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The Effects of Resistance Deception on Muscular Strength, Muscular Endurance, and Perceived Exertion

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ABSTRACT

Resistance deception during training is a lightly researched topic and is seen as a modification that can potentially act on central control during exercise. Studies that have observed effects of deception while training have yielded mixed results. The effects of deception on strength, muscular endurance, and perceived exertion and the mechanisms of action that may elicit changes are still unclear. Therefore, the purpose of this study is to determine the effects of resistance deception on muscular strength, muscular endurance, and perceived exertion in a trained population. Eight participants finished the study and underwent four trials, one of which was a baseline trial, that consisted of one-rep max and repetitions to failure testing, with 60% of one-rep max, on bench press. Ensuing three experimental trials consisted of the bench press tests but in deceived/masked conditions. One trial was a 5% increase in weight, one trial was a 5% decrease in weight, and the third trial consisted of a weight that was equivalent to that of baseline. Repetitions, bar speed, and perceived exertion were monitored during each trial. During the deceived equivalent weight trial, participants significantly increased the number of repetitions and mean bar speed during the repetitions to failure test and experienced significantly decreased perceived exertion during the one-rep max lift. These findings indicate deception during training can acutely enhance performance outcomes.

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INTRODUCTION

Resistance training is a preferred mode of training for many individuals. People who undertake resistance training methods seek to improve muscular function by inducing hypertrophy, hyperplasia, or increased motor neuron activity. Each proposed adaptation to resistance training may be able to enhance muscular strength, endurance, and power (8). These are important components to consider when implementing resistance training programs aimed at improving performance or focus on a certain physiological adaptation to exercise. Individuals perform high-load, low-repetition exercises to increase muscular strength, which in turn would enhance neuromuscular function and Type II muscle fiber contractions. Muscular endurance training may be performed with a lower load and high-repetition fashion to induce repetitive force generation in a given training scenario. Various mechanisms could affect how an individual goes about performing these modalities of training. Athletes and strength coaches alike may stress the importance of certain repetition, set, and load schemes in order to isolate a certain physiological adaptation that is pertinent to a given sport or scenario. Coaches may also recommend certain nutritional behaviors that, along with the resistance training program, may enhance performance. However, one under-looked method that has been used in strength training is load deception (33).

Weight deception in resistance training programs may be used by strength coaches in order for athletes to overcome or prevent the formation of pre-conceived notions about resistance load and intensities. If athletes do not have knowledge about resistance load or intensity, then performance could potentially be affected. Weight deception research in resistance training is sparse; however, Ness et al. (35) investigated the effects of deceptively altering weight in maximal inclined bench press assessments. The researchers conducted multiple conditions with altered weights that were either more than what the participants believed in one condition and less than what the participants believed in another condition. Results showed significant effects when the resistance load was greater than what was believed by the participants, who lifted an average of 20 pounds more than what they perceived to be their one-rep max (1RM). Motoyama et al. (33) deceptively altered resistance in an elbow flexion exercise as participants performed repetitions to failure in three different testing conditions: 70%, 80%, and 90% of a previously acquired 1RM. Each side of the bar was masked with cardboard protection around the plates loaded to ensure the participants could not see the resistance. During each condition, participants were assured the resistance equated to their 80% 1RM. Additionally, a scale of fatigue (the OMNI-RES) was administered immediately after the completion of the last repetition during each condition to assess if exertion was affected under altered and masked weighted conditions. No significant results were found in number of repetitions completed.

Perception of fatigue can be considered an important component when conducting deception resistance training exercises. Noakes (36) outlines how pacing strategy during exercise can be affected by perception of fatigue and proposes the central governor theory that may serve as a physiological safety net for the body during exercise or calamitous events. Noakes (36) proposes deception is a modification in exercise and may augment to an existence of a central governor. Therefore, it is important to consider rating of fatigue/exertion scales while implementing deceptive training strategies to observe any correlation that may exist. The rating of fatigue (ROF) scale proposed by Micklewright et al. (30) was developed to monitor level of fatigue in individuals performing cycling exercise; however, this scale has never been used in resistance training. This scale is a good tool to use for further validation in its implementation in resistance training. This, along with the OMNI-RES, may be able to correspondingly show levels of fatigue after performance of a resistance training bout.

Perception of fatigue was recorded in Motoyama et al. (33); however, physiological responses were not assessed while participants were tested under deceived and weight-masked conditions. In fact, research regarding the responses of physiological mechanisms during deceptive resistance training studies is lacking. Research on how the agonistic muscles during a certain exercise act in a deceived and masked state is warranted. Bar speed during a barbell lift could provide information regarding how agonistic muscles react to resistance that may not be what is believed by the person performing the exercise. Implementing this measurement may be able to tell researchers how power output may be affected. There has been limited research on the impact of deceptive weight strategies on muscular strength and muscular endurance exercise. Deception of weight could affect the performance outcomes on bench press assessment with the resistance set at equal to exact 1RM and just under and just over that number. Participants may respond differently physiologically and psychologically if resistance is set at near maximal loads under masked and altered conditions, which was shown by Ness et al. (35). However, more research is warranted. Muscular endurance reps to fatigue in the bench press has also not been looked at before.

REVIEW OF LITERATURE

Muscular Strength

Muscular strength can be impacted by numerous variables. Muscular strength is defined as the ability to generate maximal force under a restricted duration (11). Phosphocreatine provides most of the energy needed during shorter duration high-intensity exercise which includes the requirements for the muscle contractions that are performed in tests of muscular strength and power training. Both physiological and psychological adaptations can occur in response to strength training. An abundance of research is available detailing the strength training-induced alterations in the neuromuscular system and the muscular system itself. In addition, psychological practices have shown to impact the strength-related alterations observed in maximal strength performance tests.

Muscle physiology is a major factor in strength training. The muscular, nervous, and skeletal muscle systems are responsible for all movements performed by the human body (22). Muscles will adapt as a result of strength training and other activities. It is imperative to maximize these adaptations for certain populations/athletes. Muscular strength training causes physiological alterations in muscle over time.

Typically, when a muscle begins to show signs of increased strength with no obvious signs of hypertrophy, neuromuscular adaptations are at play (14). It is believed that enhancement of neural pathways results in an increase in the strength of skeletal muscle during the first six to eight weeks of training prior to changes in muscle is considered to be due primarily to improvement in neural input (24). The motor unit is a very important unit in the neuromuscular system. A motor neuron stems from the spinal cord and this nerve, in addition to every muscle fiber that it innervates, is considered to be an α-motor neuron (41). Muscle innervation would have to be enhanced during and after strength training in order to sustain higher amounts of contractions that generate more force. Studies investigating single motor neuron adaptations have demonstrated how neurophysiological changes are induced by strength training. Single motor neuron studies are important because every action potential created in the singular motor neuron causes an action potential in every muscle fiber that is innervated by other parent motor neurons (7). Multiple studies have displayed strength gains in association with increases in motor unit discharge rates. Häkkinen et al. (17) observed the effects of a 21-week strength training program on the electromyographical (EMG) activity of the leg extensor muscles. Thirty-two healthy male participants performed resistance training protocols two times a week. A 26% increase ($p=.05$) in EMG activity of the vastus lateralis was found at the conclusion of the 21-week strength-training program. The apparent increase in EMG activity could have been due to an increase in motor units recruited or an increase in the rate of motor unit firing frequency (17). An increase in the activation of Type II α motor neurons could also provide a possible explanation for this observation. An increase in firing frequency would account for the increasing loads on leg musculature in order to produce more force. An increase in firing frequency and action potentials, which is known as rate coding, will reach a larger cross-sectional area of muscle to produce a contraction.

Moreover, Enoka (11) synthesized a review of literature outlining the importance of neural activity and its development upon strength training. This review showed that, in trained and untrained individuals, muscle size may not initially induce strength adaptations, it is more so the higher number of motor units especially for untrained individuals. Therefore, it is essential to note the importance of increasing firing rates and increased activity of neuromuscular units.

Strength training not only induces neural adaptations but can also enhance the phenotypical profile by enhancing skeletal muscle size in individuals. Cross-sectional area (CSA) and volume of muscle can increase in response to strength training regimens. When more force production, due to an enhancement of neural activity, occurs there needs to be an expanded musculature and an increase in contractile properties. In other words, more skeletal muscle contractile proteins need to be present in order to accommodate the increase in force production. Wallerstein et al. (46) compared the effects of strength and power training on neuromuscular function and muscle cross-sectional area in older adults. Older participants, who were sedentary to lightly active, were split into two groups: a power training group and a strength training group. Strength-training group participants performed various lower and upper-body exercises at 70-90% one-rep max (1RM), and the power training group performed the same exercises at 20-30% 1RM at a higher movement velocity. The exercise protocol was performed two times per week for 16 weeks. EMG and electrical mechanical delay of the knee extensor muscles were measured, and CSA was obtained via magnetic resonance imaging (MRI). Cross-sectional area of both groups (6.5% for strength training and 3.4% for power training) increased significantly (46). A possible explanation of the increased CSA could be the upregulation of the gene expression of proteins in the protein kinase B (Akt) and mammalian target of rapamycin (mTOR) pathway, which has been studied to regulate fiber size and the responsiveness of hyperplasia in muscle (3). Cross-sectional area also improved in response to eccentric and concentric training in a study performed by Higbie et al. (20). After 10 weeks of unilateral concentric or eccentric training of the leg extensors, participants (college-aged women) experienced a marked increase in quadricep CSA in the eccentric-training group (6.0-7.8%) and the concentric training group (3.5-8.6%) as measured by MRI. Additionally, changes in average torque were apparent with the concentric group providing the most improved increase (18.4%). Similar results were seen in a study that assessed a six-month lower-body strength-training program (34). Seven healthy male participants performed six sets of eight unilateral leg extension reps at 80% of their 1RM every other day for six months. After the training protocol, participants experienced an 18.8 ± 7.2% increase of CSA in the distal portion of the quadriceps and a 19.3 ± 6.7% increase of CSA in the proximal portion of the quadriceps. Hypertrophy of certain portions of the quadriceps were apparent in response to leg extensor strength training, which was measured by MRI.

Type of muscle fiber composition may also affect muscular strength. Type II (fast-twitch) muscle fibers are thought to generate more force through an increased and quicker output of neuronal activity compared to Type I. Power and strength athletes are believed to have a higher composition of Type II muscle fibers than Type I compared to endurance athletes, who generally have a higher content of Type I muscle fibers. Type I can sustain longer durations of contractions and slower contractions and are more reliant on energy produced from oxidative phosphorylation. Due to the slower contractile speed of these muscle fibers, the motor units associated with these are called slow-twitch (41). Type II fibers are the opposite and will undergo fast and powerful contractions and receive neural input very quickly in order to contract; therefore, these fibers are called fast-twitch fibers. Color differences between the two types are apparent also. Type I display a redness due to a higher content of myoglobin (oxygen-carrying protein in muscle) and capillary density (41). Therefore, Type II fibers have lower myoglobin content and capillary density as compared to Type I fibers and have a lighter coloration. Additionally, Type II muscle fibers can be divided into two types as well: Type IIa and Type IIb. Respectively, these are called fast-twitch oxidative and fast-twitch glycolytic (41). To differentiate among the types, muscle fibers with more Type I characteristics rely on oxidative means for contraction and muscles on the Type II end (especially Type IIb) rely on anaerobic means for contraction. Research exists discussing the relationship between certain fiber types in individuals and strength training. Fry et al. (13) examined the types of muscle fiber characteristics and performance determinants in Olympic-style weightlifting males. Elite Olympic weightlifters and non-weight trained men participated for the study. Muscle biopsies from the vastus lateralis were obtained from both parties to compare the types of muscle fiber. After analysis, the weightlifters exhibited a significantly greater percentage of Type IIa (46.5 ± 2.7, 26.9 ± 3.7%) and significantly lower percentages of Type IIb compared to the control non-weightlifters (2.4 ± 2.0, 21.0 ± 5.3% respectively) (13). Interestingly, weightlifters also displayed a higher percentage of Type I fibers compared to control. Weightlifters also exhibited increased CSA in Type IIa fibers compared to control.

Strength training can also be impacted by the length of training or experience of training by the genetic attributes of individuals performing such regimens. Individuals who have been performing strength training over a chronic time period will have a more adapted muscular system compared to individuals who are beginners or who have been strength training for a short amount of time. Athletes or individuals who have practiced strength-training chronically may not respond to the same degree to newer modes of training compared to individuals who are new to the programs. The aforementioned study assessed both experienced Olympic weightlifters and non-experienced weightlifters (13). The differences in muscle fiber composition could be partly explained by the differences in training experience. Ahtiainen, et al. (1) experimented the effects of a 21-week strength training program on muscle hypertrophy, hormonal adaptations, and strength development in experienced strength-trained men (age 30.0 ± 6.5 years, height 177.2 ± 6.3 cm, weight 91.7 ± 10.0 kg, body fat 17.3 ± 3.6%) vs physically active, non-strength trained men (age 34.4 ± 4.4 years, height 177.1 ± 3.8 cm, weight 85.7 ± 16.4 kg, body fat 19.1 ± 4.3%). The weightlifting group consisted of bodybuilders and powerlifters who had several years of resistance training prior to the study. The training for the non-trained group occurred twice a week, and the strength-trained group continued with routine training. Strength-trained participants trained three days per week. Total testosterone, free testosterone, cortisol, CSA, and muscle strength were all assessed at baseline and post-study. During the 21-week intervention, the non-strength trained group experienced more of an increase in bilateral isometric leg extension force compared to the strength-trained group (22% and 10% respectively).Bilateral and unilateral isometric force exerted by the strength trained group was significantly larger than the non-strength trained group. Larger CSA values were seen in the strength-trained group compared to the non-strength trained group at baseline. Non-strength trained individuals also experienced increases in CSA in the legs while the strength-trained group did not. Individuals with more training experience showed significantly greater strength and muscle size numbers at the start of the study; however, the non-strength trained group experienced greater increases in these values over the period of the intervention. Neural input of the non-strength trained group could be a potential target in explicating these findings. Also, these individuals were higher responders to the regimen because their muscular systems were not as acclimated to the stimuli brought upon by the resistance training.

Moreover, Hagerman et al. (16) performed a study on a short-term high-intensity strength training program on untrained elderly individuals. This was a 16-week study performed to assess the metabolic and physiologic responses to strength training. Participants were split into a resistance training group and non-training group. The resistance training group performed three sets of six to eight reps on leg extensions, leg press, and half squats twice per week with 48 hours of rest in between sessions. The untrained group did not perform the exercises. At the conclusion of the study, the resistance trained group showed significant increases in 1RM on the leg extension (50.4%), leg press (72.3%), and half squat (83.5%). These significant increases in 1RM on all three lifts show how untrained participants will quickly respond to a strength-training program. The participants quickly adapted to the vigorous stress placed on them through the strength-training program. To further explicate this position, Maughan et al. (29) examined the differences in muscular strength and CSA in trained and untrained individuals. Untrained participants (n = 35) served as the control group and the trained participants (n = 8) served as the experimental group. Trained participants partook in strenuous resistance training exercise for at least two years prior to the study. Isometric force exerted by the legs were measured to assess strength of the participants. The average force exerted by the trained group in the isometric assessment was 250 newtons higher compared to the untrained group. Also, the CSA of the knee extensor muscles was around 23 centimeters thicker in the trained group compared to the untrained group. The trained group's average muscle mass of the leg extensors was substantially larger; therefore, they were able to produce more force in the isometric strength assessment.

Increased neural drive of these individuals would play a major role in these individuals due to the increased generation of force.

In conclusion, it is known that individuals who are experienced and trained show greater outputs of strength and increased muscle size compared to people who have not undergone such regimens (16). However, untrained individuals respond highly to high-intensity strength-training protocols as their neuromuscular system and their musculature will experience adaptations to the higher loads placed on them. New stimuli placed on these individuals will allow their musculature to adapt in quicker fashion in resistance training studies compared to individuals who have training experience

In summary, muscular adaptations to strength training are extensive. Studies like Häkkinen et al. (17) show significant changes to neuromuscular characteristics, muscle size, and muscle fiber composition. The previous studies mentioned show an enhanced firing frequency and a possible increase in the motor units in response to strength training. These induces in neural activity could be the mechanism behind initial strength gains prior to signs of hypertrophy. The CSA of muscle also increases in response to strength training, which was shown in Higbie et al. (20) and Nairici et al. (34). Muscle size will adapt by growing in order to sustain higher loads and higher output from motor units in order to produce force. Muscle fiber type also plays a role in strength training. Studies have shown a possible shift in muscle fiber type (11).

Psychological Factors to Muscular Strength

Perception of a strength-training task may affect strength performance and absolute force generation. Anything from confidence in a certain movement or perception of the force required, may be found to provide beneficial or detrimental effects in strength-related exercise and movements. Top-down processing can provide visually symbolic representations to either perform or stray away from a task. Top-down processing is perception that is driven by cognition (45). Motor imagery can become a crucial aspect in strength and conditioning. Motor imagery is defined as an energy-generating depiction of one's self in action in the first-person perspective (21). Being able to use imagery may seem to provide exercise-induced enhancements in performance. Moreover, research over how various psychological factors can affect muscle strength performance exists. Holmes et al. (21) developed a method encompassing different aspects of motor imagery that can be used by sports psychologist to aid in imagery use by athletes to potentially maximize athletic potential. This method incorporates seven steps in motor imagery: physical, environment, task, timing, learning, emotion, and perspective (PETTLEP). All of these states can be manipulated by the user in a fashion laid out by the model in a way that may benefit athletic performance. It is a model that can be utilized by sport psychologists to incorporate mental training in athletes. Holmes et al. (21) discuss the use of motor imagery by athletes and sport psychologists and that these techniques can potentially aid in enhancing performance. This could be compared to watching a demonstration video, watching a video of oneself performing a movement, and is related to kinesthesia. This model is based on the hypothesis of functional equivalence, which supports the idea of imagery improving performance due to the similar neurophysiological processes involved in both imagery and movement (49). Lebon et al. (25) expounded the effects of motor imagery on strength training. The effects of the imagery were assessed on bench and leg press lifts. The sample had two groups: a motor image and a control group. The motor image group performed physical training and motor imaging sessions (imaging themselves performing the movements) while the control group performed the same physical training but performed a neutral task, which was not forming mental images on how to perform the movements. Both groups performed three sessions per week over a four-week period. The motor image group performed the two movements and used motor imagery during the rest intervals. The control group also performed the bench press and leg press but without the use of motor imagery in the rest periods. Maximal force production on leg press and bench press and maximum number of repetitions were recorded and assessed. The motor image group increased significantly on maximal force production on the two movements from baseline on the leg press (25). Mentally imagining how to correctly perform the movements may be a beneficial way to enhance muscular strength. Yao et al. (50) also reported evidence of increased muscular strength, in conjunction with increased brain activity, after performing kinesthetic imagery and training using internal imagery. The goal of this study was to compare first-person and third-person imagery execution in conjunction with a strength-training regimen. First-person imagery allows the individual to visualize in the first-person the actual feeling and visualization of performing the movement being assessed. Third-person imagery allows the individual to view themselves performing the movement in their mind. In this case, the individual would be watching themselves, in their mind, performing the movement. It was assessed how both maneuvers of motor imaging can be used and compared in relation with strength training (50). Participants were separated into three groups for this study. One group performed first-person imagery training sessions while another group was assigned to third-person imagery training sessions. The third group was the control where no imagery action was performed. The two imaging groups performed multiple imaging training sessions involving their respective modes of imaging action. One-arm elbow flexion strength, EMG, and electroencephalography (EEG) measurements were all measured before and after the mental training period. The first-person imaging group was the only group to display significant increases in strength and maximal voluntary contraction-related cortical potential after the training period. Imaging without performing the actual exercise increased strength and brain activity during a single bout of exercise.

It is apparent that strength training can be affected through various psychophysiological processes, which may lead one to believe the importance of external input. Stimuli recorded through the senses may affect the performance of a strength-training program or strength tests; however, this topic of research is lacking. Many studies have been conducted examining how imagery can affect strength performance; however, there is little to no research on the effects of visual input on strength performance. The studies discussed previously in this section of the current review explicate how altering the mind state can yield significant results and changes in strength performance scores. These types of results could be seen in research that examines how strength can be impacted by altering external input.

Muscular Endurance

It is evident how muscular strength can be impacted through adaptations in muscular physiology, training experience, and the psychological factors associated with the mode of training. However, muscular endurance can entail other various neural and muscular adaptations. Muscular endurance is a standard that is used in different methods of assessment. The National Football League assesses potential draftees through different physical athletic assessments with one of them being the bench-press test. Athletes are to perform the bench press with a standardized weight of 102.27 kilograms (kg) loaded on the bar as many repetitions as possible until volitional failure. This assessment gives NFL teams a general indication of muscular performance/endurance of the athletes. Additionally, there are numerous muscular endurance tests utilized in clinical settings. Muscular endurance can also be impacted through adaptations in muscle physiology, training and experience, psychological factors, and the cardiovascular system. Muscular endurance is a different assessment compared to that of muscular strength and power. One's ability to perform muscular endurance related tests can determine the level of intensity that can be sustained until the individual will reach fatigue.

Muscle physiology is a major factor in determining muscular endurance exercise. Physiological characteristics of muscle can be altered through endurance training. The proper repetition and set scheme are imperative to ensure appropriate adaptations in endurance training. These set and rep schemes will cause the muscle to adapt in response to the endurance-type training. Much like strength training, muscular endurance training will provide alterations in neural activity, fiber type characteristics, and size of muscle after training in such a modality. Muscular endurance exercise relies on different metabolic energy pathways compared to strength and/or power training. Tests of muscular endurance involves higher numbers of repetitions as compared to tests of muscular strength. Muscular endurance sets should incorporate repetitions above 12 and could range from 15-50. It is apparent to perceive the differences in the metabolic pathways in muscular endurance compared to strength and/or power training. A single set of muscular endurance may involve repetitive movements that could constitute more than 30 seconds of continuous work, which would make glycolysis a primary contributor for muscular contraction.

The actions of muscular endurance exercise could induce altering effects on the physiological characteristics of the muscle. Taaffe et al. (44) explored the various effects and comparisons of high-intensity (high resistance, low repetition) and low-intensity (lower resistance, higher repetition) exercise on elderly women. The training period for this study was lengthy: one year. Participants used in the study were elderly women, whose body mass index was less than 30, and the variables being examined included

1RM, CSA, and muscle fiber composition. Three groups were created for the study: a control group, a high-intensity group who performed heavy-load exercise, and a low-intensity group who performed lower-load resistance exercise. Exercises performed during the training protocol were leg press, knee extensions, and knee flexions. Three sets of each exercise were performed three days per week of either 40% of 1RM at 14 reps (low-intensity group) or 70% of 1RM at seven reps (high-intensity group). After the one-year intervention, the high-intensity group experienced a higher increase in 1RM in all three lifts; however, the low-intensity group elicited a similar increase in strength in the knee flexion 1RM compared to the high-intensity group. Also, the high and low-intensity groups displayed a significantly increased CSA Type I and II muscle fiber composition compared to the control group (44). Based on these results, the women in these groups experienced increases in hypertrophy even while doing low-resistance, high-repetition exercise. Additionally, the increases in strength, even in the low-intensity group, could possibly be explained through an increased CSA of the muscle (44).

Also, Mitchell et al. (31) assessed the changes in muscle physiological actions in response to light-load exercise. Eighteen healthy, non-resistance trained men (21 ± 0.8 years old, 1.76 ± 0.04 m, 73.3 ± 1.4 kg) served as participants and went through a 10-week, unilateral knee-extension, resistance-training regimen. Each leg of the participants was assigned to a different group for the study: a single set of knee extension until volitional failure at 80% 1RM, three sets of knee extensions until volitional failure at 80% 1RM, and three sets of knee extensions until volitional failure at 30% 1RM. Each participants' legs were assigned to two of three training regimens. Quantification of muscle volume and fiber area were measured to assess the changes in hypertrophy and muscle protein action before and after the training protocols. After training, the three sets of 80% 1RM induced the greatest gain in muscle hypertrophy while the regimen that consisted of three sets of knee extensions at 30% induced the second largest gain (104 and 95 cm3 increase respectively) (31). On the other hand, however, the two 80% regimens produced higher increases in knee extension 1RM compared to the 30% regimen. The main finding from this study is that a lighter-load, higher repetition training regimen can induce significant increases in muscle hypertrophy in untrained men. Additionally, an important concept to consider from this study is that a nutritional plan was implemented to the participants. This plan included adequate amounts of protein intake to compensate for the breakdown of muscle induced by the resistance training. This fact may provide some explanation to the increases in muscle hypertrophy even in the lighter loaded regimen.

Additionally, Jenkins et al. (23) looked at differences in EMG activity in exercise performed at failure at 80% 1RM and 30% 1RM. Resistance-trained men (with six or more hours resistance training per week) and women (with three or more hours of resistance training per week) served as participants and EMG amplitude, EMG mean power frequency, volume, absolute work, and CSA of the quadriceps were assessed before and after the training protocol. Training consisted of two sessions of three sets to failure of unilateral leg extensions at 80% and 30% of a previously attained 1RM.

Electromyographical amplitude was higher in the 80% 1RM compared to the 30% (23). On the other hand, volume, absolute volume, and muscle activation were all 18-202% greater in the 30% group compared to the 80% group. Additionally, EMG mean power frequency in the repetition ranges at the end of each set decreased more significantly in this group compared to the 80% group. A decrease in mean power frequency may have resulted from decreased states of action potential created during the end reps of the lighter load exercise set.

Campos et al. (6) also investigated the effects of different resistance training programs, one being a high-repetition regimen, on the types of muscle fibers. Changes in lower-body muscle fiber composition were assessed before and after an eight-week, high-intensity resistance training program. The groups were a low-rep group, an intermediate-rep group, a high-rep group, and a control non-exercise group. Each exercise group trained two times per week for the first four weeks and three times per week for the last four weeks. The training protocols were equal in volume and consisted of leg press, squat, and knee extensions. Muscle biopsies were obtained to determine the changes in muscle composition. After training, all groups displayed a decrease in Type IIb muscle fibers, with the largest decrease present in the high-repetition group (6). Also, the high-repetition group exhibited non-significant increases in Type I and Type IIa fibers. In addition, myosin heavy-chain isoforms (MHC) Type IIb decreased significantly while MHCIIa increased significantly in the training groups. Myosin heavy chains are the thick filaments in the contractile units of skeletal muscle and can be differentiated by type in the various types of skeletal muscle due to their contractile properties (48).

Results of multiple studies convey how lighter load/higher volume resistance training regimens can induce significant changes in muscle physiology. In some studies, higher volume training with lighter loads and higher repetitions caused more enhanced alterations compared to loads with higher weight. One possible postulation behind these apparent alterations could be training longevity. Individuals or athletes who have participated in a resistance-training regimen that placed emphasis on high volume through low weight, high repetitions may respond differently to ones who are beginners to such training protocols.

Psychological Factors to Muscular Endurance

Like strength training, various psychological influencers and stimulators may affect how one performs, excels, refrains, or utilizes training routines that emphasize muscular endurance. Motor imaging sessions may be good methods to utilize in order to acutely enhance muscular endurance performance. Self-perceiving oneself performing the physical movement prior to enacting multiple muscular contractions under a low load could help to provide psychological ergogenic effects in this type of resistance training. One thing that may affect muscular endurance performance is the visual perception of the amount of weight loaded on a barbell prior to lifting (26). For example, an experienced weightlifter may be able to tell how much weight may be loaded on a barbell just by looking at the weight-loaded bar. However, if this type of perception can be manipulated, weight illusion may occur. This type of perception can be related to the size-weight illusion. Weight illusion can occur when a smaller object and a larger object of equal size are lifted yet the smaller object seems heavier. Buckingham et al. (4) put weight illusion to the test in resistance training, specifically arm curling a dumbbell until volitional failure. Two dumbbells of the same weight (five pounds) but different sizes were used to offer the size-weight illusion. One dumbbell was larger than the other; therefore, it was perceived as being heavier by the participants compared to the smaller dumbbell. Participants performed bicep curls with both dumbbells and number of repetitions, dumbbell heaviness expectancy, average velocity, and peak acceleration of bicep curls were obtained. On the other hand, after participants completed the exercise, they felt as if the smaller dumbbell was heavier. No significant differences were found between participants' number of reps completed until failure with both dumbbells. However, participants did seem to lift the smaller dumbbell with higher velocity and acceleration compared to the larger dumbbell (4). Participants could have lifted this smaller dumbbell quicker because they perceived it to be heavier prior to lifting; therefore, providing more force and exertion to lift it. This type of mechanism may happen in a compound movement setting. If one is not experienced enough, he/she may not be able to tell how much a loaded barbell weighs and may generate a pre-conceived perception about it before lifting.

Another study examined the size-weight illusion effects on the NFL Combine bench-press test and found no significant differences in repetitions completed under loads that were manipulated compared to normal loads (26). Division II football players participated in this study and went through three testing protocols. Two of the three testing protocols consisted of bench press at 102.27 kg.; however, the plate arrangements on the loaded barbell were different for both tests. The third testing protocol was a bench press test with 97.72 kg; however, the weight arrangement on the barbell made it seem like 102.27 kg was loaded on the bar. Therefore, participants perceived the weight to be 102.27 kg. Participants went through all three protocols each week one time per week by performing the bench press movements until volitional failure. Also, participants were divided into quartiles based on 1RM performance with the first quartile representing the strongest athletes and the fourth quartile representing the athletes who had the lowest number on the performance assessment. This was a five-week study and the first week served as a familiarization protocol with the last week serving as 1RM testing. Results indicated more reps were performed on the size-weight illusion 97.72 kg bench press compared to the other two bench press protocols. Also, more reps were completed on the weight-arranged 102.27 kg bench press compared to the actual 102.27 kg bench press in the fourth quartile group (26). The size-weight illusion and weight manipulation did not offer significant effects across the entire cohort. The strength effects of the stronger athletes in the cohort may have played a role in the non-significant increases in repetitions in the weight manipulated bench press.

The size-weight illusion is one psychological influencer studied to affect muscular endurance resistance training. Literature of other psychological factors on muscular endurance performance is sparse; therefore, more literature on the topic is recommended. More research on the size-weight illusion effects on muscular endurance performance, or strength performance, could be emphasized. Incorporating weighs that have been manipulated to actually be heavier may provide significant findings. For example, in the case of Luebbers et al. (26) the weight was manipulated to lighter than the actual 102.27 kg. that is usually performed on the bench press at the NFL Combine. Manipulating the weight in a way so that it would be heavier than the perceived 102.27 may have provided more significant findings. One method could consist of loading the bar with 106.81 kg (which equates to 235 lbs.) with the participants perceiving the weight to be 102.27 kg. This type of weight manipulation may have yielded novel findings.

Perception of Effort

How the brain perceives the environment affects how one performs exercise. Feedback from external stimuli provides the brain information on how to effectively perform actions that are necessary for certain physiological requirements during exercise. Perception of effort can be considered a major component of fatigue. Marcora (28) synthesized data on the effects of afferent feedback from skeletal muscle and other organs on the perception of fatigue. Afferent feedback is a mechanism that picks up information and sends it to the central nervous system (CNS). These afferent feedback mechanisms would include other peripheral organs that are active during aerobic exercise. A popular belief among physiologists is that perceived exertion during physical activity results from the integration of various inputs to the CNS. Marcora (28) presented evidence that fatigue is independent of afferent feedback from skeletal muscle, the heart, and the lungs. A theory exists that may explain how the brain can regulate how the body and its musculature may react to exercise. This is called the central governor model (CGM). It has been hypothesized that physical activity and exercise is controlled by a central governor in the brain that alters skeletal muscle recruitment; henceforth, controlling pacing strategy (38). Pacing strategies are used for any type or duration of activity. The brain has to process information from the surrounding environment in order to dictate how it wants to command the body and determine the pacing strategy (15). This could affect strength performance by altering the amount of force given for a certain task. Muscular endurance performance could be diminished or enhanced by the brain sending information to the agonistic and synergistic muscles raising or diminishing the threshold of fatigue. Power could also be affected through an altered or subconscious state of motor neuron activity for movement velocity and force development. In the terms of power, the brain may use a technique called teleoanticipation, meaning the brain obtains information of where the endpoint to a certain task is and creates an algorithm determining power output over a certain distance (15). Doing this could also determine metabolic rate and demand depending on distance covered and work intensity. The reason for this type of processing is to prevent calamitous events, like sustaining serious injury, from happening while under exercise stressors. This model will act to terminate exercise before any type of catastrophic circumstance that may arise as the onset of fatigue sets in (38). Some physiologists have accepted this model as one that potentially provides physiological safety when performing exercise. This model can be implicated when discussing fatigue. As fatigue sets in, the working skeletal muscle does not get supplied with enough oxygen due to the decreased cardiac output from the heart (37). This CGM could be the driving force behind this adaptation to exercise. MacIntosh et al. (27) also defend the notion of a governor that regulates muscle contraction by reduced muscle contraction-induced ATP hydrolysis through attenuating activation.

Morree et al. (32) examined how the perception of effort may reflect central motor command during exercise. The authors define central motor command as the activity of motor areas of the brain related to voluntary muscular contractions. Perception of effort is possibly generated through a discharge from the central motor command that is processed by sensory areas of the brain (32). In this study, movement-related cortical potential (MRCP) was measured to assess the activity of these sensory areas. Twenty-one recreationally active males (mean age 27 ± 7 years) volunteered for the study, and EMG, EEG, and RPE were measured. One-repetition maximum was assessed in a familiarization trial. Participants were randomly selected to work their right or left arms until fatigue on am isokinetic dynamometer. The participants performed three sets of 10 repetitions of maximal eccentric contraction exercise with maximal voluntary contraction testing after each set for the fatigued arm. The resting arm only performed maximal voluntary contraction tests. After the fatiguing bout, elbow flexion exercises were performed at 20% and 35% of 1RM while EEG and EMG were being measured. Amplitudes for the EEG measurements were calculated for epochs during the elbow flexion exercise: readiness potential, weight raising, weight lowering, and recovery. Results indicated RPE and muscle fatigue increased linearly. The more fatigued a subject's arm was, the higher the RPE during the muscle flexion exercise. The participants perceived a higher exertion in the fatigued arm compared to the non-fatigued arm while lifting the same weight in both arms. Also, MRCP amplitude increased with a simultaneous increase in fatigue during the weight-raising epoch of the exercise. These results indicate a central motor command effect on fatigue during maximal contractions for elbow flexion. Studies observing these effects on strength training and power training may produce similar results. Future research in this field should examine how central motor command may or may not affect strength and power performance characteristics. The findings of previous research show the effects of the brain and brain activity on perception of effort and fatigue. An increased metabolic demand for exercise may likely increase the perception of effort. Various explanations have been offered that overlook or effect fatigue and effort in some way. The CGM is a widely studied phenomenon that is believed to control the activation of muscle and its associated motor neurons. The placement of this model in the human body provides a security blanket as it allows only so much the body can handle before reaching dangerous levels of exercise. A possible peripheral governor was also hypothesized (27). This regulator attenuates muscle activation through a reduction in ATP hydrolysis; therefore, reducing the metabolic demand.

Perception of Strength

Research on how perception and top-down processing can affect performance exists. How an individual perceives a certain task, or movement, can depict the magnitude of efficiency the task is performed. Theories of weight illusions may be present to explain how altered perception can affect efficiency of tasks. For instance, the aforementioned size-weight illusion has been studied to possibly affect performance on muscular endurance exercises in resistance training. A study that examines the effects of this illusion on absolute 1RM performance or a strength training program is warranted. An individual may perform better or worse while experiencing this illusion during a 1RM assessment. A study of this type may show actions undertaken by Golgi tendon organs or muscle spindles. Golgi tendon organs are proprioceptors in muscle that are sensitive to tension applied by muscular contraction and protects the body by inhibiting muscular contraction under a large load inducing fatigue. Muscle spindles act reflexively as muscular contractions to prevent overstretching and muscle damage. Muscle spindles activate motor neurons through this stretch reflex to resist the muscle stretch (39).

Top-down processing is a well-studied psychological mechanism. For example, Ellis and Lederman (10) performed a study on top-down processing in weight perception with golfers. Golfers and non-golfers alike (aged 18-50 years) participated for this study. Half the participants were golfers who had at least four years of playing experience and the other half had no golfing experience. The cohort was shown balls of various weight (they did not know the balls' weight was manipulated before being shown) and asked which balls weighed more or which balls weighed less. Balls used were real golf balls (n = 10), which weighed 45 grams, and practice golf balls (n = 10), which weighed 7 grams. Two balls of each kind were cut open and filled with cotton and lead to weigh different weights (11, 19, 26.5, 36, or 45 grams). The golfers and non-golfers were shown a real and practice golf ball and were asked about their perceptions/expectations on the weight of the balls. Participants were then informed to pick up the balls one at a time and give estimations of its weight. Results showed the golfers in the study, who initially reported the practice balls to weigh less than the actual balls, reported the real balls to weigh less than the practice balls of the same weight (10). Even though the balls weighed the same, the experienced golfers reported the strongest illusions as they estimated the balls' weights. This is not a direct strength study; however, it does show how weight perceptions and possible perceptions of and strength can be altered due to illusions. If under a larger load, this type of effect may display alterations in muscle fiber and motor neuron recruitment to generate force.

In regard to strength training, Buckley and Borg (5) examined the relationship between the numbers selected on a Borg scale and loads relative to 1RM. A younger group and older group of individuals participated in the study. Three exercise protocols were assessed. The younger participants went through two exercise experimental protocols. The first experimental protocol called for the participants to perform two reps of triceps, rest two minutes, two reps of knee extensions, rest two minutes, then back to the triceps extensions. They performed this circuit until a seven on a modified Borg scale

(CR10) was reached. Rating of perceived exertion was asked after every two reps of the exercises. The same group performed the second experimental exercise protocol. Participants were instructed to complete 12 or more reps (until volitional failure) with the same exercises that were used in the first experimental protocol. The loads during both protocols were the same. The older individuals of the cohort went through the third experimental protocol. This group of participants was then split into groups to measure perception of output: RPE group and a CR10 group. Participants performed latissimus-pull down and leg press exercises for 15 reps giving RPE after every odd-numbered repetition. Weight was added incrementally per session in order to find a weight that could only be completed 15 times. It took about four to six training sessions for the participants to progress to a weight they could not complete more than 15 times. The RPE and CR10 numbers given during the final training session were the ones used for data. After training protocols, results showed a linear increase in RPE along with an increase in weight on the triceps and knee extension exercises. Also, there were comparisons between increases in RPE in both exercises among males and females alike (5). Rating of perceived exertion also increased along with a concurrent increase in repetitions completed. These findings suggest an increased subjective feeling of exertion after an increase in weight and/or repetitions during weight training.

Conclusion

Strength training is a large force-generating training modality that is influenced by various factors. This type of training regimen affects the muscle physiological components like neuromuscular adaptations, CSA, and fiber type composition. A majority of the literature suggests strength training increases firing frequency, increases muscle CSA, and may cause a shift from Type I or Type IIb fibers to Type IIa. These types of adaptations were also seen in muscular endurance training characterized by higher volume. Muscle CSA was even seen to increase in older individuals or sedentary individuals who participated in studies investigating low-load, high-repetition exercises. However, the research also shows the increased tolerance for fatigue. Performing exercises that are characterized by higher repetitions and lighter loads increased the threshold for fatigue and was able to allow the participants to keep muscle activated longer. Reports of increases in Type I and Type IIa fibers were made also after completing a muscular endurance training regimen.

Also, the training modes were affected by training and experience. Individuals with training experience are used to exercise movements associated with the mode being assessed. Individuals who regularly perform strength training and power training may yield larger percentages of Type II muscle fibers and more force generation compared to those who are untrained or new to such programs. However, in studies that examine the differences in adaptations between a trained and untrained group, the untrained group experience more rapid and significant gains in strength. These individuals may exhibit a lower tolerance training and their musculoskeletal systems would more rapidly adapt to the loads place on them compared to athletes or individuals who regularly perform exercise.

In addition, psychological factors come into play with these modes of training. It has been seen that mental imaging sessions, even without the actual participation in physical training, can enhance strength performance and training. Size-weight illusion is a phenomenon studied to have potential effects on strength and muscular endurance performance. When a weight becomes manipulated in some fashion, the weight is seen as either heavier or lighter than what it truly is. This illusion effect may affect the muscular system as well by the brain sending information to the working muscle to be more or less activated. Non-significant results have also been found after weight manipulation on a bench press test. Rating of perceived exertion is another psychological factor affecting strength and muscular endurance performance. What was found in the literature suggests an increase in weight and in increase in repetitions will incur an increase in RPE.

Moreover, perceptions of effort and strength apply to the modes of training. The CGM offers explanation behind the phenomenon of fatigue and how the body undergoes this process in order to protect musculature from calamitous events. Studies, reviews, and experiments have shown evidence in support of the existence of such governing command centers in central and peripheral systems. Rating of perceived exertion is a subjective assessment of how hard one is working. This shows how hard the individual thinks one is exerting force and expending energy. An increase in brain activity was seen in more fatigued states during elbow flexion exercises. This increase in brain activity could have been caused by the fatigue the participants were feeling during the exercises.

Many mechanisms are at play when administering or participating in strength or muscular endurance exercise. Perceptual information and its effects on these training modes is not a largely studied topic. Few studies exist detailing how the size-weight illusion or perceiving a certain weight before lifting it, while not knowing the actual weight, may influence metabolic or muscle action. When seeing a certain weight chosen, one may have pre-conceived expectations on how to go about performing the muscular actions necessary to move that weight. Also, if one expects a weight to be heavier or lighter than what it truly is, neural activity may be influenced.

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METHODS

Participants

College-aged (18-26 years of age), resistance-trained males and females were recruited to participate in this crossover designed study. Recruitment occurred on a college campus in the East Texas region. Participants were recruited recruited through informational flyers and word of mouth on campus in various Kinesiology courses. Participants were included if the following criteria were met: a minimum of two months of consistent resistance training experience prior to the study (per National Strength and Conditioning Association guidelines for advanced training status), no current musculoskeletal injuries, and not have any contraindications to participation in exercise. Written and verbal informed consent was obtained from all participants and the Institutional Review Board of Stephen F. Austin State University approved of the study prior to data collection from any participants.

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Protocol

This study utilized a randomized cross-over design. Participants reported to the testing facility for the first time for pre-exercise screening, execution of informed consent, and baseline data collection. Baseline data collection consisted of the measurement of body composition (dual X-ray absorptiometry (DEXA)) (General Electric Medical Systems Lunar, Madison, WI), height (medical stadiometer, Detecto, Webb, City, MO), weight (medical scale, Detecto, Webb City, MO), physical activity recall, health history screening, Physical Activity Readiness questionnaire, one-rep max (1RM) on bench press, and repetitions to failure with 60% 1RM on bench press. Participants performed the bench press on a recumbent bench (Three-Way Utility Bench, Power Systems; Knoxville, TN) with a barbell (Pro Power Bar, Power Systems; Knoxville, TN) and barbell plates (VTX Grip Plate, TROY Barbell and Fitness; Houston, TX). Participants were instructed on proper bench press mechanics prior to each assessment. Concentric bar speed during the bench press assessments was also measured using the GymAware equipment and software (Kinetic Performance Technology, Canberra, Australia). Immediately following the bench press final repetitions, each participant were administered a Rating of Fatigue Scale (ROF) (30), an OMNI resistance exercise scale (40), and a Borg Rating of Perceived Exertion (RPE) scale to determine feelings of fatigue and exertion. At least 30 minutes was provided between bench press assessments with the 1RM assessment being performed first. Ensuing meetings consisted of participants performing 1RM bench press assessments and repetitions to failure on bench press with 60% of the previously acquired 1RM under an altered and masked resistance. Bar speed during each bench press assessment was also measured using the GymAware equipment and software. Immediately following each lift, the scales of fatigue were shown. The purpose of disguising and altering the resistance was to test the effects of the participants' perception on effort. Plastic sheets were used to mask the weight loaded on the barbells during the maximal strength and muscular endurance bench press assessments. This ensured that participants not able to see the weight that is being lifted. A minimum of two days of rest were provided between testing sessions. Participants were also informed to abstain from alcohol, caffeine, and pre-workout supplementation for the 24 hours prior to each exercise protocol for the duration of the study. Participants' external exercise regimens were maintained throughout the study; however, participants were asked not to perform strenuous activity at least two days prior to exercise testing days.

Baseline Bench-Press 1RM Testing: The protocol that was used to assess maximal strength on bench press was outlined by Sheppard et al. (42). A dynamic warm-up regimen was provided prior to the test. Participants were given a warm-up regimen that consisted of two sets of 10 arm circles forward and backward, 10 internal and external shoulder rotations per arm with shoulder flexed and with upper arm resting against lateral aspect of torso, 10 push-ups, and 10 repetitions with an unloaded barbell. Participants then performed bench press against a resistance that allowed a light eight to 10 repetitions. A one-minute rest period was given. Ten to 20 pounds was then added to the resistance and the weight was lifted for three to five repetitions. A two-minute rest period was provided. Participants then completed two to three repetitions of a near-maximal resistance with10 to 20 pounds added to the prior lift. A three-minute rest period was provided. A load increase of around 10 to 20 pounds was then added and the participants performed a 1RM. If a successful lift was recorded, an extra five to 10 pounds was added and the lift was attempted after a three-minute rest period. Immediately after completion of the 1RM testing, the ROF, OMNI, and RPE scales was assessed to monitor level of fatigue.

Disguised 1RM Trials: After baseline testing, participants arrived at the test facility for three additional 1 RM assessments on bench press. The additional 1 RMs trial conditions were standardized, and the loads placed on the barbell were disguised and altered. The same warm-up regimen described in the previous section was provided to the participants prior to each assessment and the same build-up protocol to the 1RM during baseline testing was also utilized. Participants performed a disguised weight 1RM during three bench press testing conditions. One condition consisted of the participants performing bench press with the same weight (1RMEW) they acquired during baseline data obtainment and the other two conditions consisted of the participants performing bench press with a five percent increase (1RMIW) and a five percent decrease (1RMDW) of their 1RM respectively. The order of these assessments were randomized. The resistances were masked with plastic sheets around the plates at the end of the barbell to ensure the load was not visible. Test administrators informed the participants that the resistance on the barbell for each assessment was equal to that of their 1RMs acquired at baseline. Participants were not present in the room as the weight was loaded on the barbell for each assessment, and no verbal motivation was given to the participants as each performed the lifts. Spotters were available in case of lift failure. Lift off from the racks were given if necessary. The weight the participants attempted, if successful or unsuccessful, were recorded. The ROF, OMNI, and RPE scales were administered after the immediate completion of each assessment.

Disguised Muscular Endurance Trials: For the muscular endurance assessment, participants performed bench press until repetitions to failure with 60% 1RM loaded on the barbell. The same warm-up regimen outlined in the baseline and 1RM testing was provided prior to each muscular endurance bench press assessment. Participants were able to see the resistance loaded during baseline testing. Three more meetings were dedicated to muscular endurance testing and the weight was disguised and manipulated during all occasions. One experimental muscular endurance assessment consisted of the participants performing the same 60% 1RM weight (MEEW) until failure that was founded during baseline data collection but with masked resistance. The other two testing conditions consisted of participants performing bench press with a 5 % increase added to their previously acquired 60% 1RM (MEIW) and a 5% decrease from their previously acquired 60% 1RM (MEDW). Participants underwent repetitions to failure in these conditions. Also, the resistance loads were masked during these conditions. Participants were told the resistances during the three testing conditions were equal to that of the 60%

1RM assessment performed at baseline. The order of the testing conditions was randomized along with experimental 1RM trials. The number of repetitions completed per testing condition were recorded. Participants were not present in the room as the weight was loaded on the barbell for each assessment, and no verbal motivation was given to the participants as they performed the lifts. Spotters were available in case of lift failure. No lift off from the racks were given during the experimental conditions. The ROF, OMNI, and RPE scales were administered immediately following the completion of the assessments. At least two days rest was provided between trials. The experimental muscular endurance trials were performed at least 30 minutes following the corresponding 1RM trial.

Bar Speed Measurements: Bench press concentric bar speed was measured during each bench press assessment using the GymAware equipment and software. The same method for utilizing and placing the equipment of the GymAware was used before by Weakley et al. (47). During the experimental 1RM assessments, the bar speed corresponding with the successful lift was recorded. Mean bar speed during the full amount of successful repetitions completed during the muscular endurance bench-press assessments were recorded.

Statistical Analysis

Differences between baseline 1RM bar speed and 1RMEW bar speed were measured using a paired t test. Perceptions of exertion at baseline after the 1RM attainment and perceptions of exertion after each experimental masked 1RM were compared using a Wilcoxon singed ranks test. A paired samples t-test compared the means of the baseline ME bar speed and the bar speed of the MEDW trial, MEEW trial, and the MEIW trial. Perceptions of exertion after the unmasked baseline ME and the perceptions of exertion after the MEDW, MEEW, and MEIW trials were compared using a Wilcoxon signed ranks test. Repeated measures analyses of variance (ANOVA) was used to determine significant differences in the means of the repetitions successfully completed during the ME test at baseline and each trial. Statistical significance was set at $p < 0.05$ for all analyses.

RESULTS

Eight participants (five males, three females) completed all trials. Descriptive data of the participants is shown in Table 1. Results of the paired samples t-test did not show a significant difference between the bar speed generated during the baseline 1RM trial and the bar speed of the 1RMEW trial (Table 2, $p = 0.377$). The GymAware was not able to register three participants' bar speeds during baseline; therefore, mean replacement was used for these missing datapoints for the baseline trial. Also, only two participants were able to successfully lift the resistance in the 1RMIW trial. The Wilcoxon Signed Ranks Test showed a significant difference between baseline unmasked -1RM perceptions of exertion (RPE 17.25 ± 2.00, ROF 6.63 ± 1.30, OMNI 8.38 ± 0.70) and 1RMEW (RPE 14.38 ± 1.90 , $p = 0.017$; ROF 5.00 ± 1.90, $p = 0.026$; OMNI 6.63 ± 1.20, $p = .017$) (Table 2, Figure 1). Also, significant decreases were found between the unmasked baseline RPE, ROF, OMNI and 1RMDW RPE (11.88 ± 2.48, $p = 0.012$), ROF (4.00 ± 1.60, $p = 0.011$), and OMNI (4.63 ± 1.77, $p = 0.012$) (Table 2, Figure 1). No differences were found when comparing the baseline 1RM RPE, ROF, and OMNI to the 1RMIW RPE (17.00 ± 1.31, $p = 0.196$)), ROF (7.13 ± 1.39, $p = 0.096$), and OMNI (8.50 ± 1.07, $p = 0.666$) (Table 2, Figure 1). A significant difference was found between the mean bar speed during the baseline unmasked ME test and the mean MEDW trial bar speed (0.40 ± 0.10 and 0.57 ± 0.10 m/s respectively, $p = 0.001$) (Table 3, Figure 2). A significant difference was found between baseline unmasked mean ME bar speed and masked mean MEEW bar speed (0.52 ± 0.10 m/s, $p = 0.002$) (Table 3, Figure 2). Also, when compared to the unmasked baseline, no significant difference was found in the mean bar speed during the MEIW ME trial (0.44 ± 0.10 m/s, $p = 0.297$) (Table 3, Figure 2). Additionally, RPE, ROF, and OMNI after the unmasked baseline ME test (18.25 ± 2.49, 8.88 ± 3.13, 8.63 ± 1.06 respectively) were not significantly different from the RPE, ROF, OMNI from the masked MEEW trial (16.38 ± 1.99, $p = 0.072$; 7.25 ± 1.28, $p = 0.197$; 8.00 ± 0.76, $p = 0.059$ respectively) (Table 3, Figure 3). The Wilcoxon Signed Ranks Test showed a significant difference between the RPE and OMNI after the masked MEDW trial (15.75 ± 2.05, 7.25 ± 1.49 respectively) and the unmasked baseline ME test ($p = 0.027$, $p = 0.027$ respectively) but not compared to ROF (7.5 ± 1.51, 8.88 ± 3.13 respectively, $p = 0.340$) (Table3, Figure 3). Also, a significant difference was present between the RPE after the unmasked baseline ME test and the RPE after the masked MEIW ME test (16.25 ± 1.58, $p = 0.033$) but not in the ROF (8.75 ± 3.88, $p = 0.596$) and OMNI (8.13 ± 0.64, $p = 0.194$) (Table 3, Figure 3). Results of the ANOVA showed a significant main effect for repetitions during the masked ME trials ($p < 0.001$). Compared to the unmasked baseline (16.25 ± 5.20 repetitions) , the MEDW (26.63 ± 4.53 repetitions) and the MEEW (23.00 ± 3.85 repetitions) showed a significant increase in repetitions completed ($p = 0.001$, $p = 0.010$ respectively). The MEIW (18.13 ± 4.32 repetitions) did not yield any significant differences in repetitions completed compared to the unmasked baseline ($p = 0.403$) but did elicit significant differences compared to

MEEW (p = 0.004). Also, there was a significant difference in repetitions between MEDW and MEEW (p= 0.006).

DISCUSSION

The purpose of this study was to test the effects of resistance deception on muscular strength, muscular endurance, and perceived exertion in a trained population. Deception on load during resistance training is a lightly researched topic. Some research that has been conducted on resistance deception focused on perception of exertion or fatigue after completing the masked and altered conditions. However, mixed results have been found in the studies that observed deceiving participants during resistance training methods. In the case of Motoyama et al. (33) no effect was found on perception of exertion and repetitions under deceived and masked conditions during arm curl exercise in conditions where resistance was equal, increased and decreased. Some findings of Motoyama et al. (33) were not reflected in the present study. Results of the present investigation showed a significant difference in perceptions of exertion under the masked condition when the resistance during the 1RM was equal to the resistance obtained at baseline. Rating of perceived exertion, ROF, and OMNI were significantly reduced during the 1RMEW trial and participants felt as though the 1RM was lighter and less difficult to complete even though the resistance was equal to that of baseline. Participants used phrases such as, “That felt a little lighter,” and, “It felt easier than the first day,” to describe how the trial felt when compared to baseline. However, the same results cannot be said for the masked equally weighted ME test (MEEW) compared to the baseline ME test. No significant differences were found when comparing the perceptions of fatigue and exertion at baseline to MEEW. These results align with the findings of Motoyama et al. (33). However, the present study did find significant decreases in perceived exertion in the 1RMDW and MEDW trial when compared to baseline. Interestingly, there were no differences in RPE, ROF, and OMNI scores between the baseline ME test and the MEIW test. Therefore, participants felt as if the same amount of effort was required for the increased weight when compared to the lighter weight and unmasked baseline. Also, before each trial the participants were told the resistance was equal to that of what was required at baseline; therefore, each participant had previous experience with the effort required during each test. The results may indicate that perceptions of expected resistance may be a factor in determining how much exertion to put into a masked test. One explanation is that the masked condition could have been influenced through overestimation. Under deceived loads, it has been theorized the brain overestimates the resistance, which causes enhanced pre-activation of muscles and increased proprioceptive sensitivity (19). However, the results of perceptions of less exertion are in agreement with Noakes's Theory of the CGM (36). Self-imposed inhibition was negated when participants underwent the masked trials as each believed the resistance was equal to the resistance obtained at baseline. The lower perceived exertion during the 1RMEW and 1RMDW and the unchanged perceived exertion during the 1RMIW could have been affected by teleoanticipation. Anticipation of the exercise has been seen as a contributor to perceived exertion (36). Teleoanticipation refers to the expected anticipation to a certain resistance that allows for more efficient performance (19). Perception of exertion results from the interpretation of afferent sensations against an expected outcome (19). During the masked deceived trials afferent feedback could have been altered in a way that provides information to the brain conveying a lower level of exertion.

With regard to resistance successfully achieved, Ness et al. (35) found participants were able to lift on average 20 pounds more what was believed when not knowing the resistance loaded during incline bench press. The authors postulated that participants wanted to meet the self-expectations that were set in the prior trials. This was not the case in the present study. The majority of the participants were not able to lift the 1RMIW, which was set up to make the participants believe that the weight being lifted was less than what was actually being lifted. However, in the present study, participants were able to perform around the same amount of repetitions in the MEIW trial (18.13 ± 4.32 repetitions) when compared to the baseline ME test (16.25 ± 5.20 repetitions). These results support the idea that deception with increased weight can serve as a modifier in RT. As the participants expected the same resistance as what was pushed in the baseline, enhanced pre-activation of working muscle occurs to increase joint stiffness and concentric force (9). Additionally, participants were able to significantly increase the amount of repetitions completed in the MEEW trial when compared to baseline, which was the same weight. Pairwise comparisons showed that participants were able to complete about six more repetitions in the MEEW trial compared to baseline. Also, participants successfully attempted the 1RM during the 1RMEW trial and felt as though they did not exert as much effort compared to baseline. One theory that may help explain these results is that unknown loads may provide stimulation of the Central Nervous System (CNS) so much so that an overestimation of weight occurs, which will allow an over activation of muscles and enhancement of force to be produced in order to lift the weight (9). With this overestimation of weight, the activated agonistic and synergistic muscles might be able to complete more repetitions prior to fatigue when compared to known and/or unmasked loads, which may provide insight into the theory that visual perception of resistance may be a determining factor in repetitions to fatigue and 1RM at equal loads and repetitions to fatigue with a 5% increase in weight. Moreover, it has been theorized voluntary expression of maximal force could be restricted by a perceptual barrier (2). Blocking the resistance may have served as a bypass to this perceptual barrier as participants were able to increase parameters of performance in the deceived ME trials and the 1RMEW trial. This may not be the case for lighter-loaded resistances, however. Participants were able to complete significantly more repetitions in the MEDW with a corresponding decrease in perception of exertion. When deceived weight is lighter than it actually is believed to be, a psychological mechanism may be at play making the CNS activate muscles and provide neural input to motor units in a corresponding fashion that would exist when a resistance is knowingly lighter. More investigations are warranted to compare repetitions to fatigue in lower-loaded and equally loaded ME tests under masked and unmasked conditions.

Moreover, our findings represent an enhancement of bar speed when weight is masked and equal and masked and lighter than that of the baseline test. These results agree with the findings of Hernández-Davó et al. (19), who found significant increases in concentric velocity during a bench-press throw that was loaded at 50% and 70% 1RM when resistance is not known compared to when it is known. Duggan et al. (9) found similar results of increased average power and average velocity during unknown and deceived loads of 75% and 80% 1RM of a mid-thigh pull (during a power clean exercise) compared to known loads of equal weight. These results further elucidate the bar speed observations in the present study. The current investigation also found a similar output of bar speed when comparing the MEEW and MEIW trials (0.40 ± 0.059 and 0.43 ± 0.063 m/s respectively). When comparing the two trials, the mean bar speed during the MEIW test was slightly higher than that generated during baseline. This cannot be discredited with participants performing less repetitions because, in the present case, participants produced a similar amount of repetitions in the MEIW as in the baseline test. A possible explanation of this could be attributed to the overestimation of weight, which may alter voluntary pre-activation of muscles and co-activation of corresponding muscle spindles. Deception has been proposed as a mechanism that can increase proprioceptive sensitivity, which could increase force production and enhance internal visualizations of movement (18,12). This pre-activation will also increase joint stiffness and the muscular-tendon unit's ability to generate more force subsequently when performing repetitions to fatigue in the masked MEEW and MEIW trials. Additionally, enhanced concentric force during the two trials could stem from the increased concurrent activation of motor units and increased rate coding when compared to unmasked resistances (9).

Limitations

One limitation in the present study is the sample size. Only eight participants were able to complete all trials; therefore, more research is called for that has includes a larger sample size. Also, a further limitation lies within measuring the bar speed during the 1RM trials. This was apparent because some bar speeds during the baseline did not register due to the slow actions of the concentric portion of the bench press. Other modes that measure physiological responses in masked/deceived resistances versus unmasked resistances could provide more insight into how the musculature acts under these states. Electromyographical signaling could be a potential method to observe neuromuscular activity and true concentric force generation in non-power movements like the bench press.

Also, the present study observed individuals who were well trained. A study looking at the effects of resistance deception on elite populations (athletes, etc.) could yield similar or different results. Another limitation resides in the liftoff given to participants at the onset of the bench press assessments. In the present study, participants were told that no assistance would be provided during the bench press assessments; however, some participants were not able to lift the bar from the racks without assistance but were still able to complete a full repetition. This method of assistance will need to be controlled for in future studies regarding resistance deception.

Also, three spotters were not always present in the testing room when assessments occurred. A minimum of one spotter was always present during testing. The number of spotters present was not always constant due to conflicting schedules of research assistants. It has been found that the presence of spotters can positively affect bench press performance compared to when spotters are hidden from view (43). In order to minimize effects from this phenomenon, the number of spotters should remain constant in all trials.

Conclusion

This study showed using deceptive methods while resistance was masked can improve perceptions of exertion, repetitions, and bar speed in instances where resistance is equal and increased in and ME tests. Also, a lower exertion level was attributed to the masked resistance that was equal to baseline in the 1RM assessment. This study also concluded resistance that is lighter than what is believed by participants causes a linear increase in repetitions and bar speed and decreases in perception of exertion. This sort of training methodology can be applied by personal trainers and strength and conditioning specialists who want to improve performance of individuals and athletes. Our findings suggest applying such methods in tests where 1RM is equal and ME tests where resistance is equal or increased a small degree. A fiver percent increase seemed to be too much of an increase in masked 1RM testing; therefore, a smaller incremental increase may be plausible in application to training. In addition, it was found that bar speed improved when resistance is masked and equal to that of baseline in the ME tests. Also, bar speed was unchanged when comparing the baseline findings to the findings of the MEIW trial, which was masked and five percent heavier than baseline. This may accentuate the effects of deception on power-related movements as outlined by Duggan and Moody (9) and Hernández-Davó et al. (19). In addition, these findings suggest some significant results after acute bouts of bench press training. Future research can explore these effects on different strength-training exercises and how a chronic exposure to masked and deceived loads can affect local strength and muscular endurance.

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Table 1. Descriptive data of participants

Descriptive	Men (n = 5)	Women (n = 3)	Total (n = 8)
Age (years)	23.00 ± 1.58	22.30 ± 2.30	22.80 ± 1.80
Weight (kg)	93.50 ± 15.47	69.00 ± 7.50	84.30 ± 17.70
Height (cm)	177.50 ± 5.85	164.70 ± 8.50	172.70 ± 9.20
Body Fat (%)	23.58 ± 8.01	27.40 ± 3.80	25.00 ± 6.70
1RM (kg)	110.90 ± 25.70	53.00 ± 4.73	89.20 ± 78.70

All values represent mean ± SD.

Table 2. 1-RM trial bar speed (m/s) and perceived exertion

Variables	Baseline	1RMEW	1RMIW	1RMDW
Bar Speed (m/s)	0.22 ± 0.06	0.20 ±0.10	NA	0.30 ± 0.10
RPE	17.25 ± 2.00	14.38 ± 1.90*	17.00 ± 1.30	11.88 ± 2.50*
ROF	6.63 ± 1.30	5.00 ± 1.90*	7.13 ± 1.9	4.00 ± 1.60*
OMNI	8.38 ± 0.70	6.63 ± 1.20*	8.50 ± 1.10	4.3 ± 1.80*

All values represent mean ± SD. *denotes significant difference from baseline.

Table 3. ME trial bar speed (m/s), perceived exertion, and repetitions

Variables	Baseline	MEEW	MEIW	MEDW
Bar Speed (m/s)	0.40 ± 0.10	0.52 ±0.10*	0.44 ± 0.10	0.57 ± 0.10*
RPE	18.25 ± 2.50	16.38 ± 2.00	16.25 ± 1.60*	15.75 ± 2.10*
ROF	8.88 ± 3.10	7.25 ± 1.30	8.75 ± 3.90	7.50 ± 1.50*
OMNI	8.63 ± 1.10	8.00 ± 0.80*	8.13 ± 0.60	7.25 ± 1.50*
Repetitions	16.25 ± 5.20	23.00 ± 3.9*	18.13 ± 4.30†	26.63 ± 4.50*†

All values represent mean ± SD. *denotes significant difference from baseline.
†denotes significant difference from MEEW.

Figure 1.

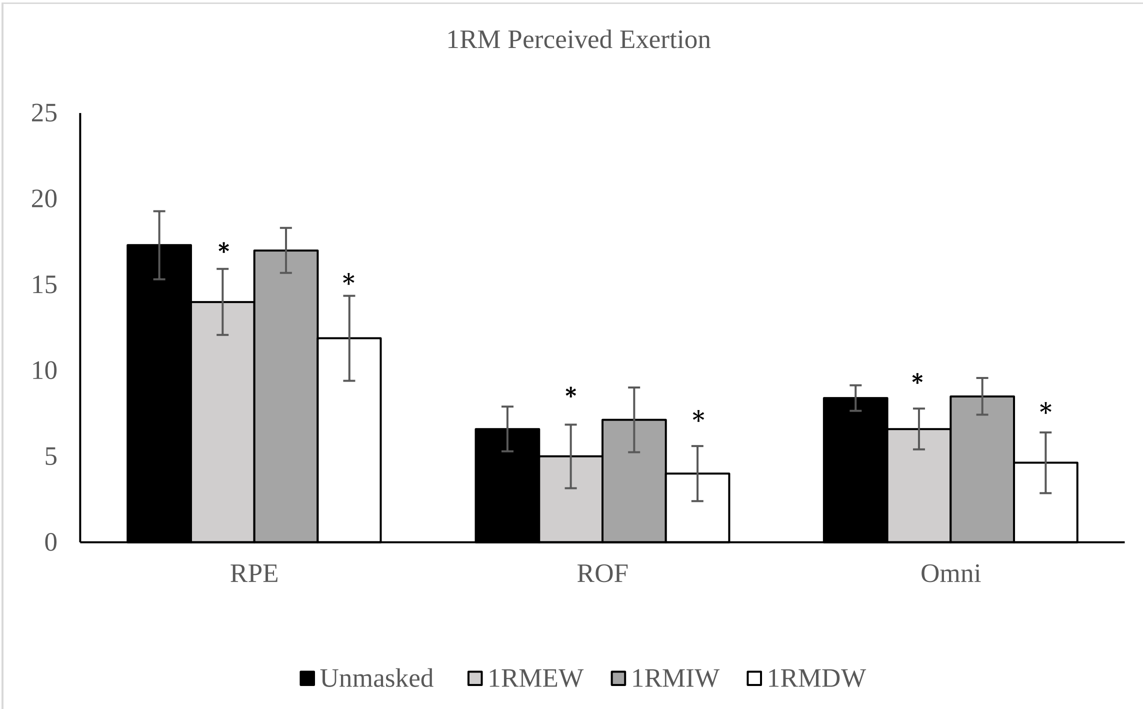
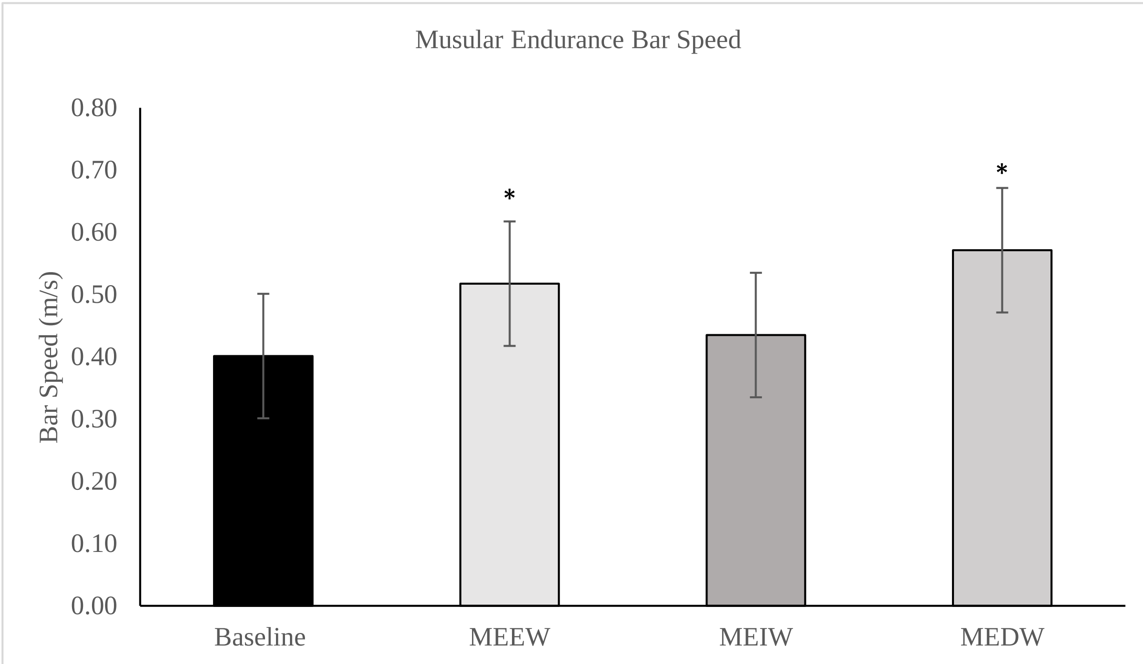

1RM Perceived Exertion
25
20
15
10
5
0
*
*
*
*
*
*
RPE
ROF
Omni
Unmasked
1RMEW
1RMIW
1RMDW

Figure 2.



Musular Endurance Bar Speed
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Bar Speed (m/s)
*
*
Baseline
MEEW
MEIW
MEDW

Figure 3.

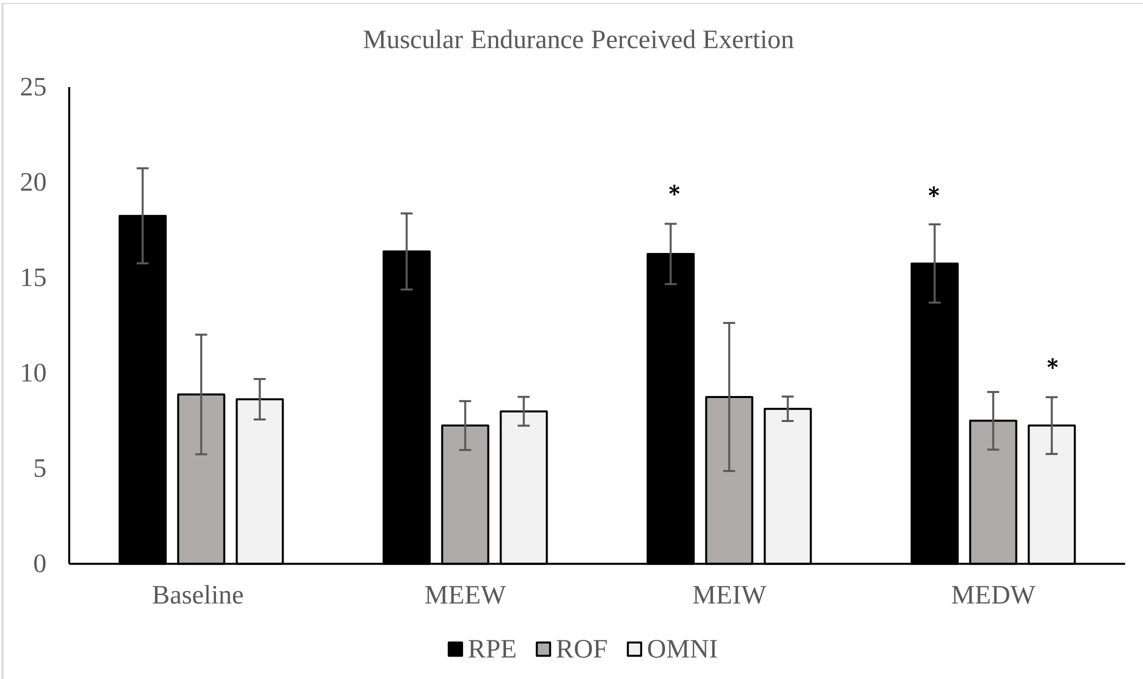

Muscular Endurance Perceived Exertion
25
20
15
10
5
0
*
*
*
Baseline
MEEW
MEIW
MEDW
RPE
ROF
OMNI

Figure 4.

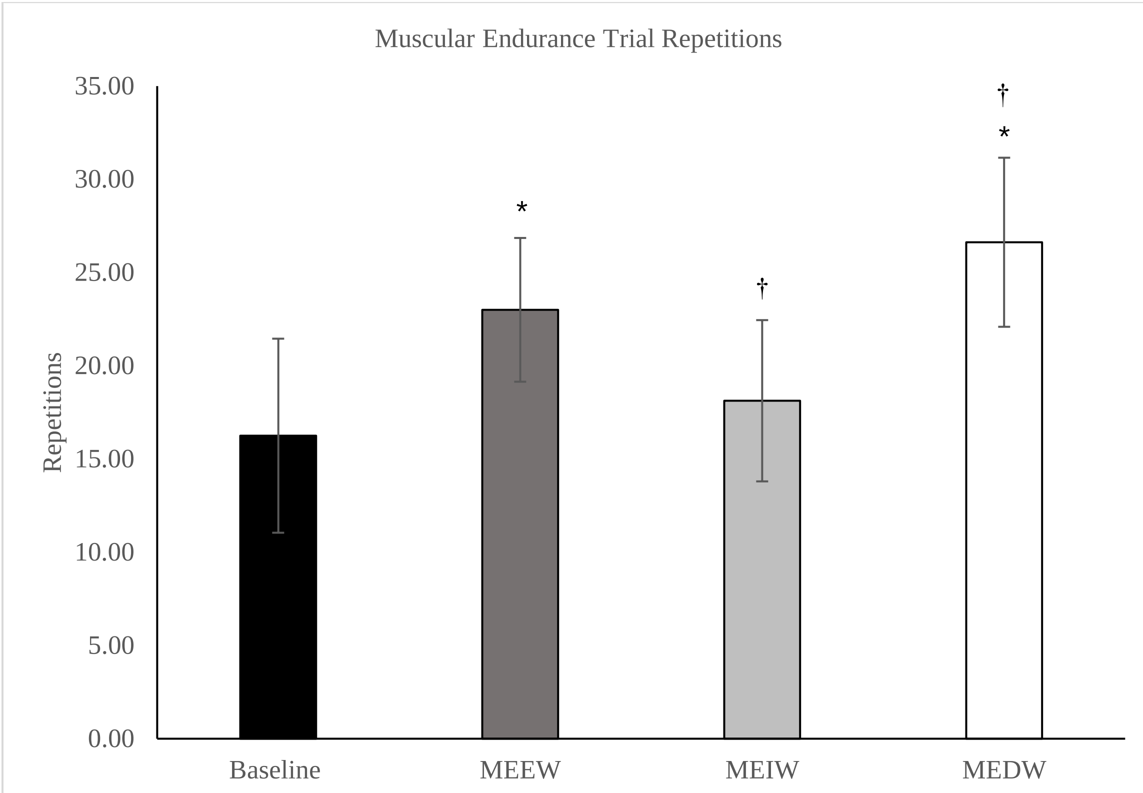

Muscular Endurance Trial Repetitions
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Repetitions
*
†
†
*
Baseline
MEEW
MEIW
MEDW

Figure 1. RPE, ROF, and OMNI reported in baseline and masked 1RM trials. Significant difference $p \leq 0.05$ between RPE, ROF, and OMNI during the 1RMEW compared to baseline. *Significant difference between trial and baseline.

Figure 2. Differences in mean bar speed (m/s) at baseline and masked trials. Significant difference $p \leq 0.05$ between MEEW and MEDW mean bar speed compared to baseline. *Significant difference between trials and baseline.

Figure 3. RPE, ROFE, and OMNI during muscular endurance tests at baseline and masked trials. *Significant difference $p \leq 0.05$ between MEIW RPE and MEDW OMNI compared to baseline.

Figure 4. Participants' mean repetitions complete during ME test of baseline and each masked trial. *Significant difference $p \leq 0.05$ in repetitions between MEEW and MEDW compared to baseline. †Significant difference $p \leq 0.05$ in repetitions between MEEW and MEIW and between MEEW and MEDW.

VITA

Broderick Dickerson, a graduate of Huntington High School, enrolled at Stephen F. Austin State University in Nacogdoches, Texas during the fall semester of 2013. He received a Bachelor of Science in Kinesiology with emphasis in fitness and human performance from Stephen F. Austin State University after the spring semester of 2018. In August 2018, he enrolled in the Graduate School of Stephen F. Austin State University in the Kinesiology and Health Science Department and was hired as a graduate teaching and research assistant. He is listed as the instructor of record under two lecture courses. He also was an instructor for multiple labs and activity courses. As a graduate assistant, he also assisted in multiple research projects.

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