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Graduate Studies

ELECTROMYOGRAPHIC ANALYSIS OF THE BACK DURING VARIOUS BACK EXERCISES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

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ELECTROMYOGRAPHIC COMPARISON OF THE BACK MUSCLES

DURING VARIOUS EXERCISES

By Holly Edelburg

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 compare electromyographic (EMG) responses in the middle trapezius, lower trapezius, infraspinatus, latissimus dorsi, and erector spinae during eight back exercises to determine which produces the greatest muscle activation for each muscle. Nineteen males completed five repetitions of the following exercises using 70% of 1 RM, or body weight resistance: lat pull-downs, inverted rows, seated rows, bent-over rows, TRX rows, I-Y-T raises, pull-ups, and chin-ups. Surface EMG was represented as a percent of the maximal voluntary contraction. A one-way ANOVA with repeated measures was used to test for differences between exercises. Greatest activation of the middle trapezius was found with I-Y-T raises, bent-overs, seated, and inverted rows. Greatest activation of the lower trapezius was found with I-Y-T raises. Greatest activation of the latissimus dorsi was found with pull-ups and chin-ups. Greatest activation of the infraspinatus was found with pull-ups, chin-ups, I-Y-T raises, bent-overs, and inverted rows. Based on the musculature of the back and the findings of this study, a variety of exercises are needed to effectively train the entire back.

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INTRODUCTION

Time is money and in today's world many people live fast paced lives with little time for exercise. The American College of Sport Medicine recommends that in addition to aerobic exercise, individuals should perform resistance training 2-3 days per week (ACSM, 2013). In 2011, only 29% of U.S. adults met the resistance training guidelines (CDC, 2013). Due to lack of time, resistance training may be ignored. Determining which exercises are the best for all of the major muscle groups may be beneficial for individuals who have a limited amount of time to exercise.

A well-rounded resistance-training program includes exercises for all of the major muscle groups, including the back. In order to train these muscles effectively, it is crucial to understand the anatomy of the back (Criswell, 2011). The major muscles of the back include the middle trapezius (MT), lower trapezius (LT), latissimus dorsi (LAT), erector spinae (ES), and infraspinatus muscles. The middle trapezius arises from the spinal processes of C-6 to T-3 and inserts on the acromion and superior lip of the spine of the scapula. The lower trapezius arises from the T-3 through T-12 and inserts on the spine of the scapula. The latissimus dorsi is a very broad muscle and arises from the lower six thoracic vertebrae, the lumbodorsal fascia, the sacrum and crest of the ilium, and the last three to four ribs. It inserts, along with the teres major, on the medial edge of the humerus. The erector spinae are the main trunk movers and stabilizers. The infraspinatus fibers arise from the infraspinatus fossa, below the spine of the scapula, and insert on the greater tubercle of the humerus. Because the back includes many muscles, which are involved in many different movements, it is difficult to choose the best back exercise. Electromyography (EMG) is used to look at activation of each muscle within each exercise movement. Electromyography has three uses in biomechanics, the first is to show the temporal structure of muscle activation, another is the level of activation produced by a muscle, and the last is the index of fatigue within the muscle. Electromyography allows us to measure the Root Mean Square (RMS) of the amplitude of the signal, and retrieve the amount of activation that a muscle produced.

Youdas et al. (2010) measured EMG of the latissimus dorsi, infraspinatus, lower trapezius and erector spinae during a pull-up, chin-up, and Perfect Pull-ups (Perfect Fitness, Durham, North Carolina, 2004). A general pattern of sequential activation occurred, suggesting that pull-ups and chin-ups were initiated by the lower trapezius and pectoralis major and completed with biceps brachii and latissimus doris recruitment. Even though the pattern was the same for pull-up and chin-up, the activation was at different intensities**.** The pull-up resulted in greater activation of the lower trapezius than the chin- up. The Perfect Pull-up did not enhance muscle recruitment to a greater degree compared to the traditional pull-up or chin-up.

Lehman, Buchan, Lundy, Myers and Nalborczyk (2004) studied muscle activation in the LAT and MT while performing four different exercises. The exercises included wide grip pull-downs, reverse grip pull-downs, seated rows with a retracted scapula, and seated rows with a non-retracted scapula. It was found that muscle activity in the MT was greatest during the seated row. Actively retracting the scapula did not influence EMG levels.

Moseley et al. (1992) compared a variety of exercises designed to strengthen the MT and the LT. The four exercises that produced the greatest muscle activation for the MT were horizontal extensions with the glenohumeral joint in a neutral or external rotation, shoulder extension, and rowing. The best exercises for activating the LT were shoulder abduction, rowing, and horizontal extension with the glenohumeral joint in either neutral or external rotation.

Ekstrom, Donatelli and Soderberg (2003) studied the upper rotators of the scapula, including the middle and lower trapezius. They performed similar exercises as those in the study by Moseley et al. (1992), but at higher intensities. They concluded that prone arm overhead raises and shoulder horizontal extension with external rotation produced the greater EMG for the MT, with 101% maximum voluntary contraction (MVC) and 87% MVC, respectfully. As for the LT, it was found that overhead arm raises in line with the LT produced the greatest muscle activation (97% MVC).

While studies have measured muscle activation within a certain exercise, there is no evidence as to which exercise activates the entire back most efficiently, thus making it the “best” overall exercise to perform. The purpose of this study was to compare EMG responses in the MT, LT, Infraspinatus, LAT, and ES during eight different back exercises to determine which exercise produces the greatest muscle activation for each muscle. The eight exercises compared in this study were pull-ups, chin-ups, TRX rows, bent-over rows, seated rows, inverted rows, lat pull-downs, and I-Y-T raises.

METHODS

Subjects

The subjects for this study were 19 apparently healthy males between the ages of 18-25 years (Table 1). Subjects had previous resistance training experience so that they were familiar with the lifts being conducted in the current study. The University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects approved the study prior to testing. Each subject was informed of the purpose, procedures, potential risks, benefits, and confidentiality of the study and provided written informed consent before participating.

Procedure

Eight different exercises were performed during this study to determine which exercise(s) most effectively activates the back muscles. Each subject was required to attend one practice session and perform each exercise prior to data collection in order to demonstrate proficiency for each exercise. Additionally, during this session each subject had their one-repetition maximal (1 RM) determined for the lat pull-down, bent-over row, seated row, and I-Y-T raises, by incrementally increasing the resistance until the subject could only perform the movement one time. A 1 RM was not performed for the pull-up, chin-up, TRX suspension row and inverted row, as body weight was used for resistance.

Subjects then completed one testing session. At the beginning of this session a MVC for each muscle of interest was recorded. The testing session consisted of performing eight exercises, in a randomly assigned order, using 70% of 1 RM or body weight. Seventy percent of 1 RM was used due to previous research by Youdas et al., (2010) identifying muscle activation >50-60% of MVC is required to promote strength adaptation. Subjects performed five repetitions of each exercise. In between each exercise set, the subject rested for 2 minutes.

For the EMG measurements, self-adhesive electrodes were placed on the muscles of the upper and lower back. The specific muscles analyzed were the middle trapezius, lower trapezius, latissimus dorsi, infraspinatus, and erector spinae. For the LT, the electrode was placed next to the spine, 1 cm below the inferior tip of the scapula. For the MT, the electrode was placed next to the root on the medial border of the scapula. For the LAT, the electrode was placed approximately 4 cm below the inferior tip of the scapula, half the distance between the spine and the lateral edge of the torso. For the infraspinatus, the electrode was placed parallel to and approximately 4 cm below spine of the scapula, on the lateral aspect, over the infrascapular fossa of the scapula. For the ES, the electrode was placed parallel to the spine approximately 2 cm from the spine over the muscle mass above the iliac crest.

The subjects were given at least 48 hours between each session and asked to refrain from any back muscle exercise for a minimum of 24 hours before each session. The exercises to be compared were:

1. Lat Pull-down: The subject was seated in the machine with their thighs under the pads. The subject grasp the bar with their hands wider than shoulder-width, palms facing forward and thumbs wrapped around the bar. With elbows straight overhead, the subject pulled their shoulder blades down and back. The subject leaned back slightly and pulled the bar down. The subject then pulled the bar to the top or mid-section of chest and paused. The elbows were pulled toward the sides of their torso, the elbows drove toward the floor. To finish, the subject slowly straightened their elbows and returned the bar to starting position.

2. Seated Row: The subject used a seated pulley cable machine and a v-bar handle. The subject placed their feet on the platform with knees bent and maintained a straight back. The subject held the handle and lifted their chest while slowly pulling the elbows backwards close to their rib cage until the handle touched the front of their stomach. To finish, the subject paused for one second before slowly straightening their arms to return the weight to the original starting position.

3. Bent-over Row: The subject gripped a barbell with their palms down so that their wrists, elbows, and shoulders were in a straight line. The subject lifted the bar from the rack, bent forward at the hips, and kept their back straight with a slight

bend in their knees. The subject lowered the bar towards the floor until their elbows were completely straight, and kept their back flat as the bar is pulled towards their sternum. To finish, the subject slowly lowered the bar to the starting position.

4. Inverted Row: The subject had a wider than shoulder width grip on a bar positioned on a rack at about waist height. The subject hung underneath the bar with their body straight and their heels on the ground with arms fully extended. The subject flexed their elbows pulling their chest towards the bar, with their shoulder blades retracted. The subject paused at the top of the motion and to finish slowly extended their elbows and returned to starting position.

5. Pull-up: The subject stood under the chin-up bar with their arms overhead and palms facing away from them. The subject reached or jumped to lift their body off the floor to grasp the handles firmly with a full grip position (thumbs wrapped around the handles) and their wrists were in a straight line with their forearms (neutral). The subject pulled their shoulders back and down bending their elbows to pull their body upward, keeping their elbows down toward sides. The subject pulled until their chin was level with the bar or their hands. To finish, in a slow and controlled manner, the subject returned to starting position by allowing their elbows to fully straighten.

6. Chin-up: The subject stood under the chin-up bar with their arms overhead and palms facing toward them. The subject reached or jumped to lift their body off the floor to grasp the handles firmly with a full grip position (thumbs wrapped around the handles) and their wrists in a straight line with their forearms (neutral). The subject pulled their shoulders back and down bending their elbows to pull their body upward. Keeping their elbows down and in front of their body pulling with a motion that caused their elbows to point directly down toward the floor. Subject pulled until their chin was level with the bar or their hands. To finish, in a slow and controlled manner, the subject returned to starting position by allowing their elbows to fully straighten.

7. TRX Row: The subject held the TRX handles in each hand and faced the anchor point. The subject stood with one foot ahead of the other and both feet facing forward. The subject pulled their shoulder blades down and back and gently leaned backwards. The subject shifted their body weight over their back leg while straightening their elbows positioned at chest height. They did not bend their wrists and kept their palms facing inward. The subjects then bent their elbows and pull entire their body towards their hands. Their elbows moved toward their sides and remained close to their body. They kept their wrists in the neutral position. To finish, the subject lowered their body back towards starting position, extending (straightening) their elbows without having their shoulders roll forward.

8. I-Y-T Raises: The subject laid on their stomach on a bench and extend their arms in front of them with their palms facing inward the subject will form the letter “I”, they lifted their arms toward the ceiling and slowly lowered to ground. The subject formed the letter "Y" by lifting their thumbs toward the ceiling. They lifted and squeezed their shoulder blades together in back. Subject slowly lowered their arms. To finish, the subject formed the letter “T” with their palms turned toward the floor and again, lifted their arms and squeezed their shoulder blades together.

Performance of Maximal Voluntary Contractions (MVCs)

At the beginning of the testing session, a maximal voluntary contraction (MVC) was recorded for each of the five muscles. The following muscle tests were used for the various muscles. For the infraspinatus, the subject held their arm in front of them bent at 90 degrees, elbows toward their side, and forcefully rotated outward against manual resistance. For the middle trapezius, the same muscle test was used. For the latissimus dorsi, the subject mimicked a pull-up action by doing a lat pull-down against a heavy resistance. For the erector spinae, the subject laid in a prone position with their hands on the back of their head. The subject lifted both their chest and legs off the surface, while manual resistance was applied to the shoulders and legs. Lastly, for the lower trapezius, the same muscle test was used as for the erector spinae.

EMG Analysis

Electrical activity of the middle and lower trapezius, latissimus dorsi, erector spinae, and infraspinatus were recorded and stored on a personal computer. The EMG signal was preamplified (gain 900x) using a differential amplifier (Delsys Trigno Wireless Systems, Boston, MA; bandwidth 20-450 Hz). Raw EMG signals were digitized at 2000 Hz. The EMG amplitude (microvolts root mean square [μVrms]) values were calculated for each trial and represented as a percentage of the maximal RMS values recorded during the MVC trial. Five repetitions were recorded for each exercise. The middle three repetitions were used for analysis.

STATISCAL ANALYSIS

For each muscle, normalized EMG activity between exercises was compared using a one-way ANOVA with repeated measures. If there was a significant difference between exercises, pairwise comparisons were made using Fisher's LSD tests. Alpha was set at 0.05 to achieve statistical significance.

RESULTS

Nineteen male subjects participated in the current study. Descriptive characteristics of the subjects are presented in Table 1. Muscle activation for each of the five muscles, for each exercise, are presented in Tables 2-6 and Figures 1-5, respectfully.

Table 1. Descriptive characteristics of subjects (N=19)

	Mean + SD	Range
Age (yrs)	22 ± 1.4	20-25
Height (in)	71 ± 2.6	67-76
Weight (lbs)	180 ± 23.5	147-230

Data for the middle trapezius are presented in Table 2 and Figure 1, respectfully. It was found that the bent-over row, inverted row, seated row and I-Y-T raises had statistically greater activation than the pull-up, chin-up, lat pull-down, and TRX row. However, these were not statistically different from each other.

Table 2. Average EMG (%MVC) for the middle trapezius during the eight exercises performed in the study.

Exercise	Average EMG
TRX row	74 ± 30.7
Bent-over row	107 ± 29.3*
Chin-up	60 ± 20.5
Inverted row	108 ± 36.5*
Lat pull-down	61 ± 23.0
Seated row	99 ± 51.1*
Pull-up	80 ± 27.2
I-Y-T-raises	108 ± 39.5*

* Significantly greater activation than all of the other exercises, but not significantly different from each other.
Values represent means ± SD.

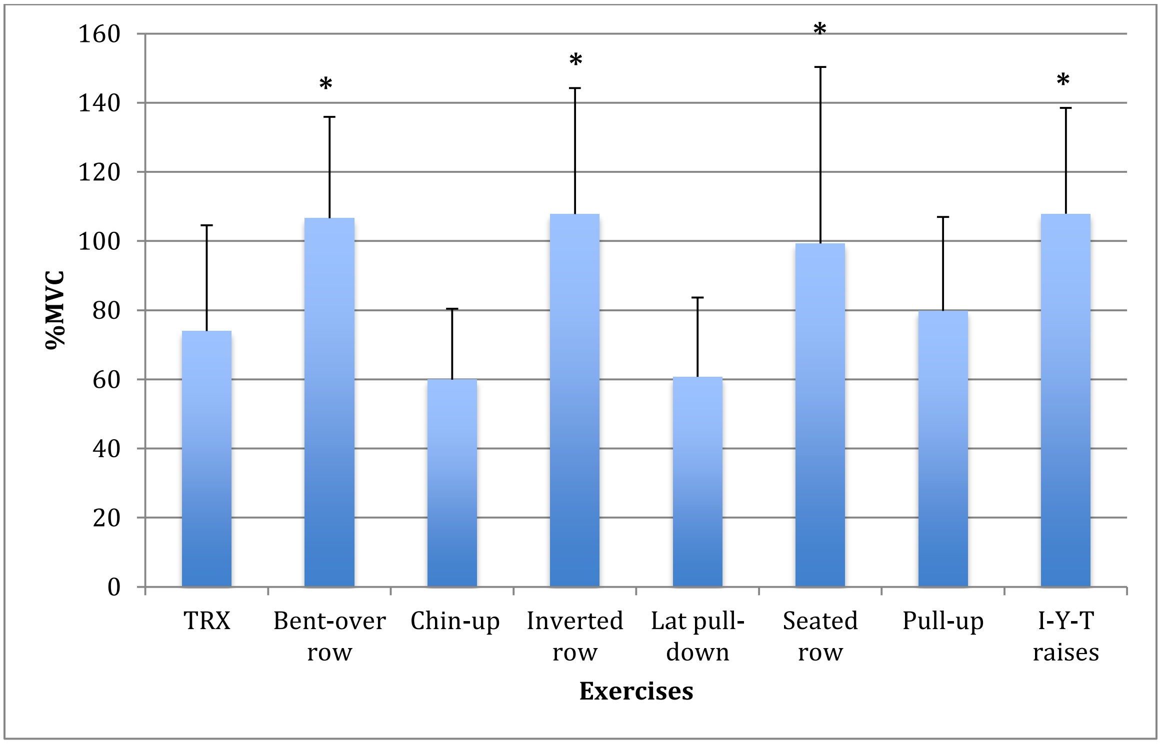

Figure 1. Muscle activation of the middle trapezius for the eight different exercises. Error bars represent SD.
* Significantly greater activation than all of the other exercises, but not significantly different from each other.

Data for the lower trapezius are presented in Table 3 and Figure 2, respectfully. It was found that the I-Y-T raises had significantly greater activation than the TRX row, bent-over row, chin-up, inverted row, lat pull-down, seated row, and pull-up. The bent-over row was the second best exercise for the lower trapezius as it had significantly greater activation than the TRX row, chin-up, inverted row, lat pull-down, seated row, and pull-up.

Table 3. Average EMG (%MVC) for the lower trapezius during the eight exercises performed in the study.

Exercise	Average EMG
TRX row	34 ± 15.3
Bent-over row	68 ± 24.2#
Chin-up	48 ± 15.6
Inverted row	55 ± 17.2
Lat pull-down	61 ± 23.0
Seated row	47 ± 20.1
Pull-up	54 ± 17.1
I-Y-T-raises	81 ± 27.5*

*Significantly greater activation than all of the other exercises.
#Significantly greater activation than the TRX row, chin-up, inverted row, lat pull-down, seated row, and pull-up.
Values represent means ± SD.

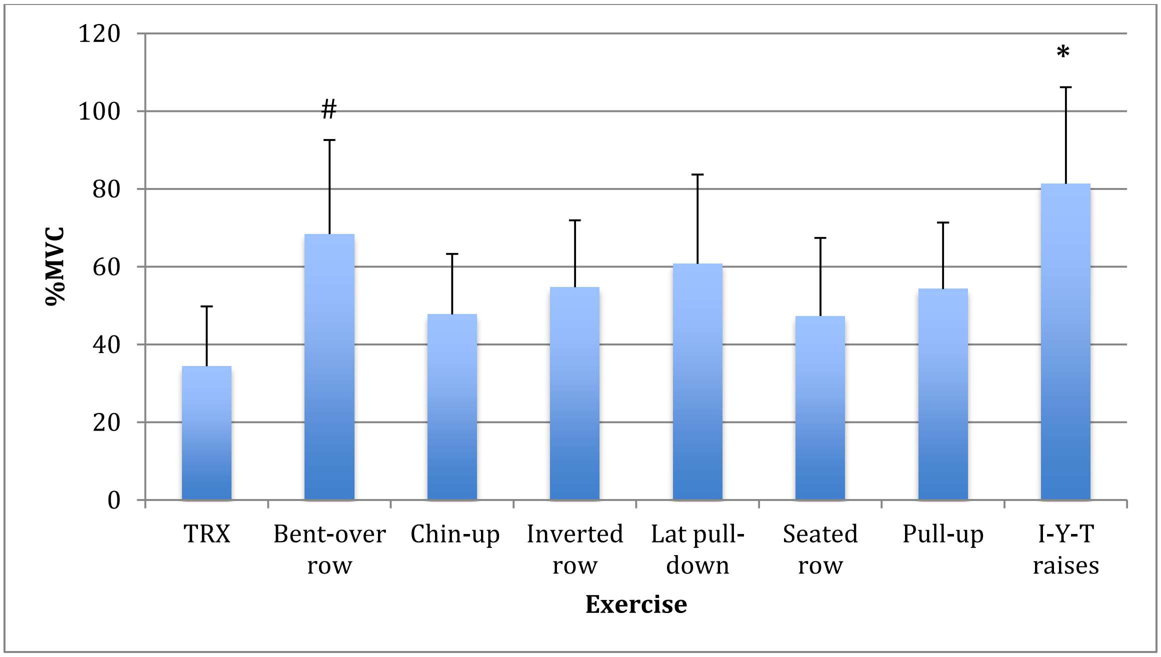

Figure 2. Muscle activation of the lower trapezius for the eight different exercises. Error bars represent SD.
*Significantly greater activation than all of the other exercises.
#Significantly greater activation than the TRX row, chin-up, inverted row, lat pull-down, seated row, and pull-up.

Data for the latissimus dorsi are presented in Table 4 and Figure 3, respectfully. It was found that the pull-up and chin-up had significantly greater activation compared to the TRX row, seated row, inverted row, lat pull-down, bent-over row, and I-Y-T raises, but were not significantly different from each other. The second best exercises to perform to activate the latissimus dorsi were the bent-over row, inverted row, lat pull-down and seated row, as they had significantly greater activation than the TRX row and Y-T-I raises. However, they were not significantly different from each other.

Table 4. Average EMG (%MVC) for the latissimus dorsi during the eight exercises performed in the study.

Exercise	Average EMG
TRX row	49 ± 23.3
Bent-over row	91 ± 23.1#
Chin-up	105 ± 29.0*
Inverted row	83 ± 19.1#
Lat pull-down	88 ± 15.3#
Seated row	90 ± 25.9#
Pull-up	108 ± 19.9*
I-Y-T-raises	39 ± 17.5

*Significantly greater activation than all of the other exercises, but not significantly different from each other.
#Significantly greater activation than the TRX row and I-Y-T raises. However, they were not significantly different from each other.
Values represent means ± SD.

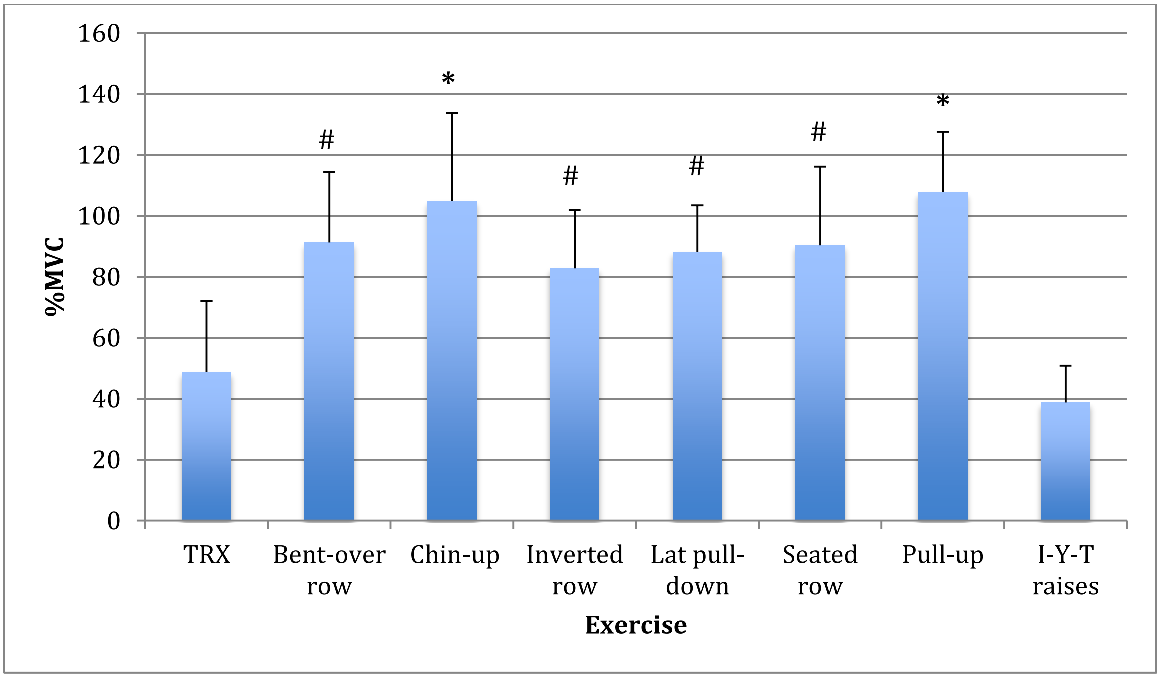

Figure 3. Muscle activation of the latissimus dorsi for the eight different exercises. Error bars represent SD.
*Significantly greater activation than all of the other exercises, but not significantly different from each other.
#Significantly greater activation than the TRX row and I-Y-T raises. However, they were not significantly different from each other

Data for the infraspinatus are presented in Table 5 and Figure 4, respectfully. It was found that the I-Y-T raises, inverted row, bent-over row, chin-up and pull-up had significantly greater activation than the TRX row, lat pull-down and seated row. However, they were not significantly different from each other.

Table 5. Average EMG (%MVC) for the infraspinatus during the eight exercises performed in the study.

Exercise	Average EMG
TRX row	42 ± 24.6
Bent-over row	55 ± 22.5*
Chin-up	53 ± 26.3*
Inverted row	51 ± 22.6*
Lat pull-down	37 ± 20.6
Seated row	46 ± 17.7
Pull-up	51 ± 33.6*
I-Y-T-raises	58 ± 21.7*

* Significantly greater activation than all of the other exercises, but not significantly different from each other.
Values represent means ± SD.

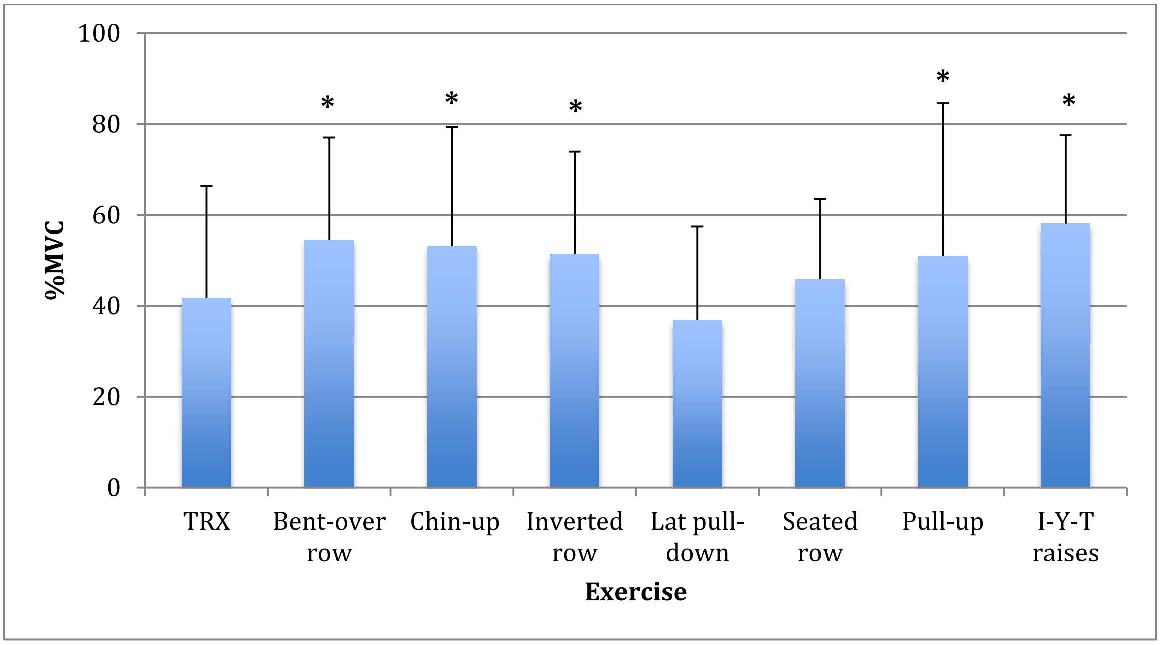

Figure 4. Muscle activation of the infraspinatus for the eight different exercises. Error bars represent standard error.
* Significantly greater activation than all of the other exercises, but not significantly different from each other.

Data for the erector spinae are presented in Table 6 and Figure 5, respectfully. It was found that the bent-over row had significantly greater activation than the TRX row, suspended row, inverted row, pull-up, chin-up, lat pull-down, and I-Y-T raises. The second best exercises to perform to activate the erector spinae would be the chin-up, inverted row, seated row, pull-up, and I-Y-T raises, as they had significantly greater activation than the TRX row and lat pull-down. However, they were not significantly different from each other.

Table 6. Average EMG (%MVC) for the erector spinae during the eight exercises performed in the study.

Exercise	Average EMG
TRX row	30 ± 18.2
Bent-over row	66 ± 20.0*
Chin-up	42 ± 27.8#
Inverted row	44 ± 15.6#
Lat pull-down	20 ± 16.5
Seated row	44 ± 12.5#
Pull-up	46 ± 21.5#
I-Y-T raises	47 ± 18.7#

*Significantly greater activation than all of the other exercises.
#Significantly greater activation than the TRX row and lat pull-down.
Values represent means ± SD.

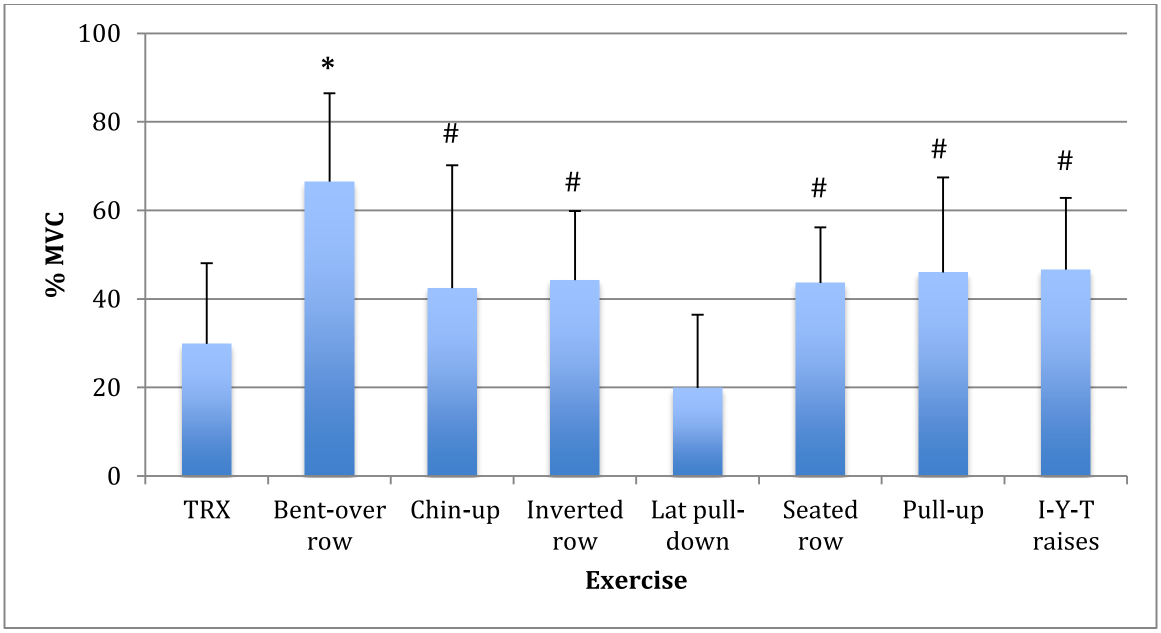

Figure 5. Muscle activation of the erector spinae for the eight different exercises. Error bars represent SD.
*Significantly greater activation than all of the other exercises.
#Significantly greater activation than the TRX row and lat pull-down

DISCUSSION

The purpose of this study was to determine which commonly used back exercise activates the most back muscles to the greatest degree. Because the back contains such a large number of muscles, five muscles were chosen which extend from the top of the back to the lowest part of the back. Electromyographical electrodes were placed on the middle trapezius, lower trapezius, latissimus dorsi, infraspinatus and the erector spinae. These muscles were chosen over others due to the layering aspect of the back muscles and because of possible cross talk with the EMG signals. Cross talk can interrupt an individual muscle's signal and interfere with a signal of another nearby muscle.

Previous studies have studied back muscle activation using EMG while comparing pull-ups, chin-ups, the Perfect Pull-up (Perfect Fitness, Durham, North Carolina, 2004), pull-downs with varying grips, seated rows with a retracted and non-retracted of the scapula (Youdas et al., 2010; Lehman, Buchan, Lundy, Myers and Nalborczyk, 2004). All of the previous studies have had a narrow focus of muscles or comparison between a few select exercises. The current study analyzed the activation of the entire range of back muscles during eight commonly used back exercises.

We found that the middle trapezius was activated to the greatest degree during the bent-over row, inverted row, seated row, and I-Y-T raises, with no significant difference in EMG values between them. This finding agrees with that of Ekstrom, Donatelli and Soderberg (2003) who found prone overhead presses to be the best activator of the middle trapezius. The prone overhead press would be the “I” portion of I-Y-T raises. It was found that the lower trapezius was also activated to the greatest degree during I-Y-T raises. In 2010, Youdas et al. found that the pull-up activated the lower trapezius to a greater degree than the chin-up. The findings of the current study agree with these findings. However, the pull-up was not the best lower trapezius specific exercise, the I-Y-T raises were. More recently, Dickie et al. (2017) compared pull-ups vs. chin-ups and found that the pull-up activated the middle trapezius, lower trapezius, and latissimus dorsi to a greater degree than the chin-up. In the current study the latissimus dorsi was activated to a similar degree during pull-ups and chin-ups, with no significant difference between the two. When looking at the infraspinatus, the bent-over rows, chin-ups, inverted rows, pull-ups, and I-Y-T raises activated this muscle to the same degree. It was found for the erector spinae, bent-over rows provided the greatest activation.

One thing was noted during the study was that everyone seems to activate and recruit muscles differently. For some subjects, a certain exercise would activate a muscle to the greatest degree and for others it would have low activation of that same muscle. For example, the lat pull-down’s name itself indicates that is should activate the latissimus dorsi, but with some subjects it was one of the least activated back muscles within that particular exercise. These findings may indicate the importance an individual mentally focusing on the particular muscle they want to work. Subjects were not told before each exercise to focus on the activation or use of a specific muscle, therefore subjects may use muscles differently if they are not mentally focused. Another reason for discrepancy between individuals and studies could be due to the anatomy of the body; some people have naturally larger, more dominant muscle groups.

The results of this study indicate that there wasn't one specific exercise that was the single best exercise to activate each of the five muscles to the greatest degree. However, if a person had to choose one exercise, the bent-over row activated three of the five back muscles to the greatest degree and was the second best exercise for the other two muscles. If able, the top two exercises would be the bent-over row and the I-Y-T raises. It was found that the I-Y-T raises had the greatest activation in three of the five muscles and was the second best in one of the muscles. If wanting to specifically work the latissimus dorsi, the exercises of choice would be chin-ups and the pull-ups. The practical application for the results of this study is that in order to train the entire back, individuals may need to use a variety of exercises in order to train the entire back effectively.

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APPENDIX A

PRE- EXERCISE HEALTH SCREENING QUESTIONNAIRE

ELECTROMYOGRAPHY ANALYSIS OF VARIOUS BACK EXERCISES

Pre-Exercise Health Screening Questionnaire

Name:__________________________

Age:_________ Height:_______ Weight:______ Gender:______

1. Have you done any strenuous exercise within the past 24 hours? Yes No

2. Are you experiencing, or have you previously experienced shoulder/back pain that is made worse with exercise? Yes No

If yes, please explain:____
____

Subject #

Testing session #1:

1.) Practice all exercises
2.) 1 RM
    a. Seated row
    b. Bent-over row
    c. I-Y-T raises
    d. Lat pull-down

Testing session #2:

1.) MVC
2.)
3.)
4.)
5.)
6.)
7.)
8.)
9.)

Name:________________________

Test Session 1:

Lift	1 RM Weight (lbs)	70% of 1 RM
Bent-over Row		
I-Y-T raise		
Lat Pull-down		
Seated Row		

Test Session 2:

Lift	Weight (lbs) (x 5 reps)
MVC	
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

APPENDIX B

INFORMED CONSENT

Informed Consent

ELECTROMYOGRAPHIC ANALYSIS OF VARIOUS BACK EXERCISES

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

- ***Purpose and Procedure***
  - The purpose of this study is to compare muscle activity (as measured by EMG analysis) during different back muscle exercises in men.
  - My participation in this study will involve two sessions, each lasting approximately 1 hour each.
  - The exercises to be tested will be chin-ups, pull ups, inverted rows, TRX rows, lat pull-downs, bend-over rows, seated rows, and I-Y-T raises.
  - During the first session, I will perform all of the 8 different exercises to become accustomed to them. I will also perform all 8 exercises to establish my maximal strength (1 RM) for each lift.
  - During the second testing session I will perform the 8 exercises, using 70% of 1 RM or body weight.
  - During the two sessions, I will have adhesive electrodes placed on my upper and lower back in order to record and measure muscle activity.
  - Testing will take place in the weight room located in Mitchell Hall 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 “pulled” muscles are possible risk factors associated with participating in this study.
  - Skin irritation from placement of the EMG electrode is possible.
  - Individuals trained in CPR and Advanced Cardiac Life Support will be present for all testing sessions and the test will be terminated immediately if complications occur.
  - The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.
- ***Potential Benefits***
  - I, and other athletes, may benefit by gaining knowledge about which is the most effective back exercise.
- ***Rights & Confidentiality***
  - My participation is voluntary.
  - I can withdraw from the study at any time, for any reason, without penalty.

- The results of this study may be published in the scientific literature or presented at professional meetings using group data only.
- All information will be kept confidential through the use of number codes.
- My data will not be linked with personally identifiable information.

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 of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that have concerned me and received clear answers so as to fully understand all aspects of the study.

If I have any other questions that arise I may feel free to contact the principal investigator: Holly Edelburg (715)302-8989, or her study advisor, Dr. John Porcari, 141 Mitchell Hall, (608) 785-8684. Questions regarding the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Intuitional Review Board for the Protection of Human Subjects at (608) 785-8124

Participant:____ Date: _____________
Investigator: ____ Date: ______________

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

According to the American College of Sports Medicine resistance training should be performed 2-3 times weekly (ACSM, 2013). In 2011, only 29% of U.S. adults met the resistance training guidelines (CDC, 2013). Back issues are a rather prevalent injury or pain. According to Seung, Sung-Hwan, & Ji-Han (2004), most low back pain results from fatigue and excessively used erector spinae and rectus abdominis muscles. Strengthening of the back muscles can be of importance when preventing lower back pain. By determining which exercises are the most efficient we can cut down the time spent on resistance training. This review of literature will discuss how EMG can help determine which back muscle exercises are most efficient at activating the middle and lower trapezius, latissimus dorsi, erector spinae, and infraspinatus muscles.

Muscles of Interest

As the purpose of this study is to determine the most effective exercises for the back muscles, it is important to first understand the muscles that will be looked at. The back consists of many muscles ranging from the upper to lower back. The major ones activated when performing various back exercises are the middle and lower trapezius, erector spinae, latissimus dorsi, and infraspinatus muscles.

The middle trapezius arises from the spinal processes of C-6 to T-3 and inserts on the acromion and superior lip of the spine of the scapula (Criswell, 2011). The middle trapezius overlaps the rhomboids making it hard to differentiate activation between the two. The lower trapezius arises from the third to the twelfth thoracic vertebrae (T-3 through T-12) and inserts on the scapular spine (Criswell, 2011). Both the middle and lower trapezius are equally active during abduction. The latissimus dorsi is a very broad muscle and arises from the lower six thoracic vertebrae, the lumbodorsal fascia, the sacrum and crest of the ilium, and the last three or four ribs; it inserts, along with the teres major, on the medial edge of the humerus (Criswell, 2011). The erector spinae are the main trunk mover and stabilizers. This group of muscles includes the multifidus, rotators, and longissimus muscle groups (Criswell, 2011). The infraspinatus fibers arise from the infraspinatus fossa, below the spine of the scapula, and inserts on the greater tubercle of the humerus (Criswell, 2011).

Basics of Electromyography

Electromyography measures muscle response or electrical activity in response to a nerve’s stimulation of the muscle. Mayo Clinic (2017) states that motor neurons of muscles transmit an electrical signal that causes the muscle to contract; this electrical signal can be picked up using EMG and turned into a readable signal.

There are two main types of electrodes for recording EMG: surface and indwelling. Surface electrodes are placed on the surface of the skin, while indwelling electrodes are inserted directly into the muscle (Kamen & Gabriel, 2010). Both types do the same thing, they convert the muscles electric potential into an electrical signal.

Within the category of surface electrodes there are passive and active electrodes. Passive electrodes require an electrode gel that helps with the conduction pathway and have no additional electronics associated with the unit itself. Active electrodes do not require gel, but have a preamplifier within the electrode itself. This preamplifier increases the signal by a factor of 10 (Kamen & Gabriel, 2010). Surface electrodes are deemed non-invasive and are user friendly. A downfall with surface electrodes is the possibility of cross-talk between smaller muscles, as they are not wired directly to the muscle of interest.

A more invasive electrode method would be indwelling electrodes. Indwelling electrodes consist of a single needle or two wires, which are planted within the muscle itself. Indwelling electrodes are used in clinical and research settings and are best used with deep muscles that surface electrodes cannot detect. Just like with surface electrodes, indwelling electrodes have two types, needle and wire. Needle electrodes can be advantageous since they allow for the detection of motor unit action potential from a very limited amount of tissue. The size of the needle varies, depending on how many wires will be passed through it, but normally it ranges 23-28 gauge, and the diameter of the wires is typically between 25-100 μm in diameter. (Kamen & Gabriel, 2010).

Wire electrodes, also known as fine-wire electrodes, are an insulated wire that is threaded through a 27 gauge needle; a small loop is formed as it comes out of the bevel. Insulation is cut from the middle and the tips of the wire so they can be connected to the amplifier. The loop is then cut, leaving two separate wires which will be bent and turned into hooks. These hooks are the anchors for the wire to the muscle. The hooks are advantageous because it allows for more dynamic movements to occur. Wire electrodes do have some disadvantages compared to the needle electrodes. The major disadvantage is that once fine wire electrodes are implanted they cannot be taken out and reinserted (Kamen & Gabriel, 2010).

Maximal Voluntary Contraction (MVC)

The EMG signal is often represented as a percent of maximal voluntary isometric contraction (MVIC) (Knutson, Soderberg, Ballantyne, & Clarke, 1994). The reason MVIC is used is to normalize data and allow for comparison between muscles. Knutson et al., (1994), found that the MVIC method of normalization provided low variability and high inter-individual reliability when compared to normalized EMG relative to the mean or peak amplitude of dynamic contractions of leg muscles for both healthy and anterior cruciate ligament deficient individuals. A previous study done by Ekstrom, Soderberg, & Dontatelli (2005) used MVIC for 9 manual tests and found that no one muscle test produced a MVIC for all individuals. It was suggested to perform 2 or 3 exercises that produced the highest EMG levels for each muscle.

Related Studies

Youdas et al., (2010) measured muscle activation with EMG's to determine muscle activation within a pull-up, chin-up, and Perfect Pull-ups. Values were determined within exercises of muscles groups and found the same muscles were recruited but at different strength intensities. Lehman, Buchan, Lundy, Myers & Nalborczyk (2004) looked at muscle activation in the biceps brachii, latissimus dorsi and middle trapezius/rhomboid while performing four tasks. The tasks included wide grip pull-down, reverse grip pull-down, seated row with a retracted scapula and a seated row with a non- retracted scapula. A comparison ratio of muscle activation was found using myoelectrical activity. The pull-up can be performed with many different grip widths and orientations, with each placing different biomechanical demands on the associated musculature (Floyd, 2012). Dickie, Faulkner, Barnes, & Lark (2017) analyzed muscle activation during different pull-up variations using EMG. Analyzed was the pull-up with pronated grip, supinated grip, neutral grip and rope style pull-up. It was found that the middle trapezius, latissimus dorsi and infraspinatus work at similar levels during both the concentric and eccentric phases of each of the pull-up variations. The only noted significant difference was found during the entire motion of the middle trapezius between the pronated grip and neutral grip pull-up, pronated grip being greater. The middle trapezius, however, was not the most highly activated muscle during the different pull-up variations. Based on these findings it appears all four pull-up grips will elicit similar strength adaptations when implemented in resistance training settings. Another grip orientation comparison study done by Lusk, Hale, & Russel (2010) looked at the anterior lat pull-down. The grips compared were wide-pronated, wide-supinated, narrow-pronated, and narrow-supinated grips. It was found that the pronated grip elicited greater activation of the latissimus dorsi than the supinated grips, however, grip did not matter for the activation of the middle trapezius. These studies have measured muscle activation within a certain exercise but as of this date there is no further evidence as to which exercise has the most back muscle activation making it the “best” exercise to perform.

Summary

Previous studies have looked at comparisons between a couple back exercises with varying grips or a few back muscles. Many studies have taken bits and pieces of the back and looked into them but none have been found the most effective exercise for the back all together. This study will compare a wide variety of exercises, eight specifically, and five muscles over the span of the entire back. The use of EMG in this study will be imperative to determine muscle activation and what the most effective back exercise(s) may be to incorporate in a resistance-training program.

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