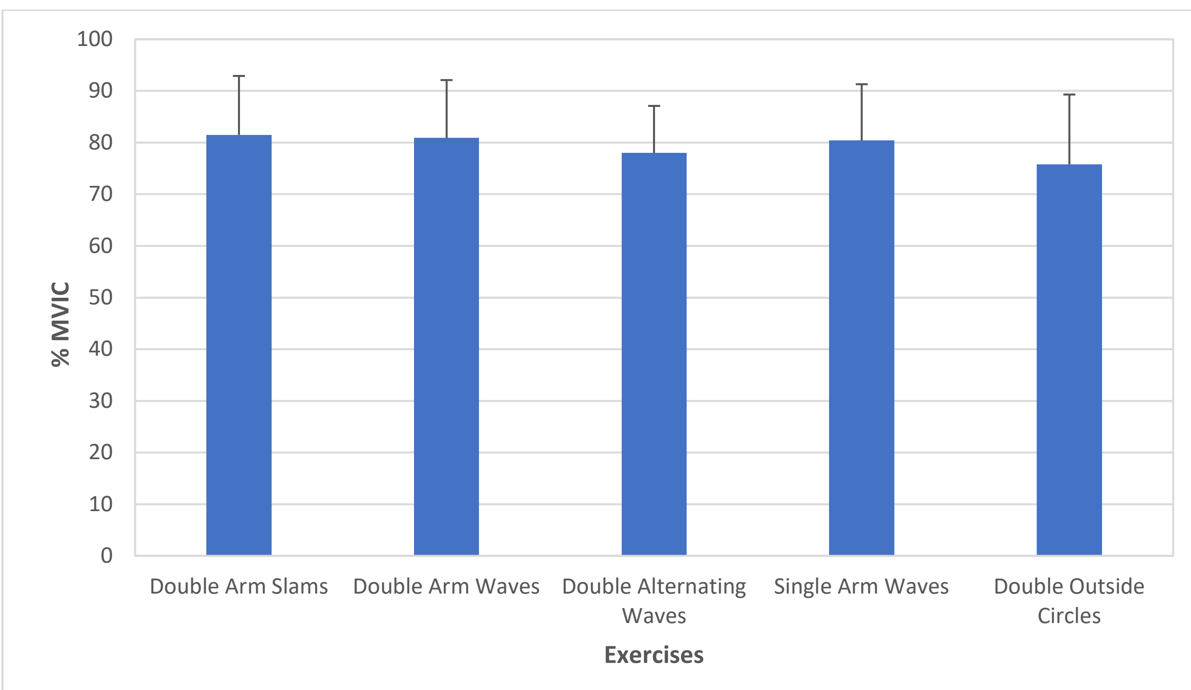

Figure 8. Activation of the palmaris longus for the five battle rope exercises.

DISCUSSION

One of the main findings of this study was that Double Arm Slams was the best exercise for activating the majority of the muscles tested. This was expected since there is more vertical motion due to more usage of the lower body and core muscles as a subject brings the BR above their head and slams them into the ground. The other main finding of this study was that all of the muscles tested, with a few exceptions, were contracting above 40% MVIC. It is generally accepted that in order to improve muscle strength, a muscle must be contracting above this minimal threshold (Fry, 2004). Double Arm Slams and Double Arm Waves were consistently above 40% MVIC for all of the muscles tested, signifying that these two exercises should improve muscle strength throughout the body. Exceptions included Double Alternating Waves and Single Arm Waves, which were contracting above 40% MVIC for all of the muscles tested except for the VM, GM, and RA. When looking at those two exercises, there isn’t as much total body movement in those muscles during these exercises. The VM, GM, and RA specifically are used as stabilizing muscles rather than primary muscles during those motions. Therefore, when preparing a BR workout, if the goal is to strengthen the VM, GM, and RA, exercise selection becomes important.

Calatayud (2015) compared unilateral and bilateral BR exercises and found that both movements can be used to provide moderate to high muscle activity in the AD, ES, and EO. This current study showed similar results as all three muscles were contracting above 40% MVIC for all five exercises. Consistent with both studies, there was higher activation in the AD and EO for Single Arm Waves compared to Double Arm Waves. It was felt that during Single Arm Waves the EO must work harder in order to maintain proper balance and trunk stability.

Muscle activation in the PL was tested since it has a significant role in grip strength. A study by Meier, Quednow, and Sedlak (2015) found that 5 weeks of training with kettlebells and battle ropes resulted in an increase in grip strength. It should be noted that subjects trained with both BR and kettlebells in that study. However, since we found that the PL was contracting in excess of 75% MVIC for all of the BR exercises, it is reasonable to assume that BR training alone will increase grip strength.

CONCLUSION

Based on the results of this study, it can be concluded that BR are a good form of exercise to increase muscular strength. However, if there is a single best BR exercise to be selected, it would be Double Arm Slams.

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APPENDIX A

INFORMED CONSENT

Informed Consent

MUSCLE ACTIVATION DURING BATTLE ROPE EXERCISES

I, ___________________________, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse.

Purpose and Procedure

- The purpose of this study is to determine whether battle rope exercises activate various muscles enough to increase muscle strength with the use of electromyography. The intention of this study is to publish the data and information.
- The study will consist of five battle rope exercises and will test eight various muscles throughout the body. A maximum voluntary isometric contraction test will also be conducted for each muscle.
- My participation in this study will require me to attend one practice session and one test session, both lasting approximately 60-90 minutes.
- Testing will take place in the Mitchell Hall Field House on the University of Wisconsin-La Crosse campus.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

- Muscle fatigue, muscle soreness, and muscle strains are possible risk factors associated with participating in this study.
- Skin irritation may occur due to the placement of the EMG electrodes.
- During all testing sessions, there will be individuals present that are certified in CPR and Advanced Cardiac Life Support if any complications were to occur. An AED will be present in the test setting.
- The risk of serious or life-threatening complications, for healthy individuals, is near zero.

Potential Benefits

- I, athletes, coaches, and trainers, may benefit from this study by gaining knowledge about battle rope exercises and their effect on muscle usage.

Rights & Confidentiality

- I am aware that participation in this study is voluntary.
- I can withdraw at any point from this study, for any reason, and without penalty.
- All data and information collected during this study will be kept confidential, and the data will not be linked with any personally identifiable information.
- The findings of this study may be published in scientific literature and presented at professional meetings using group data only.

I have read the information provided on this consent form. I have been informed of the purpose of the test, the procedures, and expectations of myself, as well as the testers, and the potential risk and benefits that relate to volunteering in this study. I have asked any questions that have concerned me and received clear answers to ensure my full understanding of the study.

If I have any questions that arise I may feel free to contact the principal investigator: Austin Salzgeber, 410 N 10^{th} Street La Crosse, WI 54601, (715) 965-1927, or his advisor: John Porcari, 141 Mitchell Hall, (608) 785-8684. Questions regarding the protection of human services may be addressed to the University of Wisconsin-La Crosse Institutional Review Board at (608) 785-8124 or irb@uwlax.edu.

Participant: ______________________________________ Date: __________________

Investigator: _____________________________________ Date: __________________

APPENDIX B

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The use of battle ropes (BR) has increased in popularity in the past few years as a tool for cardiorespiratory conditioning and muscle strengthening. Instead of using several pieces of equipment, all that is needed is a rope, an anchor, and a space. The rope is wrapped around the anchor, so the two ends of the rope can be used as handles. Battle rope sizes vary, but are typically 10 to 100 feet in length and 1 to 2 inches in diameter (Stanforth, Brumitt, Ratamess, Atkins, & Keteyian, 2015). Sizes may vary depending on the skill level of the individual. Smaller BR would likely be used by beginners to allow them to control their movements more efficiently, whereas experienced users would likely use a longer and thicker rope as it would make the exercise more difficult. Battle ropes can be used by a variety of people, ranging from beginners to professional athletes. This is mostly due to the variety of exercises that can be chosen to provide a challenge for any individual. A beginner may start with basic movements such as creating waves. As the individual progresses, more complex movements can be added, along with additional movements such as jumps, lunges, and lateral shuffles (Stanforth et al., 2015).

Effect of Training with Battle Ropes on Exercise Intensity and Muscle Usage

Battle ropes provide a full body workout which is intended to stress the cardiorespiratory system and improve muscle strength, power, and endurance (Stanforth et al., 2015). This is mostly since there are a wide variety of exercises that can be completed. Intensity of each exercise is determined by the length and thickness of the rope, wave velocity, amplitude, anchor position, and the amount of muscle mass used (Stanforth et al., 2015). The use of BR is typically in the form of high intensity interval training (HIIT), alternating bouts of high-intensity exercise followed by either low-intensity exercise or rest. Depending on the experience of the individual, the work interval may vary. A beginner may exercise for 15-20 seconds, and rest for 30 seconds to 2 minutes. An advanced individual would likely make the workout more difficult by increasing the amount of time doing the exercise and decreasing the rest time (Stanforth et al., 2015). High intensity interval training helps to maximize caloric expenditure, improve changes in body fat, strengthen muscles, and improve cardiovascular fitness in a short time period (Meier, Quednow, & Sedlak, 2015).

One of the main goals of BR, like any other resistance exercise is to increase strength, power, and endurance. To see an increase in these parameters, it is crucial that the muscle works in excess of 40% of the maximum strength (Fry, 2004). Electromyography (EMG) is used to determine how hard a muscle is working during exercise. When muscles are signaled to contract, electrical impulses are sent to the muscle. As the muscle contracts more forcefully, more muscle fibers need to be activated or they must fire at a faster rate. This is reflected in a higher electrical activity within the muscle. Electromyography is used to help quantify the degree of muscle activation (Electromyography (EMG), n.d.).

Measuring EMG

There are two types of EMG electrodes that can be used: indwelling electrodes and surface electrodes. Indwelling electrodes consist of a needle that is inserted directly into the muscle. These are effective when testing deep muscles and evaluating small movements. Surface electrodes are placed on the skin, which makes the experience more comfortable for the patient compared to indwelling electrodes. However, palpation skills, muscle testing, and visual observation of posture and movement can influence the readings. “Cross talk” may also occur, in which the energy from one muscle group travels into the area of the targeted muscle group (Criswell & Cram, 2011).

Prior to the placement of the electrodes, proper skin preparation is needed to ensure accurate readings. The removal of hair in the area and cleaning the area with alcohol will help remove any dead skin. It is advised that subjects not use lotions or oils on the skin prior to testing (Electromyography (EMG), n.d.). For placement of the electrodes, they are generally widely spaced across the midline of the muscle. However, for specific muscle monitoring, it typically involves closely spaced electrodes that are placed parallel to the muscle fibers (Criswell & Cram, 2011).

Adaptations to Exercise Training

Frequency, intensity, and duration of exercise have been found to influence cardiovascular and muscular adaptation to exercise (Pollock et al., 1998). The amount of improvement in VO_2max increases with the frequency of training, but once the frequency of exercise increases to above 3 days of exercise per week, the gain in VO_2max plateaus (Pollock et al., 1998). Intensity and duration have both been shown to be correlated with gains in fitness. The total volume of exercise that is completed will determine the adaptation. The level of improvement will be similar when comparing short frequency, higher intensity exercise and lower intensity, short duration exercise. It is recommended that 30 minutes of moderate-intensity exercise be completed every day. This can be accumulated in bouts lasting at least 10 minutes in duration (Ewing Garber et al., 2011).

For resistance training, each major muscle group should be trained 2-3 days per week. To improve strength, intensity levels should be between 40-50% 1RM for older persons and sedentary individuals, between 60-70% 1RM for novice to intermediate exercisers, and greater than 80% 1RM for experienced exercisers (Ewing, Garber et al., 2011).

Studies Relating to Battle Ropes and Electromyography

Calatayud et al. (2015) evaluated the difference between unilateral and bilateral BR exercises. The study tested the anterior deltoid, external oblique, lumbar erector spinae, and gluteus medius with the use of EMG. This study found that both types of wave movements resulted in a moderate to high level of muscle activity in the anterior deltoid, external oblique, and lumbar erector spinae. The study also suggests that the unilateral wave movements activated the external oblique muscles to a greater extent, and the bilateral wave movements activated the lumbar erector spinae the most. For certain unilateral exercises, there was a tendency to activate more core muscles compared to bilateral exercises in order to stabilize the body. This is due to the body needing to stabilize itself in the frontal and transverse planes for unilateral exercises, and sagittal and transverse planes for bilateral exercises. Meier et al. (2015) studied the effect of 5 weeks of HIIT with kettlebells and BR on body composition and handgrip strength. The experimental group completed three, 20-minute HIIT sessions per week. The sessions alternated between five kettlebell exercises and five BR exercises every 2 minutes. Body fat percentage, right handgrip strength, and left handgrip strength all improved over the 5 weeks. However, only the right handgrip strength improved significantly.

Marin, Garcia-Gutierrez, Da Silva- Grigoletto, and Hazell (2015) compared EMG levels of several muscles when the participants performed two different BR exercises with and without whole-body vibration. The BR exercises consisted of alternating arm motions and double arm motions. The muscles tested included the gastrocnemius medialis, vastus medialis oblique, vastus lateralis, rectus abdominis, multifidus, biceps brachii, and triceps brachii. The study found that the addition of whole-body vibration increased muscle activation in all muscles tested while using BR compared to exercising on stable ground. The study also found that the double arm motion had the greatest muscle activation in the vastus medialis oblique, vastus lateralis, rectus abdominis, and multifidus compared to the alternating arm motions.

Summary

From the small amount of research available, BR have been shown to be effective in certain instances regarding muscle activation. However, most of the studies were limited in terms of the number of muscles tested and the exercises evaluated. This study will determine whether the several muscles tested are activated enough to gain strength during five basic BR exercises. The muscles being tested will also be compared to see which muscles are activated to the greatest extent.

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