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The Acute Effects Of Manual Resistance On Ballistic Bench Press Performance

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by

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Abstract

Heavy conditioning activities (CA) during warm-ups has been found to improve subsequent movements. However, a problem with heavy CAs is the need for specialized equipment. Manual Resistance (MR) is accommodating resistance in which traditional exercises are replicated using resistance from a partner. This modality has led to improved muscular strength and endurance; however, the acute effects of MR have not been examined. **Purpose:** The purpose of this study was to determine if MR can lead to improvements in ballistic bench press (BBP) performance. **Methods:** Two subjects (age = 22.50 ± 0.71 years, weight = 97.88 ± 43.95 kg, BMI = 28.43 ± 10.05) attended nine sessions. One maximal strength session in which a one repetition maximum bench press was conducted, followed by four familiarization sessions, and four testing sessions. These consisted of performing three repetitions of BBP following a general warm up (baseline) and three repetitions of BBP after either a rest period (Baseline), a CA of manual resistance (MRC), and a CA of bench press (HBP) (post-CA measurements). During each BBP repetition, peak force, rate of force development, power, and electromyography (EMG) activation of the pectoralis major and triceps brachii were measured. **Results:** There was no statistically significant difference between the pre and post CA measurements, nor between the baseline, MRC, and HBP conditions. **Conclusion:** MR was not able to improve BBP performance, further research is needed with a larger sample size to determine if MR can lead to acute improvements in BBP performance.

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Chapter 1: Introduction

The use of complex training, consisting of performing a heavy resistance exercise (i.e. squat at or above 87% of 1 Repetition Maximum intensity) followed by an explosive or plyometric exercise (i.e. jumping) (DeWeese & Nimphius, 2008), has been shown to lead to acute improvements in performance during the explosive or plyometric exercise. This has been shown in numerous studies in which the use of a heavy resistance exercise has led to improvements in the vertical jump, broad jump, and shot-put performance (Evetovich, Conley, & McCawley, 2015). The use of heavy resistance exercises have also been found to improve peak torque of a knee extension, (Batista et al., 2007; Seitz & Haff, 2016), ballistic bench press throws (Kilduff et al., 2007), and even the acceleration portion of a sprint (Evetovich et al., 2015).

Furthermore, researchers have found that the addition of accommodating resistance, such as resistance bands and chains, can induce Post-Activation Potentiation (PAP) effects when added to movements such as the squat and bench press (Baker, 2009; Scott, Ditroilo, & Marshall, 2018; Seitz, Mina, & Haff, 2016; Wyland, Van Dorin, & Reyes, 2015). The addition of accommodating resistance was found to potentiate and improve performance in the broad jump (Seitz et al., 2016), 9.1 meter sprint performance (Wyland et al., 2015), counter movement jump (Scott et al., 2018), and bench press throw (Baker, 2009).

Mechanisms of Achieving Improved Performance

While the exact cause of the improvements in explosive movements following a heavy resistance exercise is unknown, there are numerous theories to explain this. Recently, Post-Activation Potentiation has gained popularity in the field of strength and conditioning and is defined as an acute effect of improved muscular performance as a result of the muscle's contractile history (Tillin & Bishop, 2009). On the other hand, theories examining the modulation of fatigue and maintenance of performance, such as motor control theories such as the onion skin scheme, after-hyperpolarization, and muscle wisdom which may be the cause of this improved performance. Muscle Wisdom is a hypothesis that states that during maximum voluntary contractions, in order to minimize fatigue, there is a decrease in motor unit discharge rate resulting in a fully activated muscle (Garland & Gossen, 2002). The onion skin scheme and after-hyperpolarization are two theories on motor unit firing rates that are almost opposite of each other with after-hyperpolarization being that as there is a transition from recruitment of low threshold to higher threshold motor units, the firing rate of motor units increases resulting in each of the motor units producing its greatest force (De Luca & Contessa, 2015) and the onion skin scheme stating that the lower threshold motor units have a greater firing rates and firing rates decrease with greater threshold motor units (De Luca & Contessa, 2015).

KNOWLEDGE GAP

Currently, researchers focus on a few exercise modalities to induce achieve this benefit of improved performance. Along with complex training, whole body vibration and plyometric exercises have been shown to improve athletic performance (Chen, Lo, Wang, Yu, & Peng, 2017). Isokinetic knee extensions performed at 60, 180, and 300 degrees/sec, have also been shown to lead to PAP and improve performance on subsequent knee extensions done at 60, 180, and 300 deg/sec (Seitz & Haff, 2016; Seitz, Trajano, Dal-Maso, Haff, & Blazevich, 2014). However, a concern with these methods is the necessity to use specialized equipment that typically require specialized or laboratory set up which may not be practical for athletes who compete in outdoor sports such as track and field.

Introduction to Manual Resistance

Manual Resistance (MR) is a form of accommodating resistance applied to target muscles. MR requires minimal equipment including, benches, chairs, tables, step boxes, polyvinyl chloride (PVC) pipes, and straps (Dorgo et al., 2009), whereby one or more partners provide resistance for the exercise movement. With this modality, there is no use of traditional weight training equipment such as barbells, dumbbells, and plates. Most traditional free-weight and machine-based resistance training exercises can be replicated with appropriate training stimuli provided when MR exercises are properly executed (Dorgo et al., 2009; Dorgo, King, & Rice, 2009). Previous studies suggest that the use of MR can improve muscular strength and endurance in untrained young adults (Dorgo, King, & Rice, 2009), recreationally trained adults (Chulvi-Medrano et al., 2017), and adolescents (Dorgo et al., 2009) at similar rates as traditional resistance training (weight training). Despite the limitation of being unable to quantify the applied resistance of the MR modality (Dorgo et al., 2009; Dorgo, King, & Rice, 2009), MR has the advantages of minimal, portable, and inexpensive equipment requirements making the MR system a viable alternative for everyday fitness applications, as well as for use in athletic settings. However, researchers have yet to examine the potential of the MR modality to induce PAP.

Purpose

Therefore, the purpose of this study was to determine if the use of MR can lead to improved ballistic bench press performance as well as to examine if there are differences in the use of the MR and a traditional resistance training modality. Since this effect is induced through maximal or near maximal muscle contractions in the target muscle groups, theoretically the application of MR with the proper exercise set-up can also elicit this acute effect of improved performance. Therefore, it is hypothesized that MR would elicit an acute effect of improved performance and that these effects will be similar to the traditional method of the bench press.

Chapter 2: Literature Review

There are many physiological phenomena that may explain the improved performance following the implementation of a heavy resistance warm up such as Post-Activation Potentiation (PAP), Muscle Wisdom, the Onion Skin Scheme, and After Hyperpolarization. There are also many factors that may influence an individual's ability to benefit from the improved performance such as conditioning activity (heavy resistance exercise), training status of the individual, and rest period between conditioning activity and type of explosive movement performed.

Possible Mechanisms for Improved Performance

As previously stated, one of the theorized reasons for improved performance following a heavy conditioning activity is Post-Activation Potentiation (PAP). PAP is an acute effect of improved muscular performance as a result of the muscle's contractile history (Tillin & Bishop, 2009). To date, the exact mechanisms of PAP are unknown, however there are a few possible theories to explain the acute improved performance including: phosphorylation of regulatory light chains, and increased recruitment of higher order motor units (Tillin & Bishop, 2009). Researchers found that the phosphorylation of regulatory light chains causes actin and myosin to be more sensitive to calcium, which increases the rate at which the myosin cross bridges move from a non-force producing state to a force producing state during twitch potentiation (Hodgson, Docherty, & Robbins, 2005). One systematic review reflected that when inducing PAP through electrical stimulation, the PAP occurred at the spinal level due to an increase in synaptic efficacy between Ia afferent terminals and α-motoneurons of the homonymous muscle (Hodgson et al., 2005). Another review by Tillin and Bishop (2009) also introduces the possibility that changes in pennation angle may be a mechanism by which PAP occurs, with the authors explaining that conditioning activities can result in a decrease in pennation angle resulting in greater force production ability (Tillin & Bishop, 2009).

As previously stated, muscle wisdom is a hypothesis that states that during maximum voluntary contractions, in order to minimize fatigue, there is a decrease in motor unit discharge rate resulting in a fully activated muscle (Garland & Gossen, 2002). It is believed that the slowing of the motor unit discharge results in the fully activated muscle due to the reduced fusion frequencies associated with the prolonged relaxation times (Garland & Gossen, 2002). Muscle Wisdom has been shown in studies which knee extensions were done for 50 repetitions with decreases in mechanomyography and mean power frequency measurements from repetitions 10-40 (Ebersole, O'Connor, & Wier, 2006), however it was concluded that these responses were muscle specific. Recently the muscle wisdom hypothesis has questioned with the sustained maximum voluntary contractions and dynamic contractions showing different responses than those expected with the muscle wisdom hypothesis (Fuglevand & Keen, 2003; Garland & Gossen, 2002).

The onion skin scheme, as previously stated, is a theory stating that the lower threshold motor units have a greater firing rates and firing rates decrease with greater threshold motor units (De Luca & Contessa, 2015). With this theory it is believed that with the decrease in firing rates, force is able to be sustained for prolonged periods and allows for a reserve capacity that would be able to be accessible in extreme situations (De Luca & Contessa, 2015). This is further supported by Colquhoun et al., which found that during a ramp up to maximal voluntary isometric contractions in the vastus lateralis, that lower threshold motor units displayed greater firing rates than the higher threshold motor units in each of their subjects. It was also found that those with greater type II fiber areas displayed lower firing rates in the earlier recruited motor units than those with greater type I fiber areas (Colquhoun et al., 2018). It is a possibility that with this scheme, the use of a heavy CA may allow for access to that reserve capacity and therefore result in an increase in the firing rate of the higher threshold motor units allowing for increase in performance.

As previously mentioned, after-hyperpolarization is the theory that as the transition from low threshold to higher threshold motor units, the firing rate of motor units increases resulting in each of the motor units producing its greatest force (De Luca & Contessa, 2015). A study even concluded that the mechanism for post activation potentiation in counter movement jumps may be due to hyperpolarization of muscle fiber membranes resulting from increased sodium and potassium pump activity (Mitchell & Sale, 2011). Therefore, it is a possibility that the after-hyperpolarization caused by a heavy CA may allow for easier recruitment of those higher threshold motor units leading to acute improvements in performance.

Conditioning Activity

There have been numerous studies examining various conditioning activities (CA) that lead to improvements in subsequent movements. For example, studies examining PAP have found that isokinetic knee extensions can lead to improvement in subsequent knee extensions, both voluntary and following electrical stimulation of the femoral nerve (Seitz, Trajano, et al., 2014). Other methods such as performing squats, squats with eccentric overload, and plyometrics have been used to improve performance in subsequent countermovement jumps (Beato, Stiff, & Coratella, 2019; Chen et al., 2017; Esformes, Cameron, & Bampouras, 2010). However, reviews and meta-analysis have examined the methods of achieving improved performance on a broader spectrum and examined the use of static and dynamic methods as the CA. A meta-analysis from 2013 examining 32 studies found that there were no differences in the use of static and dynamic upper and lower body CA to achieve this improved performance (Wilson et al., 2013). However more recent reviews and meta-analysis have concluded that the use of dynamic movements can lead to improvements in performance whereas the use of static CA results in decreases in performance (Dobbs, Toulusso, Fedewa, & Esco, 2018; Seitz & Haff, 2016). There has also been some uncertainty as to what intensity of CA would elicit the greatest improvements in performance. Some studies and reviews have suggested that high intensity exercises (≥85% 1-RM) are optimal to achieve this effect (Beato et al., 2019; Esformes et al., 2010; Seitz & Haff, 2016) whereas others have suggested that moderate intensities (60-84%) are optimal to achieve improved performance (Wilson et al., 2013).

TRAINING STATUS AND REST PERIODS

Other factors that may influence an individual's capability to achieve this improved performance are their training status and the rest period between the conditioning activity and explosive movement. Tillin and Bishop (2009) examined factors that modulate PAP effects, including strength, fiber type distribution, training level, and power to strength ratio. It was then concluded by the authors that those with greater strength levels, greater percentage of type 2 fibers, greater resistance training levels, and those with lower power to strength ratio display greater PAP effects (Tillin & Bishop, 2009). This is further supported by Seitz et al. 2014 which found that stronger individuals, those who can squat twice their body weight, not only improved performance quicker than the weaker individuals but maintained improved performance for a longer duration. This was demonstrated with the stronger group having improved performance from three minutes post CA up to 12 minutes post CA and the weaker group showing improved performance from six to 12 minutes post CA (Seitz, de Villarreal, & Haff, 2014). Meta-analysis has found that this difference may be due to stronger individuals having a greater percentage of Type II muscle fibers and therefore more phosphorylation of myosin light chains (Seitz & Haff, 2016).

Manual Resistance Training

Manual Resistance (MR) is a form of accommodating resistance in which traditional equipment such as barbells and dumbbells are not used since resistance is applied by a partner (Dorgo et al., 2009; Dorgo, King, & Rice, 2009). Previous studies utilizing MR have examined its effects on muscular strength and muscular endurance compared to traditional resistance training methods. A study done by Dorgo, King, and Rice (2009) sought to examine the effects of MR compared to traditional resistance training methods in recreationally trained college students and found that both MR and resistance training methods were able to improve muscular strength and endurance levels while showing no significant difference between the two modalities (Dorgo, King, & Rice, 2009). This is similar to the findings of other studies which found that the use of MR leading to improvements in muscular strength and endurance in adolescents (Dorgo, King, Candelaria, et al., 2009), recreationally trained men (Chulvi-Medrano et al., 2017), and in microgravity conditions (Behringer, Schuren, McCourt, & Mester, 2015). While these studies found that the use of MR was able to improve muscular strength and endurance these improvements did not result in changes in body composition (Behringer et al., 2015; Dorgo et al., 2009). As previously mentioned, there have been no studies to the authors knowledge that have examined the acute effects of this training modality. Therefore, it is currently unknown if the use of MR can have any acute benefits.

Chapter 3: Methodology

Experimental Approach to the Problem

This study used a randomized cross-over study design in which subjects attended nine sessions with a minimum of 24 hours in between sessions over the span of two to three weeks. Four of these sessions were familiarization and the other five sessions were testing sessions. The familiarization sessions consisted of a maximal effort chest press session, control session, a heavy bench press session (HBP) and a manually resisted chest press (MRC) session described below. The testing sessions consisted of a one repetition maximum (1-RM) bench press, a maximal effort chest press session, a control session, a HBP session, and a MRC session. During each of the control, HBP, and MRC sessions, the ballistic bench press (BBP) was conducted and peak force, rate of force development, peak power, and activation of the Triceps Brachii and Pectoralis Major were measured during the BBP. These were measured to determine if the addition of a heavy bench press and manually resisted chest presses during warm-up periods led to improved BBP performance compared to baseline measurements as well as to determine if there were differences between the three conditions.

Subjects

This study had eight male subjects who agreed to participate, however due to the COVID-19 pandemic resulting in the stoppage of data collection, only two of the subjects (age = 22.50 ± 0.71 years , height = 183.75 ± 9.55 cm, weight = 97.88 ± 43.95 kg, BMI = 28.43 ± 10.05) attended all sessions and were used for analysis. These male subjects self-reported to have at least one year of resistance training experience and were also free of injuries at the time of testing. Subjects were informed on the details of the study, along with all potential risks associated with participation and provided written consent prior to participation. This study was approved by the UTEP Institutional Review Board.

Maximal Strength Session

For each of the sessions, the subjects performed a warm-up consisting of two phases: a general warm-up and a dynamic (specific) warm-up. The general warm-up required the subjects to jog at a self-selected pace for three to five minutes on a motorized treadmill. After the general warm-up, subjects performed a dynamic warm-up, which consisted of 10 repetitions of the following exercises: horizontal shoulder adductions/abductions, shoulder flexions/extensions, forward arm circles, backward arm circles, and push-ups.

During the first session (Maximal Strength Testing session), anthropometrics were taken. The participants' body weight and height were measured using a Detecto scale and stadiometer respectively. Body Mass Index was calculated using the standard formula (Haff & Triplett, 2015). Following anthropometric measurements, maximal upper-body strength was obtained from a 1-RM bench press test. The 1-RM test was conducted using the methods established by the National Strength and Conditioning Association (Haff & Triplett, 2015). In brief, the subject warmed-up for the bench press using a light weight for 5 to 10 repetitions, followed by a minimum of one-minute rest. They then slightly increased the weight by 5-10% and then performed 3 to 5 repetitions followed by a minimum of two-minute rest. The weight was increased by another 5-10% and the subjects performed 2 to 3 repetitions followed by a two to four-minute rest. The weight was increased by another 5-10% and the subject performed a single repetition followed by another two to four-minute rest. The weight was then increased by 5-10 pounds and the subjects performed a single repetition and this was repeated until the weight was determined in which the subject can perform only a single unassisted full range of motion repetition. During the entire 1-RM protocol, the subject had one to two NSCA Certified Strength and Conditioning Specialist (CSCS) spotting the bar to ensure the safety of the subjects and to assist the subjects with the weight if they were unable to complete the repetition.

MAXIMAL EFFORT CHEST PRESS SESSIONS

During the maximal effort chest press sessions, subjects performed the general and dynamic warm-up previously described. Following the warm-up, the subjects performed manually resisted chest presses. The subjects performed two warm-up sets. The first warm-up set consisted of eight repetitions of manually resisted chest presses with minimal resistance followed by one to two minutes of rest. The second warm-up set consisted of five repetitions of manually resisted chest presses followed by two to four minutes of rest. After these warm-up sets, subjects performed a maximal effort chess press followed by a two to four-minute rest period in between each repetition. This was repeated two more times for a total of three repetitions, with the average of the peak force of the three repetitions being used as the maximum voluntary contraction (MVC), and then used to determine what intensity (percent MVC) the manually resisted chest press were done at during the MRC sessions.

The manually resisted chest press consisted of the subject being seated on a chair holding a reinforced PVC pipe, with hands placed in a similar position as the traditional bench press. The PVC pipe had two chains attached to handles, which the researcher pulled in order to provide resistance (see Figure 3.2) (Dorgo, King, & Rice, 2009). The researcher placed their feet on the back support of the subject's chair. During the concentric phase the subject used maximal effort to press the PVC pipe while maintaining the pipe at chest level. During this phase the researcher used their body mass to resist the press enough that the subject required maximal effort but could still move through the full range of motion. During the eccentric phase, the researcher leaned back and used their body mass to pull the PVC pipe back towards the subject's chest. The subject was instructed to try and resist the pull of the PVC pipe throughout the entire eccentric phase. Given that the MR is designed to give the spotter a mechanical advantage (Dorgo et al., 2009; Dorgo, King, & Rice, 2009), the spotter was able to ensure that the resistance is sufficient enough to require maximal effort throughout the entire chest press movement. During each of these maximal effort chest presses, force was measured by a Chronojump Force Sensor (1000 Hz, Chronojump, Chronojump Boscosystem, Barcelona, Spain).

Figure 2. Resisted seated chest press. The spotter (female) has a mechanical advantage over the lifter (male) because she is able to utilize both upper- and lower-body muscle groups to apply resistance.

Figure 3.1. Demonstrates the methods used by Dorgo, King, & Rice (2009) to replicate the bench press using Manual Resistance

CONTROL SESSIONS

During the control sessions, subjects performed the standardized general and dynamic warm up previously described. Following the warmup, subjects had two Noraxon Dual EMG electrodes placed (EMG; 3000 Hz, Noraxon, USA), one of which was placed on the pectoralis major and the other on the triceps brachii (described below). After the electrode placement, subjects performed three non-consecutive repetitions of the ballistic bench press. These were used as the baseline measurements. After which the subjects had eight-minutes of passive rest and then performed a second set of ballistic bench press which were used as the post-CA measurements.

The BBP was performed by having the subject lay on custom made platform that was resting on two AMTI force plates (AMTI OR 6-5, Watertown, MA, USA). Subjects used a barbell loaded with 30% of their 1-RM weight; 30% was chosen since it has been shown to lead to the highest power output and has been used in numerous studies utilizing the ballistic bench press (Argus, Gill, Keogh, & Hopkins, 2014; Bodden et al., 2019; Farup & Sørensen, 2010; Ulrich & Parstorfer, 2017; West, Cunningham, Crewther, Cook, & Kilduff, 2013). The barbell was placed on the safety arms of a squat rack above the chest of the subject, the safety arms were used as a secondary security measure to ensure the barbell did not fall onto the subjects. The subject was given a three second count down, upon which the subject pushed the bar up, accelerating through the full range of motion and threw the bar. During the bench press throw, subjects were required to keep their head, shoulders, and trunk in contact with the platform. To ensure the safety of the subjects after the release, there were two spotters who caught the bar at the apex of the bar height, the spotters then slowly lowered the bar (West et al., 2013). During the Ballistic Bench Press, the Speed4Lift Linear Position Transducer was attached to the right side of the bar. This consisted of a small Velcro strap attached to a wire connected to a box, which is used to measure bar displacement, velocity, and calculate power and then transferred the data to a connected device. The Speed4Lift is an iso-inertial dynamometer that consists of a cable-extension linear position transducer that attaches to a barbell. The Speed4Lift works by measuring the differentiation of the displacement data over time at a sampling rate of 100Hz (Pérez-Castilla, Piepoli, Delgado-García, Garrido-Blanca, & García-Ramos, 2019). The data is transferred to the Speed4Lift application via WIFI connection.

Heavy Bench Press Sessions

During the heavy bench press sessions (HBP), the subjects performed the standardized general and dynamic warmups previously described. Subjects then had electrodes placed on the triceps brachii and pectoralis major. Following the warmups and electrode placement, subjects performed three repetitions of BBP to get baseline measurements. After the baseline measurements, the subjects performed a standardized bench press warm-up consisting of three sets: the first being eight repetitions at 50% of their 1-RM, the second consisting of four repetitions of 70% of their 1-RM and the third consisting of two repetitions at 80% of their 1-RM (West et al., 2013). Following a two to four-minute rest period, the subjects performed three repetitions of the bench press with 87% of their 1-RM (West et al., 2013). Following the three repetitions subjects rested eight minutes then performed three repetitions of the BBP. These three repetitions were considered the post-CA measurements.

Manually Resisted Chest Press Sessions

During the manually resisted chest press sessions (MRC), subjects performed the standardized general and dynamic warmups previously described. Subjects then had electrodes placed on the triceps brachii and pectoralis major. Following the warmups and electrode placement, subjects performed three baseline BBP. These were followed by the subjects performing a similar warm up to the bench press sessions in which subjects performed a warm up set of eight repetitions of manually resisted chest presses with light resistance, a set of four repetitions of manually resisted chest presses with moderate resistance and a set of two repetitions of manually resisted chest presses with heavy resistance provided by the spotter. Following the warm-up sets, the subjects performed three repetitions of maximal effort manually resisted chest presses, followed by an eight-minute rest period, and then perform three repetitions of BBP which were used as their post-CA measurements.

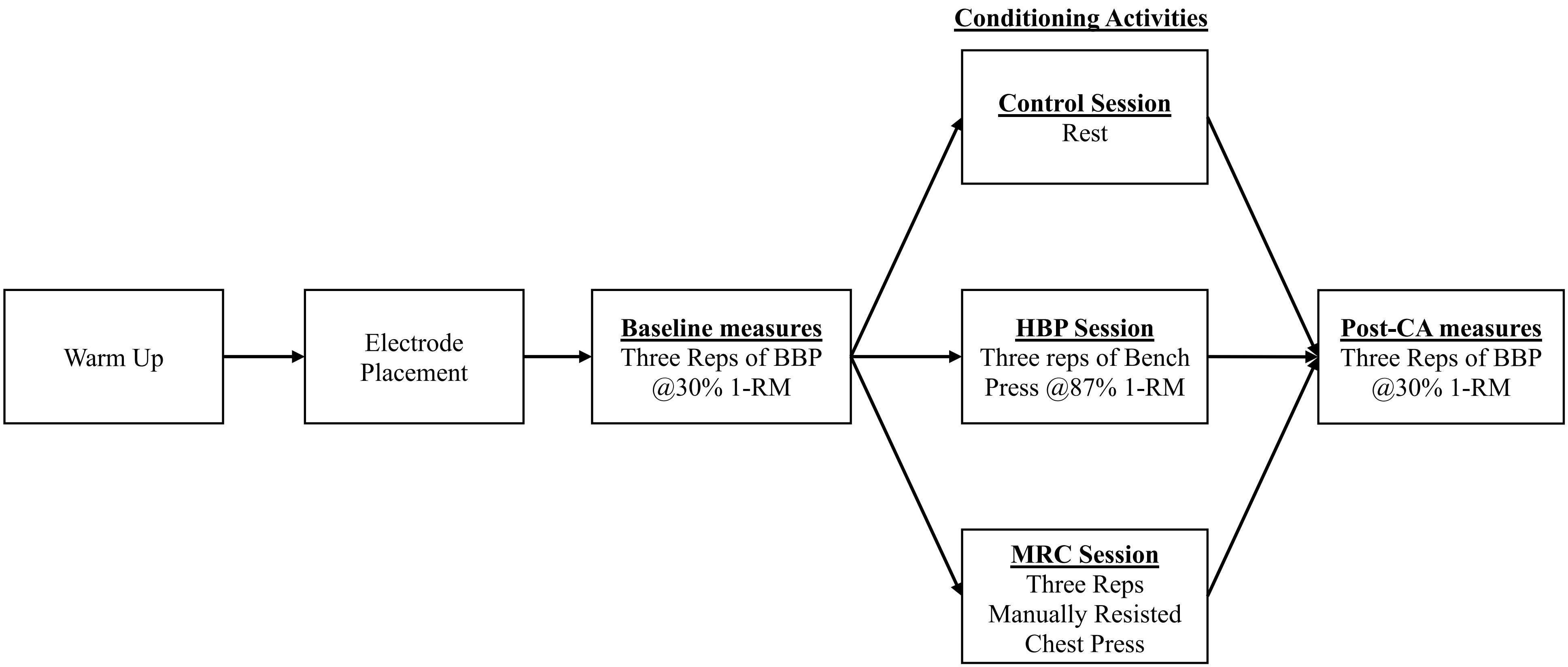

Figure 3.2. Demonstrates the procedures used during the Control, HBP, and MRC sessions. Each session was conducted on different days and done in a randomized order.

ELECTROMYOGRAPHY

Prior to EMG electrode placement, the subject's skin was prepped by shaving the skin with a disposable razor, softly abrading the skin, and cleaning the skin with an alcohol pad. During the BBP, Noraxon Dual EMG electrodes (EMG; 3000 Hz, Noraxon, USA) were placed on the Pectoralis Major at 30% of the distance between the acromion angle and the xiphoid process of the sternum (Barbero, Merletti, & Rainoldi, 2012) and on the long head of the Triceps Brachii using SENIAM guidelines, which recommend placement at 50% on the line between the posterior crista of the acromion and the olecranon with two finger widths medial to the line (Hermens et al., 1999). Electromyography data taken from the onset of the movement until the cessation of each repetition from both the pectoralis major and triceps brachii was transferred to MATLAB and filtered using a bandpass (10Hz low and 500 Hz high), then expressed as a Root Mean Square (Schick et al., 2010).

PEAK FORCE AND RATE OF FORCE DEVELOPMENT

Force data collected from two AMTI force plates during the BBP was exported to Excel (Microsoft Excel v. 2016, Microsoft, Redmond, WA, USA) where the resultant force from the y and z axis was calculated using Pythagorean theorem from the combined force data. It was then exported to MATLAB (MATLAB v. R2019a, MathWorks, Natick, MA, USA) and filtered using a fourth order low pass Butterworth Filter with a cutoff frequency of 50 Hz. The force data was used to determine Rate of Force Development and Peak Force (Wang et al., 2017). Peak force was defined as the greatest force achieved during the ballistic bench press. Rate of Force Development (RFD) was calculated from the start of the movement to the point of peak force by dividing the change in force by the change in time $RFD = \frac{\Delta Force}{\Delta Time}$ (Wang et al., 2017). Once determined, Peak force and RFD were normalized to the system (sum of the weight of the individual and the weight of the platform) and the average of the three repetitions were used for analysis.

PEAK POWER OUTPUT

Power Output was measured using a Speed4Lifts Linear Transducer. As previously mentioned, this transducer consists of a small Velcro strap attached to a wire connected to a box, which is used to measure bar displacement, velocity, and calculate power and then transferred the data to a connected device. The Speed4Lift is an iso-inertial dynamometer that consists of a cable-extension linear position transducer that attaches to a barbell and for this study the strap was placed on the right side of the barbell. The Speed4Lift works by measuring the differentiation of the displacement data over time at a sampling rate of 100Hz (Pérez-Castilla et al., 2019). This transducer uses the mass of the barbell, displacement, and time to determine power output. The peak power output data is transferred to the Speed4Lift application via WIFI connection. Peak power output was measured for each repetition of the BBP and the average of the three repetitions was used for analysis.

DATA ANALYSIS

The average peak force, peak power, rate of force development, and EMG activation of the pectoralis major and triceps brachii between the three repetitions of the BBP was used for analysis. This was done for both the baseline and post CA measurements. Data was analyzed on SPSS 26 IBM (IBM Corp. Released 2018. Version 26.0 Armonk, NY: IBM Corp). There were separate 3x2 (visit: Control, HBP, MRC x time: baseline, post-CA) Repeated Measures ANOVA conducted to determine if there are differences in peak power, rate of force development, peak force, and muscle activation of the pectoralis major and triceps brachii. Due to the small sample size of two subjects, Mauchly’s test were not able to be conducted to determine if sphericity was violated, therefore to be conservative, it was assumed that sphericity was violated and Greenhouse Geiser values were used to determine significance (Field, 2013). A significance alpha level of 0.05 was used for all statistical analysis.

Chapter 4: Results

This study initially recruited eight subjects, however due to the COVID-19 pandemic only two subjects were able to complete this study prior to the postponement of data collection and were used for analysis.

Manual Resistance Chest Press Force

During the manually resisted chest press, from both the maximal effort manual resistance chest press session (MVC measures) and the MRC session force was measured utilizing a Chronojump force sensor. On average during the MVC measures, subjects had a peak force output of 820.38 ± 271.31 Newtons during the manually resisted chest press, whereas during the MRC session subjects had a peak force output of 854.19 ± 332.14 Newtons. This indicates that during the MRC session, subjects had a peak force output of 103.06 ± 6.40% of their MVC.

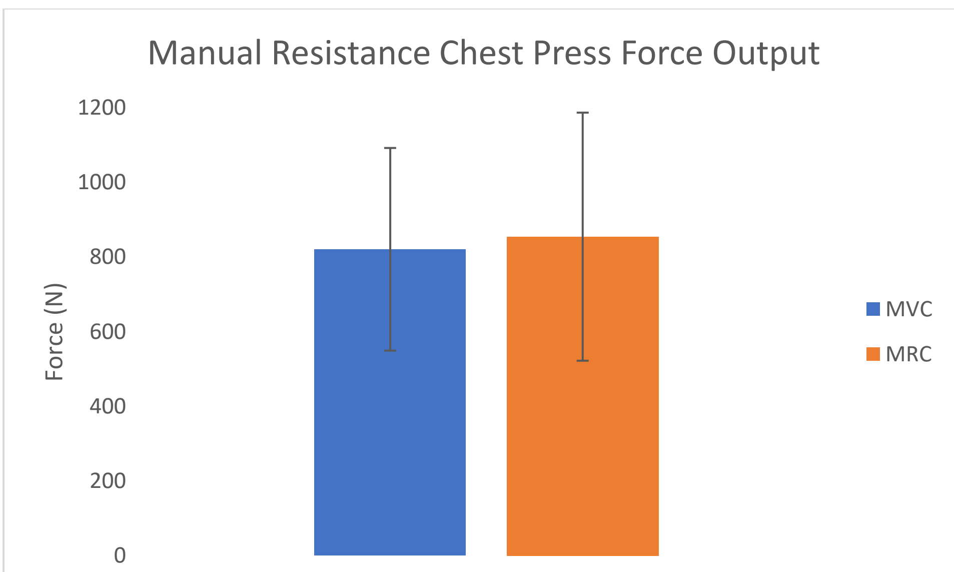

Figure 4.1 Demonstrates the force used during the manual resistance chest press from both the maximal voluntary contraction (MVC) measures and manual resistance chest press session (MRC) measures. On average during the MRC session subjects used up to 103.06 ± 6.40% of their MVC.

Peak Power

Due to there only being two subjects in the analysis, Mauchly's test of sphericity was not able to be conducted. Therefore, it was assumed that sphericity was violated and Greenhouse-Geisser p-values were used to determine significance. Two-way repeated measures ANOVA for power, measured from the Speed4Lifts transducer, determined that there was no interaction between the condition and time ($p=0.080$; $\eta_p^2=0.984$) nor was there a main effect for condition ($p=0.791$; $\eta_p^2=0.104$) or time ($p=0.769$; $\eta_p^2=0.126$).

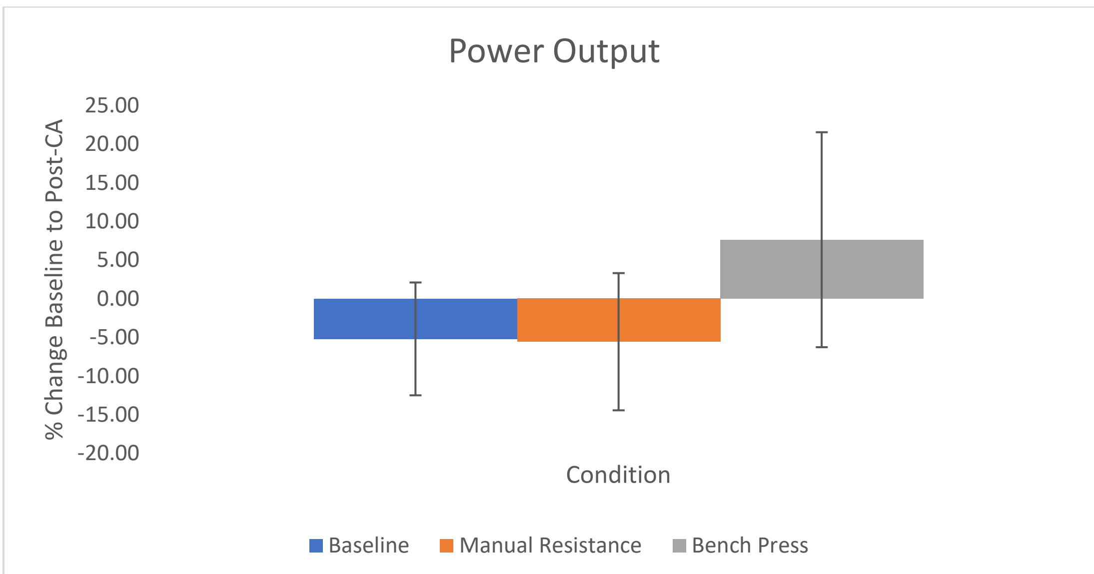

Figure 4.2 Illustrates the changes in power output from baseline to post-CA measurements. There were no significant differences in power output levels between the three conditions nor between the baseline and post-CA measurements.

Peak Force

Two-way repeated measures ANOVA for peak force determined that there was no interaction between the condition and time ($p=0.558$; $\eta_p^2=0.409$) nor was there a main effect for condition ($p=0.106$; $\eta_p^2=0.973$) or time ($p=0.850$; $\eta_p^2=0.054$).

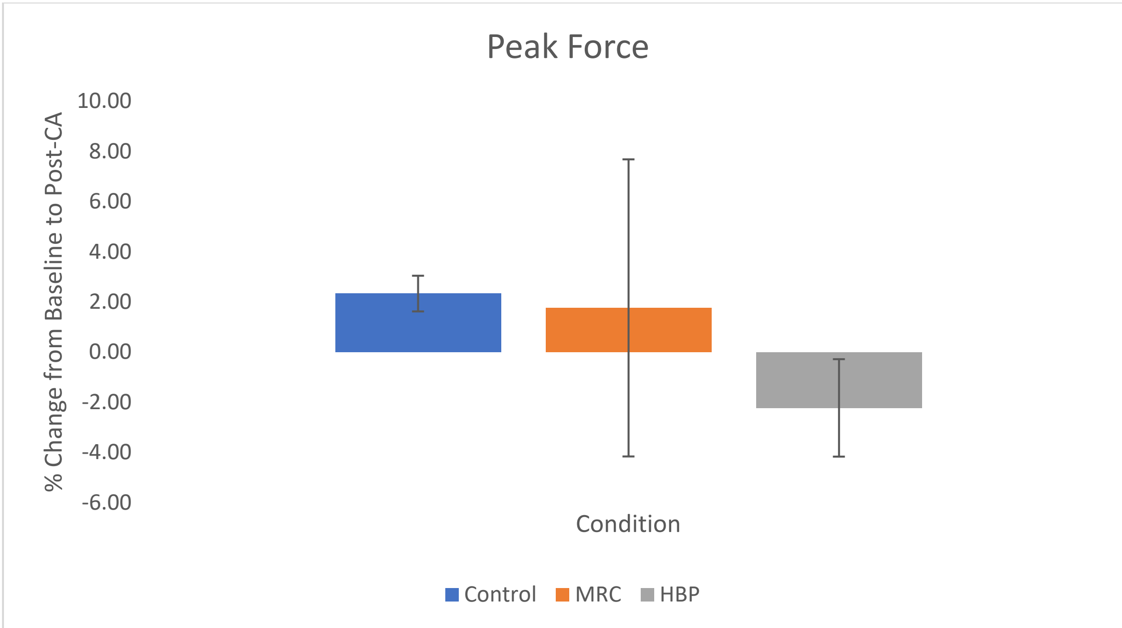

Figure 4.3 Demonstrates the percent change in peak force levels. There were no significant differences in force output between the three conditions nor was there a difference between baseline and post-CA measurements.

Rate of Force Development

Two-way repeated measures ANOVA for rate of force development determined that there was no interaction between the condition and time ($p=0.676$; $\eta_p^2=0.237$) nor was there a main effect for condition ($p=0.430$; $\eta_p^2=0.609$) or time ($p=0.652$; $\eta_p^2=0.271$).

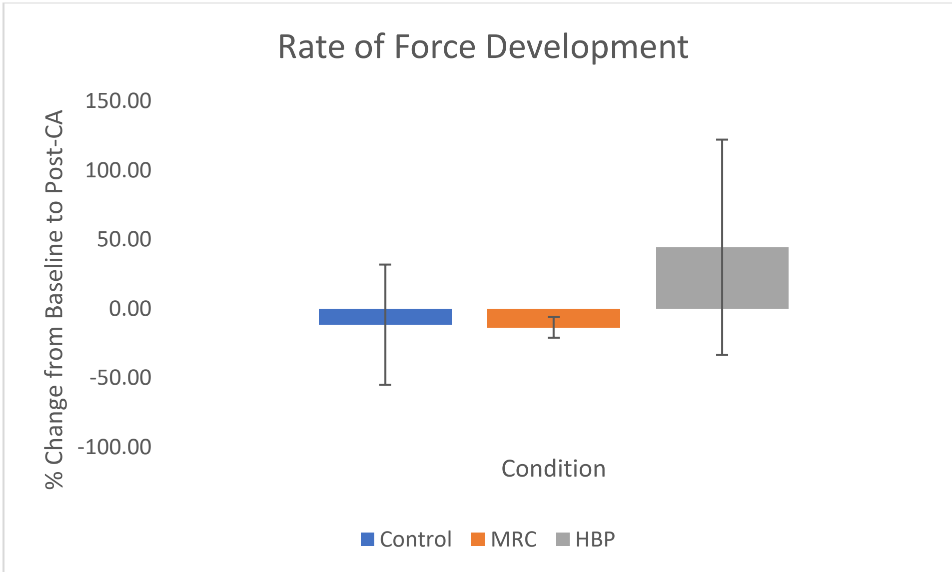

Figure 4.4 Demonstrates the percent change in rate of force development. There were no significant differences in force output between the three conditions nor was there a difference between baseline and post-CA measurements.

Muscle Activation

Two-way repeated measures ANOVA for activation of the pectoralis major determined that there was no interaction between the condition and time ($p=0.676$; $\eta_p^2=0.237$) nor was there a main effect for condition ($p=0.430$; $\eta_p^2=0.609$) or time ($p=0.652$; $\eta_p^2=0.271$).

For the triceps brachii two-way repeated measures ANOVA determined that there was no interaction between the condition and time ($p=0.584$; $\eta_p^2=0.370$) nor was there a main effect for condition ($p=0.512$; $\eta_p^2=0.481$) or time ($p=0.260$; $\eta_p^2=0.842$).

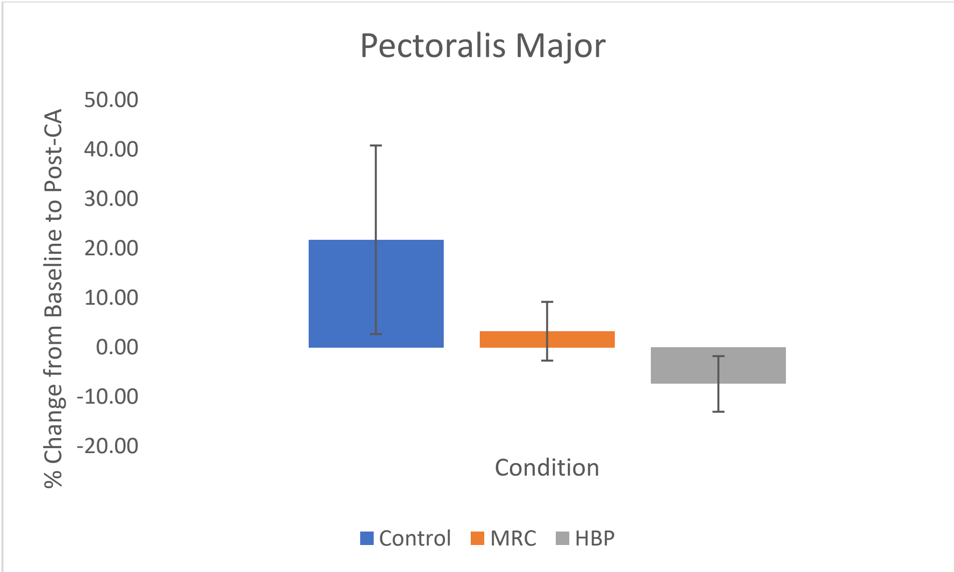

Figure 4.5 Demonstrates the percent change in pectoralis major activation. There were no significant differences in pectoralis activation between the three conditions nor was there a difference between baseline and post-CA measurements.

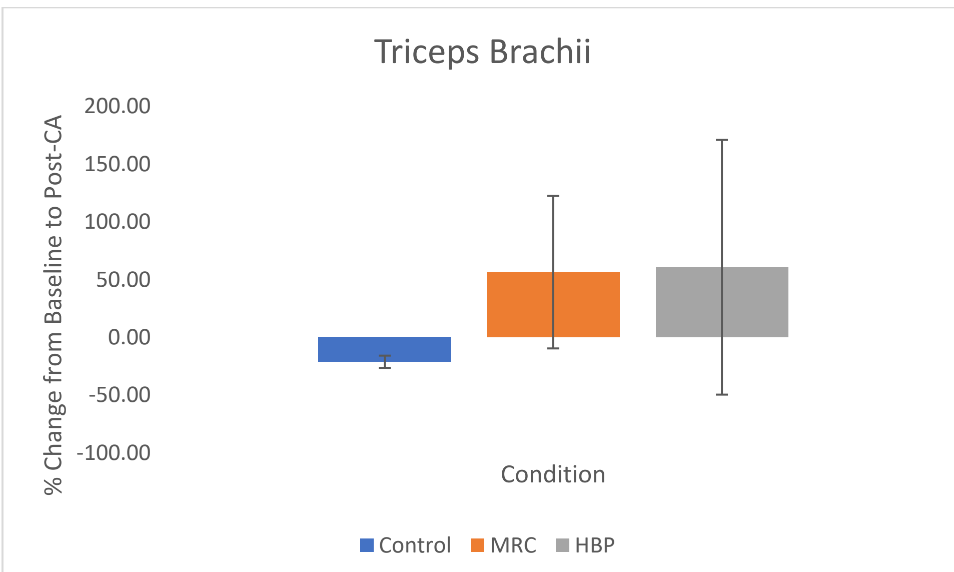

Figure 4.6 Demonstrates the percent change in triceps brachii activation. There were no significant differences in triceps brachii activation between the three conditions nor was there a difference between baseline and post-CA measurements.

Chapter 5 Discussion

The purpose of this study was to examine how a set of manually resisted chest presses had on a subsequent set of BBP. It was hypothesized that the use of MR would be able to improve performance in the BBP and that improvement would be similar to improvements caused by HBP. The current findings of this study were that the use of MR did not have any significant effects on BBP performance. However, the MR on average resulted in a non-significant decrease in power output, a small increase in peak force, a decrease in rate of force development, and increased activation of the pectoralis major and triceps brachii.

Power Output

While it has been shown that the use of a HBP can lead to improvements in power output during the BBP (Bevan, Owen, Cunningham, Kingsley, & Kilduff, 2009; de Assis Ferreira, Panissa, Miarka, & Franchini, 2012; Farup & Sørensen, 2010; Ulrich & Parstorfer, 2017; West et al., 2013) and that the addition of accommodating resistance methods with the bench press can result in increased power output (Baker, 2009), there have not been studies to the authors knowledge, examining the use of soley accommodating resistance to improve BBP performance. Currently the findings of this study have not found that the use of accommodating resistance leads to improvement in power output. This can be caused by various factors such as the fatiguing level of the MR exercise. While meta-analysis have concluded that high intensity conditioning activities at ≥85% 1-RM are required for improvements in subsequent movements (Beato et al., 2019; Esformes et al., 2010; Seitz & Haff, 2016) the current force measurements found that the subjects used over 100% of the MVC force during the manually resisted chest presses from the MRC session. Given the accommodating nature of MR the spotter adjusts the intensity throughout the full range of motion so that the individual performing the manually resisted chest press requires maximal effort throughout the entire range of motion leading to the possibility that the MR was overly fatiguing for the subjects which did allow for the improvement in performance. Future studies are needed to determine how to quantify the intensity of MR exercises as well as to determine how they compare to traditional resistance exercises.

PEAK FORCE AND RATE OF FORCE DEVELOPMENT

The current findings with these two subjects were that there were no differences in either peak force or in RFD for any of the conditions and there were no differences from the baseline to post-CA measurements. The lack of change in peak force measures has been reported before with a review from 2009 stating that while few studies have found improvements in maximal force, the improvements in power output can result from an increase in RFD (Tillin & Bishop, 2009). While on average the use of MR resulted in a decrease in RFD and power output, this may explain the slight non-significant improvement in power output from the HBP session. Another possible reason for the lack of findings in force and RFD could be the use of the force platform in this study. There is a possibility that the platform used in this study may have caused some of the force to dissipate resulting in the potential for inaccurate results.

MUSCLE ACTIVATION

Currently there were no observed differences in the activation of the pectoralis major and triceps brachii from the baseline to post-CA measurements. There was also no difference in the activation of either muscle between the three conditions. It is worth noting that both the MR and HBP resulted in increased activation of the triceps brachii. While it is not significant it is consistent with other thesis studies which found that heavy resistance exercises can lead to PAP effects and increases in triceps brachii activity (Gill, 2011; Jones, 2011). While there could be numerous explanations for this increased activation of the pectoralis major, such as PAP, muscle wisdom, onion skin scheme, and after-hyperpolarization, the exact reason for this increase is unknown. Since studies that examine these various theories often utilize methods such as isometric or electrically induced contractions to determine which theory may explain changes in performance, the findings of the current study cannot determine which of these theories may explain the increased activation.

LIMITATIONS

This study is not without its limitations. One of which being the sample size. Due to the COVID-19 pandemic data collection for this study had to be stopped, and therefore this study was only able to get complete data sets for two subjects. Further recruitment of subjects may show findings that differ than the ones currently found with two subjects. Another possible limitation is the use of MR. MR is a form of accommodating resistance which results in changing intensity throughout the movement range of motion which may have resulted in an overly fatiguing CA. Another concern with this study is that while the HBP utilized 87% of the subject's 1-RM, the MRC session resulted in subjects using over 100% of their MVC. Given that MR is accommodating in nature it is difficult to ensure that 87% of the MVC was achieved and future studies should seek to determine how to maintain a specific intensity during MR exercises.

CONCLUSION

The current findings of this study were that the use of MR did not improve performance on the BBP. This is the first study that the author is aware of that examined the acute effects of utilizing the manual resistance modality. Further research is needed with larger sample sizes and possibly different exercise movements to determine if MR can lead to improvements in subsequent movements.

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Appendix

Institutional Review Board

Office of the Vice President for Research and Sponsored Projects
The University of Texas at El Paso IRB
FWA No: 00001224
El Paso, Texas 79968-0587
P: 915-747-7693 E: irb.orsp@utep.edu

Date:	November 7, 2019
To:	Matthew Gonzalez
From:	University of Texas at El Paso IRB
Study Title:	[1509028-1] The Effects of Manual Resistance on Upper and Lower Body Post Activation Potentiation
IRB Reference #:	College of Health Sciences- Kinesiology
Submission Type:	New Project
Action:	APPROVED
Review Type:	Expedited Review
Approval Date:	November 7, 2019
Expiration Date:	November 6, 2021

The University of Texas at El Paso IRB has approved your submission. This approval is based on the appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This study has received Expedited Review based on the applicable federal regulation.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure. The renewal request application must be submitted, reviewed and approved, before the expiration date.

This approval does not replace any departmental or other approvals that may be required. Other institutional clearances and approvals may be required. Accordingly, the project should not begin until all required approvals have been obtained.

Please note that you must conduct your study exactly as it was approved by the IRB. Any revision to previously approved materials must be approved by this office prior to initiation, except when necessary to eliminate apparent immediate hazards to the subject.

All serious and unexpected adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all Non-Compliance issues or Complaints regarding this study to this office.

Remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Upon completion of the research study, a Closure Report must be submitted the IRB office.

You should retain a copy of this letter and any associated approved study documents for your records.

All research records must be retained for a minimum of three years after termination of the project. The IRB may review or audit your project at random or for cause. In accordance with federal regulation (45CFR46.113), the board may suspend or terminate your project if your project has not been conducted as approved or if other difficulties are detected.

If you have any questions, please contact the IRB Office at irb.orsp@utep.edu or Christina Ramirez at (915) 747-7693 or by email at cramirez22@utep.edu. Please include your study title and reference number in all correspondence with this office.

Sincerely,

Dr. Lorraine Torres, Ed.D, MT(ASCP)
IRB Chair

Vita

Matthew Paul Gonzalez was born in Dallas, Texas at then moved to El Paso, Texas as a child. He was the 2nd of 4 children of Joe and Yolanda Gonzalez. He graduated from Santa Teresa High School in 2014 and then begin his undergraduate studies at the University of Texas at El Paso.

During his undergraduate studies, Matthew underwent the Fast-Track program taking undergraduate and graduate courses simultaneously. Matthew also worked as a personal trainer during his undergraduate studies, competed in the 2018 Texas American College of Sports Medicine Student Bowl competition, and began assisting in research at the start of his junior year. His assistance in research allowed him to ability to attend different regional and national conferences.

Matthew earned his Kinesiology Bachelor's Degree in August of 2018 and began his graduate studies that same month. He also began working as a teaching assistant, teaching biomechanics and exercise physiology labs. During his graduate work, Matthew assisted with and presented research at conferences including the Texas Chapter of the American College of Sports Medicine conference and the National Strength and Conditioning Association National Conference. During his graduate course work he became a Certified Strength and Conditioning Coach and was also awarded the Dodson Research Grant which helped fund his thesis study. Following the achievement of his Master's degree, Matthew will enter the doctoral program and work as a graduate research assistant at the University of Texas at El Paso with the goal of beginning a career in research.