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The impact of high- vs. low-load resistance training on measures of muscle activation, strength, body composition, and hormonal markers

Marissa Laina Bello
Mississippi State University, rissab09@gmail.com

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By

Marissa Laina Bello

Approved by:

JohnEric William Smith (Major Professor)
Shawn M. Arent
Zachary M. Gillen
Stanley P. Brown
Benjamin Wax Jr.
Brent J. Fountain
Adam C. Knight (Graduate Coordinator)
Teresa Jayroe (Dean, College of Education)

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Name: Marissa Laina Bello

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Major Professor: JohnEric W. Smith

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Candidate for Degree of Doctor of Philosophy

Resistance training has shifted towards a high- vs low-load training approach. Heavier loads are suggested to maximally recruit motor units and optimize strength adaptations, whereas lower loads stimulate hypertrophy. However, a majority of the research has not used a true strength range when assessing load. Therefore, the purpose of this investigation was to examine and determine significant differences in strength, body composition, and hormonal markers over nine weeks of high- or low-load resistance training. Secondary purposes of the current investigation were to assess and quantify training load for resistance training using sEMG sensor-embedded compression shorts. 17 recreationally-trained males were randomized into two groups with training loads of 30 or 85% 1-RM. Both groups completed nine weeks of whole-body resistance training three days per week, with exercises performed as three sets to failure per movement. Measures were collected at baseline and every three weeks after, including muscle thickness, body composition, isometrics/isokinetic strength, and hormonal status (testosterone and cortisol). Predicted 1-RM testing was performed pre- and post-training. Both groups demonstrated significant hypertrophy and strength, although the 85% showed greater improvements in the predicted 1-RM and the isokinetic peak torque values. There were also

significant differences between groups for muscle load and training load as measured by the wearables, indicating the technology was able to differentiate between resistance training intensities. However, there were no changes in any of the hormonal markers either in basal levels or acutely post-exercise. Overall, our results suggest a similar hypertrophy and hormone response occurs in both low- and high-load groups when training to failure, but the high-load results in greater strength improvements and higher muscle load output when measured by wearable technology.

DEDICATION

This dissertation is dedicated to my family for their unwavering support over the years of my journey through academia.

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CHAPTER I

INTRODUCTION

A common method of exercise is resistance training, or the contraction of muscles against external loads. As a result of this training, hypertrophy of the musculature and greater neuromuscular activation can occur as an individual progressively overloads and adapts to the training stimulus. These responses are primarily to increase the size of the muscle and the strength of contractions, subsequently improving performance in both speed and power. The magnitude of these adaptations in both type I and type II fibers depend on training mode, frequency, loading, and periodization (Schoenfeld et al., 2017). The latter incorporates planned manipulation of training variables to optimize these adaptations and manage training and recovery status (Evans, 2019; Plisk & Stone, 2003).

The greater neuromuscular activation as a result of resistance training includes faster muscle firing rates and action potentials in the muscles. These can be assessed using surface electromyography (sEMG) to measure the polarization and depolarization through a contraction and thus the magnitude and timing of force production (Lynn et al., 2018; Smith, 2019; Vigotsky et al., 2018). The amplitude of activation can be influenced by the training protocols used, where higher levels of fatigue will result in greater activation. This includes differences in loading on an acute basis, where lower percentages of 1-repetition maximum (1-RM) produce lower peak and average sEMG amplitudes in both lower (Gonzalez et al., 2017; Looney et al., 2016; Morton et al., 2019; van den Tillaar et al., 2019) and upper body (Pinto et al., 2013) exercises. These

results have also been shown in longer programs of whole-body heavy resistance training (Aagaard et al., 2002) and targeted lower body exercises (Hakkinen et al., 1985; Sterczala et al., 2020).

The hypertrophy of the muscles and subsequent alterations in strength can occur at varying intensities, although it is recommended to use lower repetition ranges for predominantly training strength and higher repetitions ranges for inducing greater hypertrophy (Haff & Triplett, 2016). The mechanisms through which hypertrophy occurs are through a response to muscle damage (Vierck et al., 2000), mechanical tension (Schoenfeld, 2010), and metabolic stress (Abernethy et al., 1994). There is a moderate correlation between hypertrophy and strength, indicating both adaptations can occur simultaneously, although a specific stimulus may warrant more favorable results for one over the other (Maughan et al., 1983).

The assessment of strength can occur in both field- and lab-based settings, using true or estimated 1-RM testing (Haff & Triplett, 2016) in the former and an isokinetic dynamometer (Baltzopoulos & Brodie, 1989) in the latter. These tests can provide practical applications of strength in a resistance training program by assessing both repetitions performed as well as the maximum force applied in a dynamic movement. With regards to measuring hypertrophy, muscle cross-sectional area (CSA) and muscle thickness can be evaluated through ultrasound, muscle biopsy, or MRI machines. However, ultrasound is the least invasive and cost-effective (Pillen & van Alfen, 2011), therefore it is a more common method in a research setting. These validated measures of strength and hypertrophy can be used to assess both acute and chronic changes in the response to resistance training. However, training variables play an important role as number of repetitions (Campos et al., 2002), total volume (Schoenfeld et al., 2014), and frequency of the program (DeFreitas et al., 2011; Zaroni et al., 2019) may all influence the

magnitude of the adaptations. Particular strength or hypertrophy improvements are seen with periodizing and focusing training on one adaptation. With long-term training separated focusing more on strength (lower repetitions and higher loads or intensity), there are generally greater increases in 1-RM lifts in the strength, although increases in CSA did not significantly differ from a hypertrophy-focused training block (Campos et al., 2002; Schoenfeld et al., 2014). In order to properly recommend a load or intensity to optimize the strength and/or hypertrophy adaptations, the entire physiological response to resistance training should be accounted for.

A final adaptation that is often overlooked with regards to training but provides a more inclusive view is the inclusion of the endocrine response. In particular, cortisol and testosterone are considered the most potent catabolic and anabolic hormones, respectively. Both the acute and chronic response of these hormonal markers may provide more context with regards to the adaptations that occur in muscle activation and strength with varying resistance training. Acutely, testosterone is elevated immediately following heavy resistance exercise (Kraemer et al., 1995) and produced a more robust response during a higher intensity protocol (Raastad et al., 2000). The acute response of cortisol is inconsistent however, as many researchers employ training during the early morning when cortisol levels are already high from waking (Raastad et al., 2000; Smilios et al., 2003; Villanueva et al., 2012). Therefore, the chronic changes in resting levels of cortisol and testosterone may provide a clearer view of the training and recovery status.

Over long-term training, these increases in testosterone are observed and remain elevated with continued training along with strength and force improvements, although the removal of the training stimulus shows levels return towards baseline (Hakkinen et al., 1987, 1988; Kraemer & Ratamess, 2005). The chronically elevated cortisol response reflects a heightened stress response from training, and ultimately result in reduced secretion of regulators and consequently

performance (Charmandari et al., 2005). These changes in cortisol are not consistent as studies have shown increases (Fry et al., 1994; Hakkinen & Pakarinen, 1991), decreases (Alen et al., 1988; McCall et al., 1999), or no change (Ahtiainen et al., 2003) with long-term resistance training. Several variables should be considered when implementing hormonal measurements with training, including sex differences, circadian rhythms, and nutritional intake. Studies comparing males and females show expectedly different responses in testosterone with resistance training (Kraemer et al., 1991), and the natural circadian rhythm and thus timing of workouts influences the robustness of the cortisol response and change from baseline values (Hayes et al., 2010; Sedliak et al., 2007). The hormonal response may also be influenced by nutritional intake around exercise with the intake of protein and carbohydrate augmenting testosterone and inhibiting cortisol (Kraemer et al., 1998; Tsuda et al., 2020), although this is not always seen (Williams et al., 2002).

With all of the above training adaptations outlined, the potential disparities between training loads have gained momentum in recent research in an attempt to determine an optimal training stimulus. In particular, a “high” versus “low” approach has mainly been used to assess both acute and chronic responses, frequently using loads of 30% 1-RM for low, and greater than 70% 1-RM for high (Burd et al., 2010). It is proposed heavier loads would stimulate greater hypertrophy and strength responses than the lower loads. Overall, there appears to be a greater peak and average EMG amplitude in the higher loads (Haun et al., 2017; Jenkins et al., 2015; Jenkins et al., 2016; Jenkins et al., 2017). However while some studies note differences in strength where the high load group produces bigger improvements (Jenkins et al., 2016; Schoenfeld et al., 2015), the hypertrophy response does not appear to differ (Haun et al., 2017; Jenkins et al., 2015).

While these studies account for muscular activation, hypertrophy, and strength, a majority of them utilize untrained participants, therefore the application towards more experienced populations may prove different results. Further, the studies do not incorporate the hormonal response, and therefore may not have a comprehensive view of the training and recovery status of these exercisers. Previous research has not used a true "strength" range according to the NSCA, which suggests greater than 85% 1-RM (Haff & Triplett, 2016). Finally, the loading within a training intervention was not adjusted accordingly, therefore progressive overload was not applied and may limit the magnitude of training responses.

Therefore, the aim of this training study is to evaluate and observe the potential differences between higher and lower loads on measures of strength, hypertrophy, as well as the endocrinological response with prolonged training to create a more comprehensive and wholistic picture of the resistance training response. Using a low-load group working at 30% 1-RM and high-load group working at 85% 1-RM, a 9-week training intervention with incremental testing can provide both acute and chronic changes in physiological measures in a true strength range. It is hypothesized the higher load group will produce greater peak and average EMG amplitudes both within training and chronically, as well as improve strength measures more than the low load group. It is also hypothesized there will be significant differences in the hormonal response, with greater elevations in resting testosterone in the high-load group, and greater perturbations in cortisol with the low-load group. Secondary purposes of the current investigation aim to examine the use of EMG sensor-embedded shorts as a way of quantifying resistance training load and intensity.

CHAPTER II

LITERATURE REVIEW

Resistance Training

Resistance training is the contraction of muscles against external loads, and adaptations primarily result in increases in lean body mass or muscle mass and subsequently strength. Resistance training is not used in just strength-dominated sports but is also incorporated in many sports as supplemental training to improve performance. One of the main outcomes of resistance training is hypertrophy of muscle fibers. Muscle hypertrophy involves the growth and increase in size of the myofibrils and occurs with resistance training, particularly when training is periodized between strength/power, endurance, and hypertrophy blocks (Schoenfeld et al., 2017). Increases in muscle size occur via muscle protein synthesis, upregulated through the mammalian target of rapamycin (mTOR) pathway (Laplante & Sabatini, 2009). With resistance training, the release of adenosine monophosphate kinase (AMPK) stimulates increases in the protein enzyme mTOR and stimulates muscle protein synthesis, contributing to increased muscle mass (Ogasawara et al., 2016; Yoon, 2017).

Resistance training primarily results in neuromuscular adaptations and thus greater neuromuscular activation when training. The neural response of resistance training is mainly to maximize the expression of muscular strength/power and optimize athletic performance. Adaptations that occur in skeletal muscle include muscular hypertrophy and increased cross-sectional area (CSA) with progressive loading (Bandy et al., 1990). With high force production

at fast speeds (muscular power), there is recruitment of type II fibers therefore all muscle fibers theoretically undergo hypertrophy as they are recruited through the size principle. However, selective recruitment may occur in periods where peak muscular power is required and demands high force production at fast speeds in trained lifters (Bandy et al., 1990). There is also a positive relationship between the magnitude of force produced and rate of motor unit firing (Sale, 1988). In addition to the increased muscle CSA, there is also an increase in myofibrillar volume and accumulation of contractile proteins, such as actin and myosin, as well as titin and nebulin (Rowe, 1964). Titin helps keep myosin centered during contraction and possibly controls the number of myosin molecules. Nebulin is adjacent to actin and is thought to control the number of actin monomers joined to each other. These increases in contractile proteins are seen proportionally and allows greater muscular contraction to occur. Fiber types, as well as the changes in muscle contraction and activation which will be discussed in-detail later in this review.

Periodization

The efficacy of a resistance training program can vary from individual factors or influences, but most well-designed programs implement a periodized approach. This refers to planned manipulation of training variables to optimize performance, manage fatigue, and prevent plateaus in performance outcomes (Evans, 2019; Plisk & Stone, 2003). Training variables that are commonly adjusted are volume and intensity and can play a role in the adaptations that occur throughout a training cycle. Several approaches exist, including but not limited to linear, reverse linear, and undulating periodization. The most traditional training method is “linear”, where high training volumes and low intensities gradually progress towards low training volumes and high intensities throughout the program (Evans, 2019). It should be noted that the term “linear” in this

case is a misnomer, as all periodization models are cyclical in nature. “Reverse linear” refers to the opposite strategy, starting with higher intensities and lower volumes, and gradually progressing towards low intensity/high volume (Rhea et al., 2003). Undulating periodization incorporates frequent variations in loading and may vary on a daily, weekly, or bi-weekly basis (Evans, 2019; Rhea et al., 2003).

It is expected that resistance training can provide varying levels of muscular adaptations for a wide range of training backgrounds, but the use of a periodized program optimizes these adaptations. The comparison of periodization models is frequently debated as resistance-trained individuals seek the best program to maximize strength gains and muscular hypertrophy, however there is no unequivocal periodization model that works above the others. Rhea et al. found undulating to be superior to linear (Rhea et al., 2003). However other research has shown traditional linear periodization elicited larger strength gains and individuals may benefit more over long-term training (Apel et al., 2011). When compared to reverse linear, traditional linear programming was found to increase fat-free mass and decrease in fat mass significantly, and although both programs produced significant improvements in maximum strength, linear produced greater increases (Prestes et al., 2009).

Training Adaptations

Resistance training is often utilized for increasing muscle mass, muscle size, and overall strength. To better interpret the adaptations that occur with acute and chronic training, the mechanisms are crucial to first understand. Several types of training exist as outlined in the periodization section, although different lifters utilize their training in a more specific manner. Bodybuilders tend to train using moderate or lighter loads with high reps and short rest periods to induce a large amount of metabolic stress (Schoenfeld, 2010). On the contrary, powerlifters tend

to use higher loads with longer rest and lower rep schemes. The adaptations that occur within both these two groups are generally the desired outcome for many novice or recreational lifters hoping to either increase strength or induce hypertrophy.

Muscle Hypertrophy

Hypertrophy is regulated through the proliferation of satellite cells through the addition of nuclei to muscle fibers and increasing capacity for synthesis of contractile proteins (Moss & Leblond, 1971; Vierck et al., 2000). Exercise-induced hypertrophy primarily results in increased number of sarcomeres and myofibrils that are added in parallel (Paul & Rosenthal, 2002; Schoenfeld, 2010; Tesch & Larsson, 1982). There are three main components to the hypertrophy response: muscle damage, metabolic stress, and mechanical tension (Schoenfeld, 2010).

The hypertrophic response to resistance exercise is thought to act through localized muscular damage that occurs as a consequence of loading the muscle and inducing tears in the tissue. This in turn triggers an inflammatory and rebuilding response to repair the tissue, then signaling for the proliferation of satellite cells and results in growth of the muscles. The muscular damage that occurs as a result of training is largely dependent on the overload of muscles and is fundamentally controlled by the rate of protein synthesis (Vierck et al., 2000). Eccentric contractions can cause significantly different results than concentric, with eccentric inducing more tension due to the lengthening of the muscles and enhancing the hypertrophic response (Schoenfeld, 2010). Factors not as thoroughly studied as muscle damage and mechanical tension are the roles of metabolites in the response to resistance training. The anabolic role of exercise may occur through the accumulation of various metabolites including lactate, hydrogen ions, and creatine. The alterations in growth-related transcription factors due to these metabolites may promote a more anabolic environment and favor the hypertrophic response (Schoenfeld, 2010).

Assessing Hypertrophy

There are several methods to assess hypertrophy and muscle thickness, including magnetic resonance imaging (MRI), muscle biopsy techniques, and ultrasound. Considering the high cost of MRI machines and the invasive nature of muscle biopsies (Shanely et al., 2014; Tarnopolsky et al., 2011), the more common measure using ultrasound techniques provides a cost-effective reliable approach that has been validated (Mechelli et al., 2019; Pillen & van Alfen, 2011; Storchle et al., 2017). Ultrasound uses sound waves to produce pulses and measure the distance between different tissues (Prado & Heymsfield, 2014). Depending on the density of the tissue, the ultrasound pulse is reflected and causes varying levels of acoustic impedance to differentiate between fat, muscle, and bone (Prado & Heymsfield, 2014; Storchle et al., 2017). The use of ultrasound can provide measurements of muscle thickness and CSA at different sites of the body for both an acute timepoint and for tracking chronic changes and adaptations.

Response to Exercise

In addition to the three mechanisms outlined above, several training variables also influence the adaptations that occur as a result of resistance training and should be taken into consideration when observing potential differences in hypertrophy and strength. When comparing for repetition (rep) training using a low (3-5), intermediate (9-11), and high (20-28) group, muscular hypertrophy occurred in all fiber types for the low and intermediate groups (Campos et al., 2002). Further, although all groups demonstrated shifts in fiber types from IIB to IIA, the low rep group saw greater hypertrophy compared to the high rep group. Conversely, the high rep group displayed better adaptations for submaximal, prolonged contractions, as well as increases in aerobic power and time to exhaustion (Campos et al., 2002). Additionally, the lower repetition groups significantly increased strength more than the other two groups (Campos et al.,

2002). This is expected, as it aligns with the NSCA repetition range recommendation for strength (Haff & Triplett, 2016).

The frequency of training and separation of muscle groups is a factor thought to contribute towards maximizing hypertrophy, as bodybuilders often train each muscle group only once or twice per week but training 6-7 days per week. This method of a split training program is also feasible for most recreationally active people, as they can train at a high intensity for a muscle group and allow for ample recovery. When compared between training one muscle group per day with a whole-body split routine, there was greater hypertrophy with the whole-body suggesting training muscle groups multiple times per week is superior than a single day (Zaroni et al., 2019). This was supported in a recent investigation that used a similar split vs. whole-body program over eight weeks, there were similar hypertrophy and strength increases occurred in both groups (Evangelista et al., 2021).

Equating for volume may play a role in training adaptations or differences seen not only in acute but also chronic training. A recent study by Brigatto et al. (2019) compared weekly sets per muscle group (16, 24, 32 sets) over eight weeks of training. All groups resulted in increased muscle thickness, but the 32-set group showed a higher magnitude of increase for muscle thickness and 1-RM strength in the lower body compared to the 16-set (Brigatto et al., 2022). While this suggests that a higher volume is needed for greater hypertrophy, these results are not consistent in the literature. When comparing traditional bodybuilding (hypertrophy) and powerlifting (strength) programs for eight weeks of training with equal total volume, there were no differences observed in muscle thickness of the biceps brachii (Schoenfeld et al., 2014). As expected, there were greater strength improvements in the strength group compared to hypertrophy, particularly in the 1-RM bench press (Schoenfeld et al., 2014). Additionally

accounting for variations in time of training throughout the day was initially thought to influence adaptations. However, over a 12-week resistance training study the hypertrophy responses were similar, with no significant differences in muscle CSA in the afternoon compared to the morning (Sedliak et al., 2009).

Skeletal muscle adaptations may occur early in a resistance training program, with noticeable hypertrophy seen within three weeks of beginning high-intensity training (DeFreitas et al., 2011). Using a maximum of 8-12 repetitions for three sets of a whole-body routine, CSA was increased over the duration of the 8-week training by almost ten percent compared to pre-training, and maximum voluntary contractions increased by up to 24% (DeFreitas et al., 2011). Therefore, assuming there is adequate recovery and periodization throughout a program, a hypertrophic response and subsequent increases in strength can be expected for both acute and chronic training with varying loads and repetition ranges. Although the NSCA recommendation of high repetitions for hypertrophy and low repetitions for strength is supported in the literature, further differences in prescribed intensities play a role in determining the magnitude of these responses. These variations in loading, particularly comparing high and low loads will be discussed in a later section of this review.

The relationship between muscle hypertrophy and strength is well-known. When comparing maximal voluntary contraction of the knee extensor muscles and the CSA of the rectus femoris and three vastus muscles, a correlation of 0.59 was observed (Maughan et al., 1983), supporting the concept that hypertrophic adaptations influence strength measures. The hypertrophic response and subsequent increases in strength can also induce favorable changes in body composition when combined with proper nutritional intake and adequate recovery. For many untrained populations, the thought of improving body composition and increasing muscle

size is a desired goal and usually one of the contributing factors for beginning an exercise program.

Muscle Strength and Activation

In addition to skeletal muscle adaptations, primary adaptations to resistance training include neuromuscular changes and the subsequent alteration in muscle activation with varying loading. Greater neuromuscular activation influences the brain-muscle stimulus to contract and produce force/movement (Hakkinen et al., 2003; Hakkinen et al., 1985). With resistance training, the neural response or goal is primarily to optimize athletic performance, and an increased neural drive results in maximizing the expression of muscular strength/power. This can result from an increase in motor unit synchronization (Semmler et al., 2004), increased motor unit firing rate (Aagaard et al., 2002), and/or decreased neuromuscular inhibition (Aagaard et al., 2000).

To understand the neural adaptations that can occur with resistance training, the mechanisms or factors of muscular contraction should first be outlined. The potential of a resting muscle cell is typically -70 mV and must depolarize to -55 mV for action potential. To create this increase in voltage there is an influx of sodium ions via sodium channels (Sweeney & Hammers, 2018). Contraction begins with the generation of an action potential in the motor neuron, signaling the release of acetylcholine from the terminal axon, which diffuses across the synaptic cleft and binds to an acetylcholine receptor on sarcolemma (Brenner & Eisenberg, 1987; Eisenberg & Hill, 1985). This action potential depolarizes the transverse tubules, which causes Ca^{2+} release from lateral sacs of the sarcoplasmic reticulum. Ca^{2+} binds to troponin-tropomyosin in actin filaments. This binding reveals the binding site on actin for myosin to attach. Actin activates myosin ATPase, splitting ATP into ADP and inorganic phosphate (P_i), which moves myosin into the active position to attach to actin and form a cross-bridge (Brenner & Eisenberg,

1987). A “power stroke” is then performed that shortens the sarcomere releasing the ADP and P_i. Myosin remains attached until ATP binds and frees the myosin to reattach to a new binding site (Brenner & Eisenberg, 1987). This cycle continues while Ca^{2+} concentration remains high. The removal of Ca^{2+} causes relaxation of the muscle and restores the troponin-tropomyosin configuration that inhibited myosin-actin binding (Brenner & Eisenberg, 1987; Eisenberg & Hill, 1985; McArdle et al., 2015; Sweeney & Hammers, 2018).

From a neural perspective, motor neurons innervate muscle fibers and send the signals for muscle contraction to occur. During exercise or physical activity, the spinal cord is the major processing and distribution center for motor control and impulse signaling. Each muscle consists of a motor neuron pool that innervate the muscle, and different points exist within the muscle to allow neural stimulation throughout. The number of motor units varies in the body depending on the size and function of the anatomical structure (Stifani, 2014), such as comparing the rectus femoris or quadriceps to a muscle in the foot. The motor neuron is comprised of a cell body (neuron’s control center), axon (extends from spinal cord to deliver impulse), and dendrites (branches that receive the impulse and conduct/transmit to the muscle). Impulses move down motor neurons away from the originating center through myelinated sheaths that wrap around the axon and act as insulators (Stifani, 2014). The terminal branches, or dendrites result in a motor endplate, or neuromuscular junction. This junction is where the release of acetylcholine occurs and signals the action potential to facilitate contraction.

There are three main fiber types throughout the body: type I, type IIA, and type IIX. Each motor unit contains one muscle fiber type and are classified based on twitch, tension, and fatigue characteristics (Scott et al., 2001). Type I fibers are slow-twitch, producing low force, but having high fatigue resistance. Type II fibers are fast twitch, however IIA produce moderate force with a

moderate fatigue resistance, and IIX are high force with low fatigue resistance (Scott et al., 2001). Type II fibers develop peak tension faster than type I, which supports the differences in fatigue resistance. Tension operates through an "all-or-none" principle, or all fibers of a motor unit reacting to the impulse. Motor units are recruited through the size principle, with smaller units recruited first. Type I fibers, or slow-twitch with a lower threshold for activation are the first fibers recruited, followed by IIA, then IIX where peak force is reached (Scott et al., 2001). Fatigue resistance is impacted through several mechanisms, including alterations in CNS neurotransmitters like acetylcholine, reduced glycogen content, lack of oxygen and increases in concentrations of lactate and H^+ ions, and failure of the neuromuscular junction to transmit the signal. All the aforementioned variables can adapt with varying types of training and can result in greater neuromuscular activation and muscle firing.

Assessing Strength

Using both isokinetic dynamometers and repetition max (RM) protocols are common methods of assessing muscular strength. In more practical and field settings, 1-RM protocols are used, whereas in lab settings an isokinetic dynamometer may be more common. To evaluate a true 1-RM, specific guidelines are used often outlined by the National Strength and Conditioning Association (NSCA), however training experience and proper form are crucial to obtain an accurate value (Haff & Triplett, 2016). A predicted 1-RM can also be used by completing 3-10 repetitions and using an equation to estimate the 1-RM, with both as reliable methods of assessing strength (Brzycki, 1993; Gail & Künzell, 2014; Grgic et al., 2020; Seo et al., 2012).

In a lab setting, isokinetic dynamometers are frequently used to control for form and isolate the musculature and area of the body being tested. Compared to a 1-RM squat which utilizes several muscle groups, solely the quadriceps muscles can be tested in isokinetic

movements. The use of an isokinetic dynamometer can test both maximum voluntary isometric contractions as well as isokinetic strength or dynamic muscular contraction where velocity of movement is maintained constant and controlled (Baltzopoulos & Brodie, 1989). A useful measure obtained from an isokinetic dynamometer includes peak torque, or the maximum force applied in a dynamic movement, but can also be used to assess muscular endurance. Isokinetic dynamometers have been shown to be reliable methods for measuring strength (Drouin et al., 2004; Habets et al., 2018).

Assessing Muscle Activation

To properly manage training volume, intensity, and recovery, properly monitoring resistance training and measuring the muscular activation associated is an important factor. Surface electromyography (sEMG) is frequently used to interpret force production during exercise while measuring the timing and magnitude for the designated musculature. sEMG operates through the detection of polarizations or increases/decreases in voltages that occur on the sarcolemma (Vigotsky et al., 2018). These changes in voltages indicate changes in action potentials during contractions. Practical applications of sEMG include activation timing, magnitude of activation, resting level of a muscle, and assessing or monitoring fatigue of the muscle through a movement or workout.

The traditional setup for sEMG includes electrodes placed on the skin in the appropriate positions to detect electrical activity. This signal is then amplified and filtered to lessen potential noise in the signal, and then converted from an analog signal to digital for final analysis on a computer. This setup is typically utilized in a lab setting, limiting its practical use. As research has progressed, less invasive variations of sEMG have appeared to provide an accurate monitoring tool while allowing individuals to be tested in the field rather than the lab setting.

Due to this progression, the use of sEMG has largely increased in popularity as a potential new "wearable" for monitoring performance. An example of particular interest to this review is the use of sEMG via electrodes sewn into compression material to assess the activation of larger muscle groups (Lynn et al., 2018; Smith, 2019). This may be especially applicable in team sports where it is not as feasible to implement the more invasive monitoring methods, or even for the recreational exerciser looking to optimize their own training.

The Strive Sense3 has recently emerged as a novel method of assessing internal and external loads via sEMG embedded into compression shorts (Aquino & Roper, 2018; Davarzani et al., 2020; Lynn et al., 2018). Recent research has utilized this system in basketball players over the course of a competitive season, and the shorts were able to detect differences in muscle usage and load between positions (Saucier et al., 2021). While this review mainly focuses on the adaptations that occur with resistance training, it should be noted that the use of valid and practical wearables to assess muscle activation presents a novel approach to monitoring various modes of exercise and training.

Response to Exercise

Different training methods can induce varying levels of fatigue, impacting the amplitude and activation of the intended musculature and potential adaptations. These differences can occur both acutely and chronically, and therefore should be a primary factor when considering the practical use for sEMG within workouts and over the course of a training program. When comparing 70% versus 90% 1-RM in the leg press for repetitions to failure, both peak and average EMG amplitude were greater in the 90% set (Gonzalez et al., 2017). Using the rectus femoris, vastus lateralis, and vastus medialis, these results suggest the relationship between higher loads and greater muscle activation, which may be further supported by observing loads

less than 70%. It is worth mentioning the final repetitions for each set produced similar peak EMG, implying similar levels of fatigue and motor recruitment for both 70% and 90% 1-RM towards the end of the set. Additionally, the acute use of relatively higher loads and the direct comparison is not common in the literature, as a majority focuses on low or moderate and their contrast with heavier loads.

These results are supported by Morton et al. (2019), who assessed the speed of reps to failure for both heavier and lighter loads under the premise that heavier loads are necessary for the recruitment of larger motor units and induce type II muscle fiber activation and hypertrophy. To measure the acute response to heavier and lighter loads, 30% and 80% of 1-RM maximal voluntary isotonic strength for knee extension were performed over three sets (Morton et al., 2019). Two speeds were used for each of the prescribed percentages, using either "regular" or "slow" tempos, defined as 1:1:1 or 3:1:3 for eccentric:pause:concentric, respectively (Morton et al., 2019). Compared to the 30% 1-RM, 80% produced greater peak and average sEMG amplitude for both tempos, although it should be noted average sEMG increased more in the lower load conditions throughout the set indicating greater fatigue most likely due to the significantly higher number of repetitions completed.

The measuring of the acute response is not solely limited to a single joint movement but has been extended into multi-joint movements, such as free-weight back squats. Using resistance-trained men, a single set (50% 1-RM) versus three consecutive drop sets (90%, 70%, 50% 1-RM) to failure was used to monitor activation in the vastus lateralis and medialis, as well as rating of perceived exertion (Looney et al., 2016). Compared to the standardized warm-up sets, both 50% and 70% max effort produced significantly greater amplitude in both muscles. Expectedly, the 90% set showed the highest peak amplitude in both muscle groups compared to

all other sets, supporting previous research that higher loading is needed to maximize muscular strength and hypertrophy adaptations.

Using loads starting from 30% 1-RM and increasing by 10% each set, sEMG was measuring in the biceps femoris, semitendinosus, gluteus maximum, rectus femoris, and vastus lateralis and medialis (van den Tillaar et al., 2019). Two repetitions were performed in loads up to 60%, with one repetition from 70-100% 1-RM. Overall, the only muscle group that showed a consistent increase with the loading was the rectus femoris, with greater glute activation seen in higher loads (60-80%), and only the medial and lateral vastus increased with 100%. The biceps femoris and semitendinosus both increased between from lighter to heavier loads, although these increases were only seen between varying loads and the pattern was not consistent. These results are expected, as the back squat heavily utilizes the rectus femoris and quadriceps and demonstrates the changes in muscle activation with increasing loading may not be a linear relationship (van den Tillaar et al., 2019). However, the implications of this study should be taken with caution, as all repetitions measured were conducted following a 10-minute break from 1-RM back squat testing and fatigue may have influenced the activation amplitudes observed. Additionally, these results cannot infer fatigue levels when performed to failure or when performing greater than two repetitions.

These increases with loading are also seen in the upper body musculature, as demonstrated between 60-90% of maximal voluntary contraction in the bench press (Pinto et al., 2013). There were significant differences between 60%, 70%, and 80%, although no significant change was seen between 80-90% suggesting there is no additional motor unit recruitment. However, while the differences were not statistically significant, there were linear increases with

the changes in loading, and supports the positive relationship between strength and sEMG amplitude (Pinto et al., 2013).

It is unequivocal that higher loads produce greater peak EMG amplitudes on an acute basis, but the impact on chronic activation and adaptations are more applicable for those who resistance train consistently. Following a 14-week training program, increases in isometric strength and contractile rate of force development were seen with heavy resistance training where intensity was kept between a 3- and 10-RM per set (Aagaard et al., 2002). These findings are further supported when using a 24-week program, where maximal isometric strength and force, muscle activation, and muscle biopsies to assess fiber type were performed every four weeks throughout the duration of the program. The program included three days per week of exercises targeted mainly towards the leg extensor muscles, but also incorporated a whole-body workout to keep program adherence and interest. Maximal isometric strength increased significantly and strongly correlated with the increases in neural activation/EMG of the leg extensor muscles (Hakkinen et al., 1985). This study also observed a period of detraining lasting twelve weeks, and all adaptations seen over the 24-week program were reversed towards baseline values (Hakkinen et al., 1985). It should be noted the hypertrophy of type II muscle fibers occurred during the first 12 weeks of training, with no further changes seen in the remainder of the program despite the progressive increases of repetitions and loads.

A recent study by Streczala et al. (2020) examined the impact of resistance training on muscular strength and the influence of motor unit firing rates and size on these gains. College-aged males completed eight weeks of resistance training with three lower body sessions per week, with measures of isometric strength and motor unit properties assessed pre- and post-intervention. Each session included complex multi-joint and single-joint movements for three

sets. Following the training intervention there were significant increases in muscle CSA indicating hypertrophy of the muscles and increased the amplitude and recruitment threshold (Sterczala et al., 2020). These results should be interpreted with caution considering the participants were not previously training for the last six months and the strength gains and adaptations may be attributed to novice improvements from a new stimulus.

Endocrine Response

An often omitted measure of training and the physiological response are the acute and chronic changes in hormonal biomarkers, particularly with limitations regarding funds and invasiveness of the measures. As measuring these markers have become more feasible and gained momentum in identifying potential training adaptations or issues, more literature has been released, particularly in athletes and team sports (Lee et al., 2017). Two hormones of unique interest to resistance training are cortisol and testosterone. These are often used in a ratio (testosterone/cortisol or T/C) to reflect the balance of anabolic and catabolic processes within the body, respectively. However, these hormones do not solely represent the anabolic or catabolic environment of the body, as other hormones interact within their individual pathways. Cortisol and testosterone levels can be measured through serum or salivary measures, with the salivary method as a cost-effective and less invasive measure and producing nonsignificant differences from serum values (Gozansky et al., 2005; Lane & Hackney, 2015; Lippi et al., 2016; Vining et al., 1983).

Testosterone

Testosterone is a steroid hormone produced in the Leydig cells of the testes under hypothalamic and pituitary control through the conversion from cholesterol (Vingren et al.,

2010). Compared to females, males produce an abundance of circulating testosterone when made in the testes, although it can also be produced and secreted in the zona reticularis of the adrenal glands in smaller quantities (Borer, 2012; Vingren et al., 2010).

The signaling of testosterone release from the gonads functions through the hypothalamic-pituitary-gonadal axis. The hypothalamus acts as a direct link between the nervous and the endocrine systems, secreting gonadotropin releasing hormone (GnRH). GnRH then travels to the anterior pituitary via the hypothalamic-hypophyseal portal vein to signal for the production and release of luteinizing hormone (LH) from the gonadotrophs. LH travels through the circulation to the gonads, where it binds to a G-protein-coupled receptor and signals the production of testosterone. This pathway operates in a feedback loop to regulate production and secretion of testosterone in an intensity-dependent manner.

Testosterone can circulate as free or bound to sex-hormone binding globulin (SHBG). Changes as a result of exercise and adaptations may result in increases in SHBG as well, reflecting the increased capacity of testosterone binding and inversely affecting circulating free testosterone concentrations (Kraemer & Ratamess, 2005). Testosterone is often researched in the context of its role as an androgenic-anabolic hormone, stimulating muscle protein synthesis and inhibiting protein degradation. This is turn would result in muscular hypertrophy and potentially increases in strength and power, and correlations between testosterone and isometric force suggest testosterone is an important factor in muscle strength and hypertrophy development (Ahtiainen et al., 2003).

Cortisol

Similar to testosterone, cortisol is also a steroid hormone, and is released in the adrenal cortex through the hypothalamic-pituitary-adrenal (HPA) axis. Onset of stress on the body,

regardless of physical or psychological, signals for release of corticotropin releasing hormone from the hypothalamus and travels to the anterior pituitary, where it regulates the release of adrenocorticotropic hormone (ACTH). ACTH then travels to the adrenal cortex and signals for the release of cortisol from the zona fasciculata (Charmandari et al., 2005; Mastorakos et al., 2005). This in turn acts in a feedback loop to regulate cortisol secretion depending on the intensity of the stressor (Borer, 2012). Adaptive changes occur and can present as both physical and behavioral changes (Mastorakos et al., 2005).

Cortisol can circulate as either free or bound, either to albumin (~15%) or corticosteroid-binding globulin (~75%); unbound cortisol constitutes approximately 10% and is considered the most bioactive fraction of cortisol (Kraemer & Ratamess, 2005; Kraemer et al., 2008). The central role of cortisol is as a catabolic hormone, stimulating lipolysis in adipose cells, and increases protein degradation and inhibits protein synthesis in muscle cells (Kraemer et al., 2008). It's been suggested cortisol's role is also to protect glycogen stores, and with adaptation receptors can become desensitized with uninhibition of elevated cortisol concentrations (Kraemer et al., 2008).

Acute Response

Resistance training has been shown to increase levels of testosterone (Fink et al., 2018; Kraemer & Ratamess, 2005), with a majority of the research focusing on acute changes or responses to varying resistance training methods. A more robust testosterone response following resistance training appears to be preferential for favorable changes in muscle mass, strength, and adaptations to exercise.

When measured acutely and compared to endurance training, high-intensity resistance training produced significant increases in testosterone immediately following a strength session,

with no changes in resting concentrations (Kraemer et al., 1995). When moderate- and high-intensity (70 versus 100% of 1RM) strength training sessions were compared, plasma testosterone was significantly higher during training in the high-intensity protocol, but differences throughout the remainder of the day were not significant (Raastad et al., 2000). Additionally, cortisol demonstrated large significant differences between protocols, with no changes noted during the high-intensity protocol compared to baseline, but a significant decrease in the moderate-intensity. This could be attributed to levels remaining high rather than increasing in the higher intensity, as cortisol peaks immediately upon waking, and this protocol was implemented during early morning hours (Raastad et al., 2000).

A recent study by Morton et al. investigated the impact of high- vs low-load resistance training on acute measures of serum testosterone and cortisol before and after a 12 week training program. Blood draws were taken prior to exercise, immediately post, and every 15 minutes after for up to 1 hour; this protocol was repeated at the end of the training program to assess the acute response of testosterone to exercise and potential adaptations due to training. While there were weak correlations between the hormonal response and muscle CSA and no significance noted (Morton et al., 2016), serum hormone concentrations were measured at pre- and post-training program, and do not necessarily reflect the fluctuations or adaptations that occur throughout a resistance training program. The consistent protocol as well may influence the results, as the intensity was maintained and could produce nonsignificant conclusions. The response of testosterone to resistance exercise may be influenced by several factors, including exercise type, volume, intensity, and training experience (Kraemer & Ratamess, 2005). When large muscle group exercises are used, there are larger elevations in testosterone, therefore the designing of training programs may prompt desired results (Kraemer et al., 2008).

Many studies are influenced by variations in training intensity and load, as a greater number of sets has shown substantial elevations compared to fewer sets, and shorter rest times eliciting a similar response compared to longer rest times (Kraemer & Ratamess, 2005; Kraemer et al., 2008). A study by Smilios et al. investigated varying resistance protocols and the acute response of cortisol up to 30 minutes into recovery. Three protocols were used: muscular strength, hypertrophy, and strength endurance, using 2, 4, or 6 sets in the first two protocols and 2 and 4 sets in the latter (Smilios et al., 2003). The different number of sets for each muscle group was shown not to impact the hormonal response, although a more robust response was noted overall in the hypertrophy and strength endurance programs compared to the muscular strength. This may indicate specific rep ranges may elicit a greater cortisol response, at least on an acute basis (Smilios et al., 2003). This research is not conclusive however, as Villanueva et al. found no significant change in cortisol following either a strength or hypertrophy exercise protocol with shortened rest intervals of 60 or 90 seconds (Villanueva et al., 2012).

Chronic Response

Resting concentrations can reflect the muscle tissue's current state and may fluctuate with variations in training intensity or volume. The chronic response of testosterone in resting or basal levels in men and women is not well-defined, with much of the recent research existing in team sports instead of solely resistance training. Hakkinen et al. investigated the long-term response of hormones to resistance training using weightlifters and monitoring them over four-month intervals for one (Hakkinen et al., 1987) and two years (Hakkinen et al., 1988). Increases in resting testosterone concentrations were noted following a full year of training, although more frequent sampling may show fluctuations that occurred with the variations in training intensity

and volume as these trained lifters periodized their training and prepared for competitions (Hakkinen et al., 1988).

Substantial changes in volume and intensity may present in elevated resting conditions, although it can be postulated that these elevations would return towards baseline or normal levels with the cessation of training or decrease in volume (Kraemer & Ratamess, 2005). It appears the protocol or training regime used impacts the changes or lack thereof in resting concentrations of testosterone (Kraemer & Ratamess, 2005; Vingren et al., 2010). Following a 21-week training protocol of 2 sessions per week, basal testosterone was shown to increase through the first 14 weeks, although this increase was not statistically significant.

A chronic elevation in resting cortisol concentrations generally reflects long-term heightened stress response from training. Hypoactivation of the HPA axis and stress system can result in chronically reduced secretion of regulators in the pathway (Charmandari et al., 2005), and can result in decreases in performance and present as chronic fatigue or psychological changes. The observed outcomes from the long-term training stress have not been consistent, as the pattern observed can increase, decrease, or present as no change. It should be noted the increases occurred through short-term training lasting two to three weeks, and may not reflect long-term changes in cortisol with periodized training (Hakkinen & Pakarinen, 1991). The previously mentioned studies investigating weightlifters over the course of one and two years measured resting cortisol concentrations as well and found nonsignificant increases in cortisol (Hakkinen et al., 1987, 1988). These elevations occurred around periods of preparatory phases for competitions, and reductions during periods of reduced training, potentially indicating a dose-response relationship between resistance training volume and cortisol (Hakkinen et al., 1987, 1988). This increased volume training has also exhibited increases in cortisol following two

years of periodized resistance training with a 7-day period of increased volume in the middle to simulate overreaching (Fry et al., 1994).

Significant decreases in cortisol have been observed in both trained and untrained males who completed 12 weeks of high volume resistance training (McCall et al., 1999). These decreases were also noted by Alén et al., with decreases occurring over 24 weeks resistance training, and increasing towards baseline values following the cessation of the training (Alen et al., 1988). The aforementioned elevations or decreases are not consistently seen, as in the 21-week study in untrained and strength-trained males, no significant changes were seen in basal cortisol at any point in the training (Ahtiainen et al., 2003).

Additional Considerations

Testosterone/Cortisol Ratio. The comparison of testosterone, our potently anabolic hormone, and cortisol, the catabolic hormone, are often used in a testosterone/cortisol ratio to reflect the anabolic/catabolic environment of the body. An increase in testosterone and/or a decrease in cortisol would indicate a favorable anabolic state, and the reverse would indicate an elevated catabolic state. However, this seems like an oversimplification and is only an estimate or indirect measure of the properties in skeletal tissue. Changes with training and the ratio were seen in weightlifters over the course of two years of training, and correlated with increases in muscular strength, suggesting its use and importance with high volume and high intensity training (Hakkinen et al., 1988).

Circadian Rhythms. The body's circadian rhythm may play an important role in adaptations due to training, regardless of training mode or intensity. Therefore, when observing the fluctuations in testosterone and cortisol and response to training, time of day or when an individual trains can potentially be a large confounding variable as the natural biological rhythms

over the 24-hour day can influence the levels. The natural rhythms of cortisol and testosterone follow similar patterns, peaking in the morning around waking, and decreasing throughout the day into overnight (Hayes et al., 2010). In a study lasting 11 weeks and controlling for resistance training with the only difference being morning vs. afternoon sessions (Sedliak et al., 2007), blood samples were collected prior to strength testing to assess plasma cortisol and testosterone. Although resting levels of testosterone did not differ between groups, cortisol trended towards higher values in the morning group (Sedliak et al., 2007). This could be a function of the natural increase in cortisol in the morning, as cortisol spikes immediately upon waking as it mobilizes fuels and primes the body to begin the day (Hayes et al., 2010).

Diurnal changes in ACTH and cortisol secretion can also be influenced by feeding schedules, activity, and changes in environment (Charmandari et al., 2005). However, the intensity of exercise may influence this, as a study comparing high- to moderate-intensity showed no significant differences in the magnitude of the endocrine response in females (Galliven et al., 1997). These results should be taken with caution as they only investigated in females, and sex differences play a role in responses of cortisol.

Physical vs. Psychological Stress. There have been several research studies investigating the cortisol response comparing physical to psychological stressors (Ponce et al., 2019; Singh et al., 1999). Particularly when utilizing college-aged or young adults as a research population, determining the stress on a participant is important to interpret the results accordingly. Research by Singh et al. demonstrated similar responses to psychological and physical stress, regardless of being a high or low responder (Singh et al., 1999). These similar physiological responses may contribute towards the acute or chronic changes in an individual and overshadow any potential effects due to training stimuli. Particularly in a college population, there may be variations in

stress as a student navigates the semester including midterms, assignments, and final exams. Depending on the difficulty of the course and other outside influences, this stress level can grow exponentially and influence the interpretation of the cortisol response and resistance training.

Nutrition. The endocrine response may also be influenced by nutritional intake around resistance training, as some research suggests protein and carbohydrate supplementation may acutely augment the testosterone and inhibit the cortisol response (Kraemer et al., 1998; Tsuda et al., 2020). These results are not conclusive, as other studies have shown no effect on the cortisol response with either protein or carbohydrate supplementation (Williams et al., 2002).

High- vs. Low-Load Training

Recent resistance training programming has shifted its focus towards the comparison of high- and low-load training. Higher loads include ≥ 70% of 1-RM, and low loads refer to less than 50% 1-RM (Burd et al., 2010). With heavier loads, maximal recruitment of motor units occurs and may optimize hypertrophy and strength adaptations with resistance training (Schoenfeld et al., 2016). Therefore, it is suggested heavier loads would stimulate improvements in strength and hypertrophy and would be significantly greater than lighter loads.

A comparison of 30% vs. 80% of 1-RM leg extension was performed in a crossover design over four working sets to assess EMG and the acute muscular response. Unsurprisingly the number of repetitions completed were greater in the 30% sets, as well as greater post-expression of phosphoproteins associated with hypertrophy (Haun et al., 2017). Conversely there was higher EMG amplitude found in the 80% sets, although these sets still demonstrated similar levels of phosphoproteins expressed post-exercise (Haun et al., 2017). However, these findings are not conclusive for strength or hypertrophy measures, as Fisher et al. investigated sets to voluntary failure while comparing heavier and lighter loads as 80% vs. 30% of maximum

voluntary isometric torque. Despite significantly higher reps, discomfort, and training time in the low-load training group, strength improvements were not significantly different between groups (Fisher & Steele, 2017).

Additionally, Jenkins et al. (2015) investigated the acute differences in loading and the effects on the musculature of the upper thigh in both men and women using three sets at 30% and 80% 1-RM unilateral leg extension. When comparing acute responses to higher and lower training loads (80% vs 30% respectively of 1-RM leg extension), muscle activation was found to be significantly greater in the 80% 1-RM group, although measures of muscle hypertrophy and volume were similar (Jenkins et al., 2015). It can be advocated that chronic changes due to a specific training program are more important to assess rather than acute changes within a single workout, as the balance of training and recovery is appropriately adjusted.

These acute differences between loading may contribute to the chronic adaptations observed with resistance training and may aid in determining the most benefit regimen for an individual's training goals. When using a program of three days per week for eight weeks, both high-load (8-12 reps per set) and low-load (25-35 reps per set) significantly increased muscle thickness throughout with no differences between training styles (Schoenfeld et al., 2015). However, muscular strength demonstrated significantly larger increases in back squat 1-RM and trended towards significance in bench press 1-RM in the high-load group. As expected, muscular endurance improved more in the low-load group.

In a later study of untrained men who completed two and four weeks of 30% or 80% 1-RM training to failure three days per week, there were greater muscle strength improvements in 80%, although the hypertrophic response was similar (Jenkins et al., 2016). The exercises used included forearm flexion and may not be applicable towards other muscle groups, therefore a

comprehensive training program should be utilized to assess the whole-body response to these different training styles. A follow-up experiment was conducted using leg extensors, following three and six weeks of 80% vs 30% of 1-RM leg extension. Participants completed resistance training to failure three times per week, and those who were assigned to the high-load group demonstrated greater improvements in strength and maximum voluntary isometric contraction (MVIC), although the peak twitch torque to MVIC ratio was significantly reduced (Jenkins et al., 2017). Overall, training at 80% resulted in a lower neural cost to produce the same submaximal torques as the low-load group, despite the similar hypertrophy responses.

As expected, the increases in 1-RM strength are favorable in the high-load groups in each of these studies with an overall moderate effect size (Schoenfeld et al., 2017). However, the impact on muscular hypertrophy is nearly identical resulting in interpretations as low is equal to high-load for simply increasing muscle mass. Equating for volume is an important aspect when comparing higher and lower loads, as the large difference in volume can impact the resistance training adaptations that occur (Schoenfeld et al., 2014). The inclusion of multiple exercises in a training program also allows for synergist adaptations and activating a whole-body response, compared to solely a lower body exercise, and applying the results to other muscle groups. The training experience of participants also plays a role in novice gains that occur, including motor patterns, motor recruitment, and strength gains. By utilizing a group that has experience resistance training and is familiar with most movements, it is possible to control more variables that may cloud or confound the results.

Further, a majority of the current literature does not account for changes or adjust loading during longer training interventions. With an acute study of two to four weeks of training, there may not be many load differences or adjustments to make to keep the loading and intensity

consistent. However, with chronic studies lasting six weeks or more, monitoring strength changes more frequently as well as modifying the loads appropriately may result in greater differences between heavier and lighter loads and may provide more insight into a more preferential form of training.

While it appears unequivocal that both loading schemes can induce muscular hypertrophy, high-load training tends to provide greater increases in muscular strength. Current literature does not utilize prescribed strength ranges from the NSCA of greater than 85% and using 80% is equated to an estimate of 8-RM, the lower end of the hypertrophy range (Haff & Triplett, 2016). To our knowledge there is no study that has compared high vs. low training using recommended strength ranges. Therefore, it was of current interest to this study to advance the literature and potentially determine any further significant differences between higher and lower loads on measures of strength, hypertrophy, as well as the endocrinological response with prolonged training to create a more comprehensive and wholistic picture of the resistance training response. It is hypothesized the lower load group would result in greater hypertrophy, whereas the higher loads will increase strength more. Further, it is hypothesized there would be greater increases in cortisol both at basal levels and acutely post-exercise in the lower load group, while the higher loads will result in a more robust testosterone response. Lastly, we hypothesized the high-load group will produce greater peak and average sEMG amplitudes as measured by the wearables. Secondary purposes of the current investigation aim to examine the use of EMG sensor-embedded shorts as a way of quantifying resistance training load and intensity.

CHAPTER III

METHODOLOGY

Participants

Twenty healthy, recreationally resistance-trained lifters were recruited for this study. Participants were included if they were currently training between 2-4 days per week for at least the previous six months. Participants were excluded if they had any medical conditions or injuries that would prevent them from participating. There were three drop-outs resulting in 17 participants total, with nine participants in the 30% group, and eight in the 80% group. A power analysis was conducted prior to recruitment indicating a sample size of 20 participants was needed to fully power the study. Resistance training occurred three days per week, for nine weeks total, resulting in 27 training sessions. Participants were required to attend a minimum of 85% of sessions, or 23 to remain in the study. Training sessions were missed or cancelled due to weather events (hurricanes, tornadoes, ice storms) that closed campus facilities, holidays, or conflicts that arose throughout the study. All training sessions were restricted to one participant and two study staff members to follow University-regulated COVID-19 restrictions. Dietary habits were evaluated prior to beginning the training intervention, and participants were asked not to make any large changes to their diet. If participants were currently taking supplementation of any kind (vitamins, creatine), they were asked to continue their normal habits. Participant demographics can be found in table 1.

Screening and Evaluation

All participants completed a physical activity readiness questionnaire (PAR-Q) to screen for any potential medical conditions that may prevent them from participating in this study and signed an informed consent. Participants then completed an activity questionnaire to evaluate training experience and current training habits, followed by a 3-day food recall to establish baseline caloric intake over the course of a typical week.

Experimental Design

Each participant completed familiarization sessions for isokinetic strength and all exercises performed during their training sessions. These were performed in the same week as the screening and evaluations of participants. During the second week, baseline measures were collected across two days, separated by a minimum of 48 hours. On the first day, resting salivary cortisol/testosterone, body composition, muscle thickness, and isokinetic strength were assessed. The second baseline day included predicted 1-repetition max (1-RM) testing using the protocol outlined below. These loads were used to calculate percentages and loading throughout the training protocol. These measures were collected prior to the third training session of every third week throughout the training intervention. Participants completed resistance training three days per week, for nine weeks total. Participants were randomized into either low- or high-load training (LL vs. HL), where LL (n=9) trained at 30% of 1-RM, and HL (n=8) trained at 85% of 1-RM. There were four timepoints, with baseline (T1) and testing (T2-T4) at weeks 3, 6, and 9 of the training program. The schedule of the study is outlined in figure 1. Total duration of the study was 11 weeks.

Experimental Procedures

Salivary Cortisol and Testosterone

Participants were given their respective saliva collection vial prior to each testing day. Immediately upon waking, participants filled their collection aid using unstimulated passive drool. Participants were instructed to avoid foods with high sugar, acidity, or caffeine prior to their saliva collection. Vials were labeled accordingly and refrigerated immediately upon transfer to the study team. During each testing week (weeks 3, 6 and 9), an additional saliva sample was collected immediately post-training, to result in seven collection time points in total (4 basal, 3 post-exercise).

A minimum of 1.0 mL was provided for each saliva sample. Samples were stored in a -80°C freezer until analysis. Once thawed, samples were centrifuged at 1500 rcf for 15 minutes and enzyme immunoassays were performed in duplicate following manufacturer instructions (Salimetrics, Carlsbad, CA). The sensitivity of the kit was 0.028 μg/dL for cortisol, and 0.67 pg/mL for testosterone. Mean intra assay coefficients of variation were 9.4% for cortisol and 8.5% for testosterone for duplicate samples.

To account for external stress factors, the College Student Stress Scale (CSSS) was used. An 11-point scale was used to quantify additional stress factors outside of the training study including coursework, exams, and relationships.

Muscle Thickness

An assessment of muscle thickness (MT) was conducted via ultrasound (LOGIQ e Diagnostic Ultrasound System, General Electric, Wauwatosa, WI, USA). A transducer with an imaging frequency bandwidth of 5.0-23.0 MHz and 12.7 x 53 mm footprint was used to measure MT of the biceps, triceps, pectoralis major, hamstrings, and rectus femoris. Each muscle was

measured (gain = 58 dB; image depth = 5 cm) three times and the average was used for data analysis. To ensure proper MT measurements across all participants, the following standardized sites were used. The triceps was measured at 50% of the distance from the olecranon process to the acromion process along the muscle belly. Directly horizontal from the triceps site, the biceps site was measured. During measurement of the triceps and biceps, participants were seated, relaxed, and resting their arm to the side with their elbow extended at a comfortable position. During measurement of the rectus femoris, participants were in a supine position on a training table, with their knee slightly flexed. Measurement was taken at the anterior midline of the thigh midway between the inguinal fold and the top of the patella. The hamstrings were measured at midway of the posterior aspect of the fibular head and ischial tuberosity while participants lied prone relaxing on a training table. The pectoralis major was measured at the site between the third and fourth rib under the clavicle midpoint. All measurements were conducted on the right side of the body and made by the same investigator.

Body Composition

Body composition was assessed using bio-electrical impedance analysis (InBody 370, InBody, Cerritos, CA). Testing was performed following manufacturer guidelines and electrodes were wiped down prior to teach test to ensure optimal electrical conductance. Urine specific gravity were tested to ensure similar hydration status between testing timepoints.

Isometric and Isokinetic Strength

Each participant was fitted to the isokinetic dynamometer (HumacNorm, Computer Sports Medicineicine Inc., Stoughton, MA) in accordance with manufacturer instructions. Three trials of maximal voluntary isometric contractions were assessed for both extension and flexion,

followed by isokinetic trials of three repetitions at a speed of $60°\cdot s^{-1}$ and $120°\cdot s^{-1}$. Knee and elbow extension and flexion were used to assess peak torque of the hamstrings, quadriceps, biceps, and triceps. Order of testing was elbow extension/flexion, followed by knee extension/flexion, and side was randomized during each testing timepoint.

Predicted 1-Repetition Maximum

Each participant's predicted maxes were assessed using a 3-10 repetition max for all movements used in the training protocol. All lifts performed fell within this range for all participants. All max testing procedures were completed according to guidelines by the NSCA (Haff & Triplett, 2016). These predicted maxes were used to calculate the percentage used in training sessions for each respective group (Brzycki, 1993). Each participant warmed up with light resistance that easily allowed 5-10 repetitions, followed by a 2-minute rest period. The weight was then increased between 4-9 kg (10-20 lbs) for upper body movements or 14-18 kg (30-40 lbs) for lower body movements. Participants completed 3-5 repetitions at this weight followed by a 2-minute rest. Increases were again between 4-9 kg for upper body movements or 14-18 kg for lower body movements. A near-maximal load at estimated 85% of participants perceived 1-RM was used for the third and final set. Participants were instructed to complete as many repetitions as possible with proper exercise technique and motivation from the study team. Testing was completed in the following order: back squat, deadlift, bench press, T-row, bicep curls, skullcrushers. Predicted maxes were assessed prior to the training intervention during baseline testing and again at the end of the training program.

Dietary Control

Each participant was at least four hours post-prandial for training and testing sessions. Participants were asked to refrain from the use of caffeine products or preworkout within six hours of their training session. To ensure there were no large fluctuations in dietary intake, a 3-day dietary recall was used every three weeks during the testing day. The three days used were a training weekday, a non-training weekday, and a weekend day. These three days were averaged together and used for analysis. Dietary variables used for analysis included absolute calorie intake and absolute gram intake of carbohydrates, fat, and protein. Following each training session, participants were provided 20 g of ProTYM whey isolate protein (TYM Performance, Dallas, TX) mixed with 475 ml of water.

Training Protocol

Participants arrived for three days of training per week separated by 48 hours. Each training session occurred at the same time of day and under direct supervision of a certified strength and conditioning specialist with a current certification through the NSCA. Two warm-up sets were completed for each exercise followed by three working sets at the prescribed load with repetitions performed to failure. Only two working sets were completed for bicep curls and skullcrushers. Each set was separated by a rest interval of two minutes. Order of exercises alternated between two days and are shown in table 2. Each participant created a music playlist with songs of their choosing. Order of songs was kept the same to control for any additional extrinsic motivation between training sessions. Training volume was calculated as repetitions x sets x weight. Average training volume and total training volume were separated into 3-week blocks by testing timepoint (T1-T2 = Block 1, T2-T3 = Block 2, and T3-T4 = Block 3).

Monitoring During Training

During each session, participants wore their assigned pair of compression shorts with built-in EMG sensors (Sense3, Strive Inc., Seattle, WA) to monitor muscle usage. The sensors were wet with a damp cloth prior to each session. The Sense3 used dry sEMG sensors aligned with the hamstrings (biceps femoris), glutes (gluteus), and quadriceps (rectus femoris) and reported total muscle values for each muscle group, as well as muscle and training load that were calculated following a proprietary algorithm. The EMG signals were recorded with a sample rate 1024 Hz. The analog signal was amplified and passed through a bandpass filter of 70 – 500 Hz. It then reached the microprocessor and was digitally converted by a 12-bit analog-to-digital converter. The EMG signal completed processing and was sent through third-party analysis algorithms to provide desired performance metrics. The Sense3 contained a small, detachable device located on the front of the waistband that housed the EMG processing hardware, the accelerometer, and the wireless transmission nodule. The accelerometer had a 100 Hz sampling frequency, and the device used Bluetooth transmission to transmit data to the data box connected to the associated company website with protected cloud access. Data collected from the wearable that were used for analysis included training load, muscle load, and total muscle usage for each group (quads, hamstrings, glutes; represented as the sum of sEMG values recorded over time for both left and right muscle groups). Values reported by the manufacturer represent an equivalent to μV but are expressed in arbitrary units following the developer's algorithm. The training program was separated into weekly averages for each measure.

Statistical Analysis

All experimental measures are reported as mean ± standard deviation with an alpha level set a priori at $p < 0.05$. Baseline characteristic comparisons between groups were analyzed using

an independent samples t-test. All measures including body composition, muscle thickness, cortisol, testosterone, and isokinetic strength testing were analyzed using a two-way repeated measures analysis of variance (RM-ANOVA; group x time; 2 x 4). Changes in predicted 1-RM over time and between group were analyzed using a two-way RM-ANOVA (group x time; 2 x 2). Changes from basal to acute concentrations for the hormones was calculated and analyzed using a two-way RM-ANOVA (group x time; 2 x 3). Training volume was analyzed using a two-way RM-ANOVA (group x block; 2 x 3). All wearable measures (training load, muscle load, and total muscle groups) were both separated by exercise as well as collapsed into total values across training sessions and were analyzed using a two-way RM-ANOVA (group x week; 2 x 9). Partial eta squared were calculated for all RM-ANOVAs. Partial eta squared represents the proportion of variance explained by treatment effects and can be useful in interpreting differences. Effects are presented as follows: η_p^2: 0.2 = small; η_p^2: 0.5 = moderate; η_p^2: 0.8 = large. All statistical analyses were completed using SPSS (Version 26, IBM Corporation, Armonk, NY, USA).

CHAPTER IV

RESULTS

Body Composition

Body composition results are shown in table 3. Data are presented as mean ± standard deviation for all measures. There were no significant effects or interactions in USG ($p > 0.148$) indicating hydration status was consistent between BIA measurements.

Body Mass

There was a significant time effect for an increase in body mass ($F = 3.810$, $p = 0.016$, $\eta_p^2 = 0.203$). Pairwise comparisons revealed a significant increase from T1 to T3 ($p = 0.046$) that stayed elevated at T4 ($p = 0.037$). There was no group x time interaction ($F = 1.384$, $p = 0.260$, $\eta_p^2 = 0.084$), or differences between groups ($F = 4.424$, $p = 0.053$, $\eta_p^2 = 0.228$).

Body Fat Percentage

There was no significant time effect in %BF ($F = 1.418$, $p = 0.250$, $\eta_p^2 = 0.086$). There were no significant differences between groups ($F = 2.757$, $p = 0.118$, $\eta_p^2 = 0.155$) or a group x time interaction ($F = 0.921$, $p = 0.438$, $\eta_p^2 = 0.058$).

Skeletal Muscle Mass

There were significant differences in SMM across time ($F = 4.481$, $p = 0.008$, $\eta_p^2 = 0.230$), but no significant differences between groups ($F = 3.556$, $p = 0.079$, $\eta_p^2 = 0.192$). There was a significant group x time interaction ($F = 2.831$, $p = 0.049$, $\eta_p^2 = 0.159$). Follow-ups

revealed a significant increase in the 85% group from T1 to T2 (p = 0.038), T3 (p = 0.024), and T4 (p = 0.005).

Muscle Thickness

Ultrasound results are presented in table 4. The data are presented as mean ± standard deviation for each muscle and group.

Biceps

There was a significant time effect in biceps muscle thickness (F = 8.545, $p < 0.001$, η_p^2 = 0.363). Pairwise comparisons revealed a significant increase from T1 to T3 (p = 0.012) and T1 to T4 ($p < 0.001$). There were no group differences (F = 0.499, p = 0.689, η_p^2 = 0.103) or group x time interaction (F = 0.725, p = 0.542, η_p^2 = 0.046).

Triceps

There were significant differences in muscle thickness of the triceps across time (F = 5.781, p = 0.002, η_p^2 = 0.278), with pairwise comparisons revealing a significant increase from T1 to T4 (p = 0.009). Additionally, there was a significant group x time interaction (F = 4.627, p = 0.007, η_p^2 = 0.236), with significance solely in the 85% group from T1 to T2 (p = 0.026), T3 (p = 0.003), and T4 (p = 0.003). There were no significant differences between groups (F = 3.024, p = 0.103, η_p^2 = 0.168).

Chest (Pectoralis Major)

There were no significant differences in muscle thickness of the chest across time (F = 0.303, p = 0.823, η_p^2 = 0.020), group (F = 3.245, p = 0.092, η_p^2 = 0.178), or a group x time interaction (F = 1.220, p = 0.342, η_p^2 = 0.220).

Hamstrings (Biceps Femoris)

There was a significant difference for time in hamstring muscle thickness (F = 3.306, p = 0.028, η_p^2 = 0.181). Pairwise comparisons revealed a significant increase from T1 to T2 (p = 0.020), T3 (p = 0.049), and T4 (p = 0.036). There were no differences between groups (F = 1.066, p = 0.318, η_p^2 = 0.066), or a group x time interaction (F = 1.688, p = 0.183, η_p^2 = 0.101).

Quadriceps (Rectus Femoris)

There was a significant time effect for muscle thickness in the quadriceps (F = 5.603, p = 0.002, η_p^2 = 0.272). Pairwise comparisons revealed a significant increase from T1 to T2 (p = 0.003) and T1 to T3 (p = 0.016), before decreasing from T3 to T4 (p = 0.011). There were no group differences (F = 2.889, p = 0.110, η_p^2 = 0.162) or group x time interaction (F = 0.791, p = 0.505, η_p^2 = 0.050).

Elbow Isometric Strength

Data for both right and left elbow extension and flexion are presented in table 5.

Extension

There were no significant time effects in left elbow extension (F = 3.308, p = 0.054, η_p^2 = 0.433) or right elbow extension (F = 1.896, p = 0.180, η_p^2 = 0.304). There was a significant group effect in right elbow extension (F = 4.751, p = 0.046, η_p^2 = 0.241) with the 30% group being stronger, but no difference in left (F = 4.117, p = 0.061, η_p^2 = 0.215). There were no group x time interactions for left (F = 1.034, p = 0.410, η_p^2 = 0.193) or right (F = 0.561, p = 0.650, η_p^2 = 0.115).

Flexion

There were no significant time effects in elbow flexion for left ($F = 1.871$, $p = 0.184$, $\eta_p^2 = 0.302$) or right ($F = 0.935$, $p = 0.452$, $\eta_p^2 = 0.177$). There was a significant group effect in elbow flexion for left ($F = 5.707$, $p = 0.030$, $\eta_p^2 = 0.276$) with the 30% group having higher values, but no significance in the right ($F = 3.517$, $p = 0.080$, $\eta_p^2 = 0.190$). There were no group x time interactions observed for left ($F = 1.048$, $p = 0.404$, $\eta_p^2 = 0.195$) or right ($F = 0.111$, $p = 0.952$, $\eta_p^2 = 0.025$).

Knee Isometric Strength

Data for both right and left knee extension and flexion are presented in table 6.

Extension

There were no significant time effects in left ($F = 0.624$, $p = 0.612$, $\eta_p^2 = 0.126$) or right knee extension ($F = 0.713$, $p = 0.561$, $\eta_p^2 = 0.141$). There was a significant group effect in left ($F = 6.395$, $p = 0.023$, $\eta_p^2 = 0.299$) and right ($F = 5.425$, $p = 0.034$, $\eta_p^2 = 0.266$) with the 30% group having higher peak torque than the 85%. There were no group x time interactions for left ($F = 1.924$, $p = 0.176$, $\eta_p^2 = 0.307$) or right ($F = 1.336$, $p = 0.306$, $\eta_p^2 = 0.236$).

Flexion

There were no significant time effects in knee flexion for left ($F = 0.360$, $p = 0.783$, $\eta_p^2 = 0.077$) or right ($F = 1.466$, $p = 0.270$, $\eta_p^2 = 0.253$). There was no significant group effect in knee flexion for left ($F = 3.696$, $p = 0.074$, $\eta_p^2 = 0.198$) or right ($F = 3.514$, $p = 0.080$, $\eta_p^2 = 0.190$). There were no group x time interactions observed for left ($F = 0.545$, $p = 0.660$, $\eta_p^2 = 0.112$) or right ($F = 0.943$, $p = 0.448$, $\eta_p^2 = 0.179$).

Elbow Isokinetic Strength

Data for both right and left elbow extension and flexion for both speeds are presented in table 7.

60°·s^{-1} Extension

There was no significant time effect seen in 60°·s^{-1} for left (F = 3.119, p = 0.063, η_p^2 = 0.419) elbow extension. However, a significant time effect was seen in right (F = 4.331, p = 0.025, η_p^2 = 0.500) elbow extension. Pairwise comparisons revealed a significant decrease from T1 to T2 (p = 0.003) that was maintained at T3 (p = 0.005) and T4 (p = 0.002). There was also a significant group effect in right (F = 4.877, p = 0.043, η_p^2 = 0.245), and left (F = 4.987, p = 0.041, η_p^2 = 0.249) with 30% having higher peak torque values. There were no significant group x time interactions for either left (F = 0.548, p = 0.658, η_p^2 = 0.112) or right (F = 0.013, p = 0.981, η_p^2 = 0.013) extension.

60°·s^{-1} Flexion

There were no significant time effects seen in 60°·s^{-1} for left (F = 0.575, p = 0.642, η_p^2 = 0.117) or right (F = 0.792, p = 0.520, η_p^2 = 0.155) elbow flexion. There was a significant group effect in left (F = 5.173, p = 0.038, η_p^2 = 0.256) with the 30% group having higher peak torque, and no significant difference for right (F = 3.783, p = 0.071, η_p^2 = 0.201). There were no significant group x time interactions for either left (F = 1.068, p = 0.396, η_p^2 = 0.198) or right (F = 0.518, p = 0.677, η_p^2 = 0.107) flexion at 60°·s^{-1}.

120°·s^{-1} Extension

There was no significant time effect seen in 120°·s^{-1} for left (F = 1.368, p = 0.291, η_p^2 = 0.242) elbow extension. However, a significant time effect was seen in right (F = 3.988, p =

0.032, η_p^2 = 0.479) elbow extension. Pairwise comparisons revealed a significant decrease from T1 to T2 (p = 0.006) that was maintained at T3 (p = 0.003) and T4 (p = 0.013). There was also no group effect in right (F = 2.966, p = 0.106, η_p^2 = 0.165), but a significant group difference in left (F = 5.047, p = 0.040, η_p^2 = 0.252) with 30% having higher peak torque values. There were no significant group x time interactions for either left (F = 0.233, p = 0.872, η_p^2 = 0.051) or right (F = 1.234, p = 0.337, η_p^2 = 0.222) extension at 120°·s^{-1}.

120°·s^{-1} Flexion

There were no significant time effects seen in 120°·s^{-1} for left (F = 0.115, p = 0.952, η_p^2 = 0.026) or right (F = 1.535, p = 0.252, η_p^2 = 0.262) elbow flexion. There were also no group effects in left (F = 3.767, p = 0.071, η_p^2 = 0.201), or right (F = 1.631, p = 0.221, η_p^2 = 0.098). There were no significant group x time interactions for either left (F = 1.051, p = 0.403, η_p^2 = 0.195) or right (F = 0.826, p = 0.503, η_p^2 = 0.160) flexion at 120°·s^{-1}.

Knee Isokinetic Strength

Data for both right and left knee extension and flexion for both speeds are presented in table 7.

60°·s^{-1} Extension

There was a significant time effect seen in 60°·s^{-1} for left (F = 8.777, p = 0.002, η_p^2 = 0.669) and right (F = 6.513, p = 0.006, η_p^2 = 0.600) knee extension. Pairwise comparisons in the left leg revealed a significant decrease from T1 to T2 (p = 0.006) that was maintained at T3 (p < 0.001) and T4 (p < 0.001). Pairwise comparisons for right leg mirrored this pattern with a significant decrease seen from T1 to T2 (p = 0.009) that was maintained at T3 (p = 0.002) before returning towards baseline at T4 (p = 0.058). There was also no significant group effect in left (F

= 4.145, $p = 0.060$, $\eta_p^2 = 0.217$), or right (F = 4.089, $p = 0.061$, $\eta_p^2 = 0.214$) knee extension. There were no significant group x time interactions for either left (F = 2.757, $p = 0.085$, $\eta_p^2 = 0.389$) or right (F = 2.373, $p = 0.118$, $\eta_p^2 = 0.354$) knee extension at $60°\cdot s^{-1}$.

$60°\cdot s^{-1}$ Flexion

There was no significant time effect seen in $60°\cdot s^{-1}$ for left knee flexion (F = 1.346, $p = 0.303$, $\eta_p^2 = 0.237$), but there was a significant time effect in the right knee flexion (F = 5.358, $p = 0.013$, $\eta_p^2 = 0.553$). Pairwise comparisons revealed a significant decrease from T1 to T2 ($p < 0.001$) that was maintained at T3 ($p = 0.003$) and T4 ($p = 0.005$). There were no significant group effects in either the left (F = 1.811, $p = 0.198$, $\eta_p^2 = 0.108$) or right knee flexion (F = 1.251, $p = 0.281$, $\eta_p^2 = 0.077$). There were no significant group x time interactions for either left (F = 0.619, $p = 0.615$, $\eta_p^2 = 0.125$) or right (F = 0.820, $p = 0.506$, $\eta_p^2 = 0.159$) flexion.

$120°\cdot s^{-1}$ Extension

There was no significant time effect seen in $120°\cdot s^{-1}$ for left knee extension (F = 2.133, $p = 0.145$, $\eta_p^2 = 0.330$). However, a significant time effect was seen in the right knee (F = 5.283, $p = 0.013$, $\eta_p^2 = 0.549$). Pairwise comparisons revealed a significant decrease from T1 to T3 ($p = 0.016$). There was also no group effect in left (F = 4.455, $p = 0.052$, $\eta_p^2 = 0.229$) or right (F = 3.956, $p = 0.065$, $\eta_p^2 = 0.209$). There were no significant group x time interactions for either left (F = 1.006, $p = 0.421$, $\eta_p^2 = 0.188$) or right (F = 1.092, $p = 0.387$, $\eta_p^2 = 0.201$) knee extension at $120°\cdot s^{-1}$.

$120°\cdot s^{-1}$ Flexion

There were no significant time effects seen in $120°\cdot s^{-1}$ for left (F = 0.536, $p = 0.666$, $\eta_p^2 = 0.110$) or right (F = 2.388, $p = 0.116$, $\eta_p^2 = 0.355$) knee flexion. There were also no group effects

in left (F = 2.237, $p = 0.156$, $\eta_p^2 = 0.130$), or right (F = 2.076, $p = 0.170$, $\eta_p^2 = 0.122$). There were no significant group x time interactions for either left (F = 0.680, $p = 0.580$, $\eta_p^2 = 0.136$) or right (F = 0.961, $p = 0.441$, $\eta_p^2 = 0.181$) flexion at $120°\cdot s^{-1}$.

Predicted 1-Repetition Max

Predicted 1-RM changes are shown in figure 2. There was no significant time effect for squat (F = 1.513, $p = 0.238$, $\eta_p^2 = 0.092$). A significant time effect was seen for increases in all other lifts (deadlift: F = 8.492, $p = 0.011$, $\eta_p^2 = 0.361$; bench: F = 7.354, $p = 0.016$, $\eta_p^2 = 0.329$; T-row: F = 27.601, $p < 0.001$, $\eta_p^2 = 0.648$; bicep curl: F = 20.916, $p < 0.001$, $\eta_p^2 = 0.582$; skullcrushers: F = 7.260, $p = 0.017$, $\eta_p^2 = 0.326$).

There was a significant group difference in squat (F = 7.151, $p = 0.017$, $\eta_p^2 = 0.323$), deadlift (F = 7.418, $p = 0.016$, $\eta_p^2 = 0.331$), and bicep curl (F = 7.266, $p = 0.017$, $\eta_p^2 = 0.326$). There were no differences between groups for bench (F = 2.853, $p = 0.112$, $\eta_p^2 = 0.160$), T-row (F = 2.918, $p = 0.108$, $\eta_p^2 = 0.163$), or skullcrushers (F = 0.660, $p = 0.429$, $\eta_p^2 = 0.042$).

There were significant group x time interactions for squat (F = 8.058, $p = 0.012$, $\eta_p^2 = 0.349$), deadlift (F = 5.644, $p = 0.031$, $\eta_p^2 = 0.273$), and bicep curl (F = 8.145, $p = 0.012$, $\eta_p^2 = 0.352$). Follow-ups revealed a significant increase from pre to post training in the 85% group for squat ($p = 0.014$), deadlift ($p = 0.002$), and bicep curls ($p < 0.001$). There were no significant changes from pre to post training in these three lifts for the 30% group. There were no significant group x time interactions for bench (F = 1.519, $p = 0.237$, $\eta_p^2 = 0.092$), T-row (F = 1.760, $p = 0.204$, $\eta_p^2 = 0.105$), or skullcrushers (F = 0.818, $p = 0.380$, $\eta_p^2 = 0.052$).

Hormonal Markers

There were no significant differences in the CSSS across time (F = 0.541, p = 0.657, η_p^2 = 0.035), between groups (F = 0.845, p = 0.373, η_p^2 = 0.053), and no significant group x time interaction (F = 0.569, p = 0.638, η_p^2 = 0.037).

Cortisol

There were no significant effects in basal levels across time (F = 0.149, p = 0.929, η_p^2 = 0.033) or group (F = 0.162, p = 0.693, η_p^2 = 0.011). Additionally, there was no significant group x time interaction (F = 0.424, p = 0.739, η_p^2 = 0.089).

There was no significant effect across time (F = 0.312, p = 0.737, η_p^2 = 0.043) or between groups (F = 1.398, p = 0.255, η_p^2 = 0.085) for acute post-exercise cortisol measurements. There was no significant group x time interaction (F = 1.352, p = 0.290, η_p^2 = 0.162). Data for basal cortisol are presented in figure 3.

When comparing change scores (acute post-exercise – basal value) for each testing timepoint, there was no significant time effect (F = 0.430, p = 0.659, η_p^2 = 0.058) or differences between groups (F = 0.528, p = 0.479, η_p^2 = 0.034). There was no significant group x time interaction (F = 2.149, p = 0.154, η_p^2 = 0.235). Changes from pre to post are represented in figure 4.

Testosterone

There were no significant effects in basal levels for time (F = 0.201, p = 0.894, η_p^2 = 0.044) or group (F = 0.268, p = 0.612, η_p^2 = 0.018). Additionally, there was no significant group x time interaction (F = 1.075, p = 0.394, η_p^2 = 0.199).

There was no significant effect across time (F = 0.362, $p = 0.703$, $\eta_p^2 = 0.049$) or between groups (F = 1.563, $p = 0.230$, $\eta_p^2 = 0.094$) for acute post-exercise testosterone measurements. There was a significant group x time interaction (F = 4.609, $p = 0.029$, $\eta_p^2 = 0.397$). Follow-ups revealed a significant difference at week 3, with the 30% reporting higher testosterone concentrations compared to the 85% group ($p = 0.046$). Pairwise comparisons also revealed a significant decrease from week 3 to week 6 in the 30% group ($p = 0.015$), with no significant changes in the 85% group. Data for basal testosterone are presented in figure 5.

When comparing change scores for each testing timepoint (acute post-exercise – basal value), there was no significant time effect (F = 0.623, $p = 0.551$, $\eta_p^2 = 0.082$) or differences between groups (F = 0.004, $p = 0.952$, $\eta_p^2 = 0.000$). There was no significant group x time interaction (F = 3.481, $p = 0.059$, $\eta_p^2 = 0.332$). Changes from pre to post are represented in figure 6.

Testosterone/Cortisol Ratio

There was no significant effect for time (F = 0.761, $p = 0.616$, $\eta_p^2 = 0.314$) or between groups (F = 1.402, $p = 0.255$, $\eta_p^2 = 0.085$). There was no significant group x time interaction (F = 0.198, $p = 0.970$, $\eta_p^2 = 0.106$).

Dietary Intake

Dietary intake data can be found in table 9. There were no differences across timepoints for total calories consumed (F = 0.858, $p = 0.487$, $\eta_p^2 = 0.165$), carbohydrate intake (F = 0.538, $p = 0.665$, $\eta_p^2 = 0.110$), fat intake (F = 1.127, $p = 0.374$, $\eta_p^2 = 0.206$), or protein intake (F = 0.604, $p = 0.624$, $\eta_p^2 = 0.122$).

There were no group differences for total calories consumed (F = 1.988, $p = 0.179$, $\eta_p^2 = 0.117$), carbohydrate intake (F = 3.115, $p = 0.098$, $\eta_p^2 = 0.172$), fat intake (F = 0.814, $p = 0.381$, $\eta_p^2 = 0.051$), or protein intake (F = 1.324, $p = 0.268$, $\eta_p^2 = 0.081$).

There were no group x time interactions for total calories consumed (F = 0.298, $p = 0.827$, $\eta_p^2 = 0.064$) carbohydrate intake (F = 3.157, $p = 0.061$, $\eta_p^2 = 0.421$), fat intake (F = 0.366, $p = 0.779$, $\eta_p^2 = 0.078$), or protein intake (F = 2.185, $p = 0.139$, $\eta_p^2 = 0.335$).

Wearable Technology

All wearable technology data can be found in table 10.

Squat

There was no significant time effect in training load (F = 1.381, $p = 0.204$, $\eta_p^2 = 0.032$). There were significant changes across time for muscle load and usage for all muscle groups (muscle load: F = 3.173, $p = 0.002$, $\eta_p^2 = 0.070$; quads: F = 6.009, $p < 0.001$, $\eta_p^2 = 0.124$; hamstrings: F = 2.723, $p = 0.006$, $\eta_p^2 = 0.060$; glutes: F = 2.571, $p = 0.010$, $\eta_p^2 = 0.057$). There were also significant group differences between all variables (training load: F = 202.493, $p < 0.001$, $\eta_p^2 = 0.374$; muscle load: F = 23.785, $p < 0.001$, $\eta_p^2 = 0.066$; quads: F = 21.061, $p < 0.001$, $\eta_p^2 = 0.058$; hamstrings: F = 14.611, $p < 0.001$, $\eta_p^2 = 0.041$; glutes: F = 28.248, $p < 0.001$, $\eta_p^2 = 0.077$). There were no significant group x week interactions in any variables apart from quad usage (training load: F = 1.095, $p = 0.366$, $\eta_p^2 = 0.025$; muscle load: F = 1.767, $p = 0.082$, $\eta_p^2 = 0.040$; quads: F = 2.940, $p = 0.003$, $\eta_p^2 = 0.065$; hamstrings: F = 1.848, $p = 0.067$, $\eta_p^2 = 0.042$; glutes: F = 1.110, $p = 0.356$, $\eta_p^2 = 0.026$).

Deadlift

There was a significant time effect in all variables (training load: F = 2.455, $p = 0.013$, $\eta_p^2 = 0.050$; muscle load: F = 3.380, $p < 0.001$, $\eta_p^2 = 0.067$; quads: F = 3.805, $p < 0.001$, $\eta_p^2 = 0.075$; hamstrings: F = 3.082, $p = 0.002$, $\eta_p^2 = 0.062$; glutes: F = 2.816, $p = 0.005$, $\eta_p^2 = 0.057$). There were also significant group differences between all variables (training load: F = 225.709, $p < 0.001$, $\eta_p^2 = 0.376$; muscle load: F = 49.649, $p < 0.001$, $\eta_p^2 = 0.117$; quads: F = 28.465, $p < 0.001$, $\eta_p^2 = 0.071$; hamstrings: F = 52.833, $p < 0.001$, $\eta_p^2 = 0.124$; glutes: F = 44.790, $p < 0.001$, $\eta_p^2 = 0.107$). There was also a significant group x week interaction in all variables apart from training load (training load: F = 0.931, $p = 0.491$, $\eta_p^2 = 0.020$; muscle load: F = 2.047, $p = 0.040$, $\eta_p^2 = 0.042$; quads: F = 2.540, $p = 0.011$, $\eta_p^2 = 0.052$; hamstrings: F = 2.278, $p = 0.022$, $\eta_p^2 = 0.046$; glutes: F = 1.959, $p = 0.050$, $\eta_p^2 = 0.040$).

Bench Press

There was no significant time effect in any variable (training load: F =1.899, $p = 0.059$, $\eta_p^2 = 0.043$; muscle load: F = 0.980, $p = 0.452$, $\eta_p^2 = 0.023$; quads: F = 1.668, $p = 0.105$, $\eta_p^2 = 0.038$; hamstrings: F = 1.050, $p = 0.398$, $\eta_p^2 = 0.024$; glutes: F = 0.634, $p = 0.749$, $\eta_p^2 = 0.015$). There were no significant group differences in any variable (training load: F = 2.472, $p = 0.117$, $\eta_p^2 = 0.007$; muscle load: F = 0.757, $p = 0.385$, $\eta_p^2 = 0.002$; quads: F = 0.947, $p = 0.331$, $\eta_p^2 = 0.003$; hamstrings: F = 0.947, $p = 0.331$, $\eta_p^2 = 0.003$; glutes: F = 0.003, $p = 0.958$, $\eta_p^2 = 0.000$). There were also no significant group x week interactions in any variables apart from quad usage (training load: F = 0.938, $p = 0.485$, $\eta_p^2 = 0.022$; muscle load: F = 1.764, $p = 0.083$, $\eta_p^2 = 0.040$; quads: F = 2.192, $p = 0.028$, $\eta_p^2 = 0.049$; hamstrings: F = 1.060, $p = 0.391$, $\eta_p^2 = 0.046$; glutes: F = 1.766, $p = 0.083$, $\eta_p^2 = 0.040$).

T-Row

There were significant changes over time in all variables apart from training load (training load: F = 0.842, $p = 0.566$, $\eta_p^2 = 0.019$; muscle load: F = 2.728, $p = 0.006$, $\eta_p^2 = 0.060$; quads: F = 3.497, $p < 0.001$, $\eta_p^2 = 0.075$; hamstrings: F = 2.487, $p = 0.012$, $\eta_p^2 = 0.055$; glutes: F = 3.519, $p < 0.001$, $\eta_p^2 = 0.076$). There were no significant group differences in any variable apart from training load (training load: F = 21.705, $p < 0.001$, $\eta_p^2 = 0.060$; muscle load: F = 0.067, $p = 0.795$, $\eta_p^2 = 0.000$; quads: F = 0.547, $p = 0.460$, $\eta_p^2 = 0.002$; hamstrings: F = 0.000, $p = 0.991$, $\eta_p^2 = 0.000$; glutes: F = 0.073, $p = 0.787$, $\eta_p^2 = 0.000$). There were also no significant group x week interactions in any variables apart from training load (training load: F = 4.751, $p < 0.001$, $\eta_p^2 = 0.100$; muscle load: F = 0.819, $p = 0.586$, $\eta_p^2 = 0.019$; quads: F = 1.042, $p = 0.404$, $\eta_p^2 = 0.024$; hamstrings: F = 1.152, $p = 0.328$, $\eta_p^2 = 0.026$; glutes: F = 0.855, $p = 0.554$, $\eta_p^2 = 0.020$).

Bicep Curls

There were significant time effects in training load (F = 2.839, $p = 0.005$, $\eta_p^2 = 0.062$) and hamstrings usage (F = 2.274, $p = 0.022$, $\eta_p^2 = 0.051$). There were no significant time effects in any other variable (muscle load: F = 1.763, $p = 0.083$, $\eta_p^2 = 0.040$; quads: F = 1.602, $p = 0.123$, $\eta_p^2 = 0.036$; glutes: F = 1.815, $p = 0.073$, $\eta_p^2 = 0.041$). There were significant group differences in training load, muscle load, and usage in the glutes (training load: F = 26.747, $p < 0.001$, $\eta_p^2 = 0.073$; muscle load: F = 6.205, $p = 0.013$, $\eta_p^2 = 0.018$; glutes: F = 4.177, $p = 0.042$, $\eta_p^2 = 0.012$). There were no significant group differences for usage of quads or hamstrings (quads: F = 2.068, $p = 0.151$, $\eta_p^2 = 0.006$; hamstrings: F = 2.766, $p = 0.097$, $\eta_p^2 = 0.008$). There were also no significant group x week interactions in any variable (training load: F = 1.782, $p = 0.079$, $\eta_p^2 = 0.040$; muscle load: F = 1.407, $p = 0.192$, $\eta_p^2 = 0.032$; quads: F = 1.343, $p = 0.221$,

η_p^2 = 0.030; hamstrings: F = 1.833, *p* = 0.070, η_p^2 = 0.047; glutes: F = 1.208, *p* = 0.293, η_p^2 = 0.027).

Skullcrushers

There was no significant time effect in any variable (training load: F = 1.209, *p* = 0.293, η_p^2 = 0.028; muscle load: F = 0.635, *p* = 0.749, η_p^2 = 0.015; quads: F = 1.230, *p* = 0.280, η_p^2 = 0.028; hamstrings: F = 0.648, *p* = 0.737, η_p^2 = 0.015; glutes: F = 0.796, *p* = 0.606, η_p^2 = 0.018). There were no significant group differences in any variable (training load: F = 3.632, *p* = 0.058, η_p^2 = 0.011; muscle load: F = 2.090, *p* = 0.149, η_p^2 = 0.006; quads: F = 0.346, *p* = 0.557, η_p^2 = 0.001; hamstrings: F = 1.656, *p* = 0.199, η_p^2 = 0.005; glutes: F = 0.908, *p* = 0.341 η_p^2 = 0.003). There were also no significant group x week interactions in any variable (training load: F = 0.519, *p* = 0.842, η_p^2 = 0.012; muscle load: F = 1.064, *p* = 0.388, η_p^2 = 0.024; quads: F = 1.056, *p* = 0.394, η_p^2 = 0.024; hamstrings: F = 1.622, *p* = 0.117, η_p^2 = 0.037; glutes: F = 0.721, *p* = 0.673, η_p^2 = 0.017).

Total Session

There was a significant time effect for usage of all muscle groups (quads: F = 3.241, *p* = 0.001, η_p^2 = 0.069; hamstrings: F = 2.069, *p* = 0.038, η_p^2 = 0.045; glutes: F = 2.801, *p* = 0.005, η_p^2 = 0.060). There were no significant differences across time noted for training load (F = 1.404, *p* = 0.193, η_p^2 = 0.031) or muscle load (F = 1.750, *p* = 0.086, η_p^2 = 0.039). There were significant group differences in both training load (F = 46.476, *p* < 0.001, η_p^2 = 0.118) and muscle load (F = 4.977, *p* = 0.026, η_p^2 = 0.014), with follow-ups revealing a higher training load in the 30% group, but a higher muscle load in the 85% group. There were no significant differences between groups noted for use in any muscle group (quads: F = 0.018, *p* = 0.892, η_p^2 = 0.000; hamstrings: F =

0.249, $p = 0.618$, $\eta_p^2 = 0.001$; glutes: F = 0.230, $p = 0.632$, $\eta_p^2 = 0.001$). There were no significant group x time interactions for any variable except hamstrings usage (training load: F = 0.996, $p = 0.439$, $\eta_p^2 = 0.022$; muscle load: F = 1.136, $p = 0.338$, $\eta_p^2 = 0.025$; quads: F = 1.534, $p = 0.144$, $\eta_p^2 = 0.034$; hamstrings: F = 1.976, $p = 0.049$, $\eta_p^2 = 0.043$; glutes: F = 0.863, $p = 0.548$, $\eta_p^2 = 0.019$).

Training Volume

Both average and total training volume are shown in table 11.

Average Training Volume

There was a significant group effect in average training volume with the 30% group having higher training volumes compared to the 85% group across all lifts (squat: F = 36.263, $p < 0.001$, $\eta_p^2 = 0.707$; deadlift: F = 29.080, $p < 0.001$, $\eta_p^2 = 0.660$; bench: F = 29.089, $p < 0.001$, $\eta_p^2 = 0.660$; T-Row: F = 13.196, $p = 0.002$, $\eta_p^2 = 0.468$; bicep curls: F = 32.695, $p < 0.001$, $\eta_p^2 = 0.686$; skullcrushers: F = 70.100, $p < 0.001$, $\eta_p^2 = 0.824$).

There were no significant time effects for squat (F = 1.106, $p = 0.344$, $\eta_p^2 = 0.069$) and deadlift (F = 1.819, $p = 0.180$, $\eta_p^2 = 0.108$). There were significant time effects in bench (F = 6.257, $p = 0.005$, $\eta_p^2 = 0.294$), with pairwise comparisons revealing slight increases from Block 1 to Block 2 ($p = 0.015$) and block 3 ($p = 0.016$). There were significant time effects in T-row (F = 8.895, $p < 0.001$, $\eta_p^2 = 0.372$), with increases from Block 1 to Block 2 ($p = 0.018$) and block 3 ($p = 0.004$). There were significant time effects in bicep curls (F = 5.092, $p = 0.012$, $\eta_p^2 = 0.253$), with increases from Block 1 to Block 3 ($p = 0.023$). There were also significant time effects in skullcrushers (F = 4.968, $p = 0.014$, $\eta_p^2 = 0.249$) with increases from Block 1 to Block 2 ($p = 0.006$).

There were no group x time interactions in squat (F = 0.466, $p = 0.632$, $\eta_p^2 = 0.030$), bench (F = 1.843, $p = 0.176$, $\eta_p^2 = 0.109$), T-row (F = 3.728, $p = 0.036$, $\eta_p^2 = 0.199$), bicep curls (F = 0.841, $p = 0.441$, $\eta_p^2 = 0.053$), or skullcrushers (F = 1.710, $p = 0.198$, $\eta_p^2 = 0.102$). There was a significant group x time interaction for deadlift (F = 4.742, $p = 0.016$, $\eta_p^2 = 0.240$). Pairwise comparisons revealed a significant increase from Block 1 to Block 2 ($p = 0.007$) in the 30% group, with no differences seen in the 85% group.

Total Training Volume

There was a significant group effect in total training volume with the 30% group having higher training volumes compared to the 85% group across all lifts (squat: F = 39.359, $p < 0.001$, $\eta_p^2 = 0.724$; deadlift: F = 28.140, $p < 0.001$, $\eta_p^2 = 0.652$; bench: F = 28.639, $p < 0.001$, $\eta_p^2 = 0.656$; T-Row: F = 13.718, $p = 0.002$, $\eta_p^2 = 0.478$; bicep curls: F = 34.197, $p < 0.001$, $\eta_p^2 = 0.695$; skullcrushers: F = 67.360, $p < 0.001$, $\eta_p^2 = 0.818$).

There were no significant time effects for squat (F = 0.258, $p = 0.774$, $\eta_p^2 = 0.017$), deadlift (F = 0.607, $p = 0.552$, $\eta_p^2 = 0.039$), bench (F = 1.545, $p = 0.230$, $\eta_p^2 = 0.093$), bicep curls (F = 3.145, $p = 0.058$, $\eta_p^2 = 0.173$), or skullcrushers (F = 1.173, $p = 0.323$, $\eta_p^2 = 0.073$). There was significant time effect in T-row (F = 5.699, $p = 0.008$, $\eta_p^2 = 0.275$) with increases from Block 1 to Block 3 ($p = 0.001$).

There were no group x time interactions in any of the lifts (squat: F = 0.206, $p = 0.815$, $\eta_p^2 = 0.014$; deadlift: F = 2.253, $p = 0.123$, $\eta_p^2 = 0.131$; bench: F = 0.364, $p = 0.698$, $\eta_p^2 = 0.024$; T-row: F = 1.806, $p = 0.182$, $\eta_p^2 = 0.107$; bicep curls: F = 0.545, $p = 0.585$, $\eta_p^2 = 0.035$; skullcrushers: F = 0.454, $p = 0.640$, $\eta_p^2 = 0.029$).

CHAPTER V

DISCUSSION

The purpose of this investigation was to examine and determine significant differences in strength, hypertrophy, as well as the endocrinological response with prolonged training using a high- or low-load. Secondary purposes of the current investigation were to assess and quantify training load for resistance training using EMG sensor-embedded compression shorts. It was hypothesized the 30% group would result in a more robust cortisol response acutely following training, as well greater hypertrophy and higher muscle usage when recorded by the wearables. Further, it was hypothesized the 85% group would present greater increases in strength as measured by predicted maxes and the isokinetic dynamometer, as well as large increases in basal testosterone over time and following training.

Overall, the results of this investigation indicate there are similar levels of hypertrophy that occur regardless of loading scheme when repetitions are performed to failure. Additionally, there were greater increases in strength in the 85% group when using predicted 1-RM, but few significant changes when looking at isometric and isokinetic strength. However, this may be due to isolation of a single muscle group or motion compared to a whole-body movement. The endocrine data demonstrates no changes in both basal cortisol and testosterone, as well as the acute post-exercise response. Finally, the wearable shorts were demonstrated to assess differences between groups in an overall training session, but when split by lifts the data were not consistent for both changes over each week and between groups.

There were similar increases in body mass over time for both groups, with a similar pattern observed in skeletal muscle mass (SMM). However, the group x time interaction in SMM revealed the increases were largely driven by the 85% group, with a significant increase from T1 to all other time points for SMM. There were no significant changes in the 30% group, suggesting the increases in body mass may be attributed mainly to increases in SMM in the 85% group. This aligns with the body mass results, as the 85% group reached a significant increase at T4 ($p = 0.018$). Despite this significance, the increases in SMM did not influence %BF.

Additionally, the ultrasound data demonstrated similar hypertrophy in all muscles apart from the pectoralis major. The only group x time interaction occurred in triceps, with muscle thickness in the 85% group increasing across all timepoints with no significant changes in the 30% group. Interestingly, this pattern in the pairwise comparisons occurred in several other muscles despite the lack of significant differences between groups or group x time interactions. In the biceps, a significant increase was noted in both groups by T4, however the 85% group reached significance three weeks earlier at T3. The hamstrings (biceps femoris) demonstrated no significant hypertrophy in the 30% group, while the 85% increased from T1 to T2 and T3 before a small decrease at T4. These comparisons within each group support the group x time interaction seen in SMM, as the increases in the 85% group may be significant overall, but not when separated into individual muscle groups.

While the timing of the participant's training may play a larger role in the hormone response, previous research has not shown differences in the hypertrophy response (Sedliak et al., 2009). Additionally, similar hypertrophy has been noted in previous research using equated volume between hypertrophy and strength programs (Schoenfeld et al., 2014). This was further supported as the methods were altered to use high and low loads, with no differences in training

styles or muscle thickness over eight weeks (Schoenfeld et al., 2015). However, in the current study, the training volume reflected large group differences, which was expected following the number of repetitions performed in training.

The 85% group typically completed up to 6-8 repetitions on their first set, followed by a steady decrease over the remaining sets, whereas the 30% completed approximately 40 repetitions on average. There were no significant changes across time in a majority of the lifts when collapsed across groups, indicating the participants maintained their average and total training volumes. Only T-row and bicep curls presented with an increase in average and/or total training volume. While recent research has also found a greater number of repetitions completed in their low load group, there was also greater expression of phosphoproteins associated with hypertrophy (Haun et al., 2017). While these differences suggest greater hypertrophy as a result of low-load lifting, the protocol only used leg extensions, whereas the current investigation used whole-body lifts which may contribute to the lack of significant group differences in hypertrophy. These differences in protocols between the current study and other high- vs. low-load studies may influence several measures of the study, particularly in the strength changes.

Despite the lack of significant group x time interactions in all lifts apart from deadlifts and T-row, follow-ups revealed a pattern in all other lifts with increased average volume in the 30% group. This may reflect an adaptation to the training program as participants were able to complete more repetitions. The only decreased noted was in the 30% group for average squat volume, with a decrease from T2 to T3. This may be a result of slight fatigue in the movement with the high number of repetitions performed, as the squat targets more muscle groups compared to several of the other lifts in the current training program.

The changes in predicted 1-RM testing from pre- to post-training are of particular interest from a practical perspective. Performing a true 1-RM with a recreationally trained athlete is not always feasible, therefore a predicted 1-RM can be a useful tool in monitoring changes in strength over time. The lack of significance in squat over time can be attributed to the large standard deviation, as the change from pre to post training was 4.16 ± 19.13 kg. However, there were still significant increases across all other lifts and overall strength improvements following the training program regardless of loading scheme. The current study incorporated a whole-body routine that utilized several muscle groups to allow synergist adaptations.

Interestingly, there were only group differences in three of the lifts (squat, deadlift, and bicep curls). This persisted in the group x time interactions, and while there were increases in the 85% group, the 30% showed nonsignificant increases. Additional pairwise comparisons also revealed the only lift the 30% significantly improved in from pre to post training was in T-row ($p = 0.012$), while the 85% group demonstrated significance in all lifts ($p < 0.026$). This aligns with our hypothesis of the higher load group resulting in greater strength improvements even when repetitions are performed to failure. It should be noted these increases also occurred with a lower training volume in the 85% group for all lifts performed. The results of our investigation are supported by multiple research projects using a high- vs. low-load approach, who also demonstrated greater strength improvements with higher loads using 1-RM methods (Schoenfeld et al., 2015; Schoenfeld et al., 2014).

The comparison of practical strength testing with laboratory methods revealed a large contrast in the current study, but has also been seen in previous research (Gentil et al., 2017). The lack of significant changes in the dynamometer results despite the changes in the predicted 1-RM may be a result of isolating a single joint compared to a whole-body lift. This is reflective

of the parts vs sum, as the predicted 1-RM use stabilizers and recruits other muscle groups to perform a lift, while the dynamometer isolated the knee or elbow joint. Previous research investigating changes in MVIC have shown greater improvements in the high-load group (Jenkins et al., 2016; Jenkins et al., 2017). However, these results are not unequivocal, as the lack of changes in isometric extension/flexion seen in the current study are supported by a previous study using unilateral training of the knee extensors. (Fisher & Steele, 2017).

The significant group differences noted in the dynamometer data simply denote the 30% group was stronger than the 85% group when collapsed across timepoints. Due to the nature of this investigation, participants were randomly assigned into their respective groups, and this resulted in the 30% group having higher overall peak torque values compared to the 85% group. What is of more interest to the investigation is the changes over time and the patterns or trends observed. While two strength speeds were used, the changes in isokinetic strength are of particular interest in the $60°\cdot s^{-1}$ speed, as this reflects more of a strength speed compared to the $120°\cdot s^{-1}$ (Coyle et al., 1981; Jenkins et al., 1984; Laforest et al., 1990). MVIC is used to assess strength using a high- vs. low-load approach more often, but some research has used isokinetic strength and found similar patterns seen in the current study.

Interestingly, the significant decreases seen across time in both the elbow and knee joints were largely driven by the 30% group. Despite the lack of significant group x time interactions, follow-ups revealed significant decreases in the 30% groups from baseline. These decreases have also been seen in previous research that showed decreased isokinetic torque in all velocities (60, 180, and $300°\cdot s^{-1}$) following four sets of leg extensions to failure (Haun et al., 2017). The decreases in $120°\cdot s^{-1}$ knee extension revealed significant decreases in left from T1 to T2 (p =

0.018) that remained significant decreased at T3 ($p = 0.016$) and T4 ($p = 0.046$). In the left leg it only decreased from T1 to T2 ($p = 0.046$) before returning towards baseline.

In the $60°\cdot s^{-1}$ knee extension, pairwise comparisons revealed significant decreases in the left leg from T1 to T2 ($p < 0.001$), that remained depressed at T3 ($p < 0.001$), and T4 ($p < 0.001$), with no significant changes in the 85% group. This pattern was similar in the right leg, apart from a nonsignificant T4 ($p = 0.130$). This was also mirrored in right knee flexion, with pairwise comparisons revealing significant decreases from T1 to T2 ($p < 0.001$), T3 ($p = 0.004$), and T4 ($p = 0.003$), with no significant changes in the 85% group. This could be indicative of fatigue over the course of the training program, as the higher number of repetitions with limited rest prior to testing days could yield lower peak torque values. Additionally, the decreases may also be a result of the increases in volume in the 30% group and may also explain why the only decreases in training volume occurs in squats. Considering the squat heavily uses knee extension and flexion, and the resulting decreases in volume as well as strength at $60°\cdot s^{-1}$, the 30% may have simply experienced localized fatigue. Despite both groups training to failure the 85% group demonstrated no statistically significant changes over time, suggesting a maintenance of isokinetic strength at both 60 and $120°\cdot s^{-1}$. The significance found in a single limb may be attributed to the participants shifting their weight or usage differences. Follow-up investigations into the wearables and muscle usage differences between sides could partially explain these results.

A secondary aim of this investigation was to monitor and quantify resistance training intensity and load using wearable technology. Interestingly, the Strive data presented with significant changes in time, although these were not consistent between lifts. The sporadic pattern of the decreases over time were noted for several measures and only seen in all measures

in the deadlift. However, the group x time interactions were only consistently seen with squats and deadlifts, as these lifts heavily utilize the lower body. There is currently no upper body version of the compression shorts to address the musculature being used during the lifts. This can reduce the training load seen in the lifts, particularly in bench press, row, and the arms, and the overall training load and muscle load may be underestimated as a result. This may also explain why there were so few significant changes or group differences in the lifts that utilize more upper body. While splitting the training sessions up by lifts may be helpful in determining fatigue and ratios, a coach or trainer may find total session values more practical, as they represent overall loads.

With regards to changes over time in total session values, only the measures of muscle group usage demonstrated significance, with a decrease from week 1 to week 9 when collapsed between groups, and no changes in training or muscle load. The opposite pattern was shown in group differences, with only muscle and training load showing significant differences and the muscle groups showing no significant differences. It should be noted the training load was higher in the 30% group, but muscle load was higher in the 85% group. This suggests that a lower training load in the 85% group still resulted in higher muscle usage or load throughout, despite both training groups performing their repetitions to failure. This is supported by previous research demonstrating greater peak and average EMG amplitudes with higher load (Gonzalez et al., 2017; Looney et al., 2016), which may contribute more to the muscle load data compared to the traditional training load.

This was also demonstrated by Morton et al. (2019) who used a 30 vs 80% repetitions-to-failure approach and found greater peak and average amplitudes in the 80% group. However, this study also found greater increases in average amplitude in the lower load group and greater

fatigue (Morton et al., 2019), which may also be a contribution of the higher training volumes and the onset of fatigue not only acutely within the training sessions but over the course of the 9 weeks of training. The group differences in training load also parallels the training volume data, where overall there were lower training volumes in the 85% group. This suggests that evaluating the training load using the shorts may be reflective of training volume differences between athletes and can be a useful monitoring tool particularly in team sports. Further, the muscle load data may suggest the wearable technology's ability to differentiate between intensities. Gonzalez et al. (2017) also found the final repetitions for each set produced similar peak EMG values, suggesting similar levels of fatigue and motor recruitment towards the end of the set. While this research used a 70 vs 90% difference in loading, it would be interesting to use the wearables in the current study to determine if the fatigue was similar towards the end of each set despite the large difference in loading.

Although the research on sEMG-embedded compression shorts has been mixed regarding its validity, the Strive Sense3 shorts have demonstrated good concurrent validity and interrater reliability when compared to laboratory EMG methods (Davarzani et al., 2020). The Strive shorts have several limitations that should be addressed. The placement of the sensors embedded in the shorts varied between participants, due to anatomical differences and brand. The data produced from the shorts thus is represented as "quadriceps", "hamstrings", and "glutes" to account for these individual differences. Further, while the placement can vary between participants, each participant was given an assigned pair of shorts to keep placement consistent within their own sessions. Participants' shorts were fitted based on personal preference, which could result in a looser or tighter fit and consequently less accurate sEMG readings.

Contrary to our hypotheses, the cortisol and testosterone data were not significant for either basal or acute post-exercise levels. There were no large fluctuations in the 85% group for basal cortisol, and while not significant, the 30% group presented a pattern of decreasing cortisol over time, particularly in the final resting timepoint and the final post-exercise sample. This may suggest an adaptation to the training and may also help explain the higher training volume in the 30% group in the second and third training blocks as participants adapted to the stimulus. Interestingly, at the final post-exercise timepoint there were two participants that heavily pulled the averages and created a noticeable group difference, although still not statistically significant. In particular, participant 3 had received their second COVID-19 vaccine the day prior and the cortisol values were almost doubled, although the overall extent to how this influenced the cortisol results is not well-known.

It was hypothesized the 30% group would present with higher cortisol levels following training. Previous research demonstrated a more robust response in hypertrophy and strength endurance programs compared to solely muscular strength (Smilios et al., 2003). Similar to the findings in the current study, other investigators have found no changes despite differences in training volume (Villanueva et al., 2012). Interestingly, the patterns of cortisol changes from basal to post between the two groups were inverse. At the first testing timepoint, the 85% group showed decreases and the 30% group had increases. By the 6-week timepoint, this effect was flipped, and by the end of the training program, the differences approached significance (p = 0.076). This may reflect the 30% group experiencing a novel stimulus initially, as a majority of the participants in the current study had never lifted with lighter loads and/or trained to failure. The lack of significant changes seen from basal levels to immediately post exercise may be attributed to the timing of sessions, particularly in the 30% group. Out of nine participants in the

group, six had morning sessions, while only two out of eight participants in the 85% group were in the morning. Cortisol peaks immediately upon waking (Kraemer & Ratamess, 2005), therefore while the early training sessions may have presented an appropriate stimulus, the concentrations of cortisol were already high and was just maintaining the higher secretion rate. To strengthen the current study, the addition of a sample immediately post-training would assess true within day pre-post differences, especially in participants who trained in the afternoon or evening.

The aforementioned differences in training volume may also contribute to the lack of differences between groups, particularly in the testosterone findings. From a monitoring perspective, the use of testosterone to reflect the training volume and status is beneficial, as a chronic decrease may indicate the training exceeds the body's tolerance (Lee et al., 2017). The fluctuations in testosterone are thought to impact the muscle signaling following exercise (Griggs et al., 1989), and previous research has demonstrated a low load, high volume group (30%) had greater muscle protein synthesis than a high load, low volume group (90%) following unilateral leg extensions (Burd et al., 2010). If volume were to be equated in the current study, particularly at the higher volume in the 30% group, there may be greater increases in testosterone with the 85%. This may augment the decreases already seen and result in significant group differences. Due to the nature of this study, it was not possible to equate volume between groups as the participants trained to failure and the typical discrepancies in repetitions completed.

While the changes from basal to post-exercise do not necessarily reflect true changes due to the peaking of cortisol early in the morning, testosterone does not fluctuate as much and can reflect a true change. Interestingly, a slight decrease was noted following training sessions in both groups. Although nonsignificant, these decreases reflect an interesting pattern not often reported in research as a majority demonstrate increases following exercise (Kraemer et al.,

1995; Raastad et al., 2000). However, some studies have reported an acute decrease following resistance training and repetitions to failure (Cardaci et al., 2020). This may be attributed to receptor uptake, as the current study measured free testosterone in saliva and the signaling for androgen receptor binding following exercise is upregulated. This upregulation has been shown to increase in response to resistance exercise (Bamman et al., 2001; Gonzalez et al., 2015), which in turn would decrease the circulating free testosterone. Additional and frequent intervals following the cessation of training could show a rebound and increase in testosterone, as Cardaci et al. (2020) demonstrated an increase back towards pre-training values after 24 hours.

Several factors have been known to influence hormonal markers. The nutritional intake around training suggests protein and carbohydrate impacts performance and can acutely inhibit the cortisol and augment the testosterone response (Arent et al., 2020; Kraemer et al., 1998; Tsuda et al., 2020). To account for this, both dietary intake and timing of meals around training were controlled. Each participant arrived a minimum of four hours post-prandial, and the lack of changes in dietary intake following the 3-day recall indicate the dietary habits of the participants were maintained over the course of the training study. Further, it should be noted the interpretation of the hormone data in the current investigation cannot necessarily translate from males to females, as they do not necessarily respond the same (Kraemer et al., 1991). Therefore, the application of these results can simply be applied to the male population.

An additional factor is the comparison of physical and psychological stressors, as there have been several studies on the impact on cortisol that demonstrated a similar stress response (Ponce et al., 2019; Singh et al., 1999). To account for this, the use of the college stress scale was used to assess for outside stressors the participants may experience. There were no significant changes in the college stress scale, suggesting stress levels were consistent over the training

program and had minimal influence on the resulting cortisol values. This maintenance of stress may contribute to the consistent basal levels of cortisol seen throughout the training program. The maintenance of intensity in the current study may have also played a role in the lack of significant changes in both cortisol and testosterone. as previous research as noted variations in training intensity and load have elicited more robust responses in hormonal markers (Kraemer & Ratamess, 2005; Kraemer et al., 2008).

The ratio of testosterone to cortisol (T:C) was also of interest using the current markers to assess the anabolic/catabolic balance within the body. Increases in testosterone and/or decreases in cortisol would indicate a favorable anabolic state, and the reverse would indicate an elevated catabolic state. While this is a suggested estimate of training status overtraining status (Lee et al., 2017; Urhausen et al., 1995), there were no significant changes or differences in the current study, further supporting the overall maintenance seen in the performance measures. Although this ratio can be a useful tool, future research would benefit from the use of several other markers to further assess the changes in testosterone and cortisol. When measuring circulating levels of free testosterone, sex hormone binding globulin (SHBG) and albumin, a blood protein, could help demonstrate stress and recovery changes as well as receptor uptake. SHBG binds testosterone and could be an indicator of the uptake following the training protocol (Lee et al., 2017). Additionally, albumin is a testosterone carrier protein circulating in the blood and can be a useful tool when measuring testosterone and the circulating levels, as free testosterone levels would decrease when bound and reflect as high albumin levels (Czub et al., 2019).

Several limitations exist in the current study. Firstly, while the use of a 3-day recall for nutritional intake can be a valid measure, it still relies on a participant's recall abilities and may under or overestimate their intake. Participants were also told they could not participate in any

other form of structured activity or exercise outside of the training program. If a participant completed additional exercise outside of the study, it may have influenced their training sessions as an additional source of fatigue. To control for this, participants were asked prior to every session if they have completed any additional activity. Finally, as mentioned in the hormone results, the participants trained at different times throughout, with the earliest starting at 7:00 am and the latest at 7:30 pm. While this may impact the hormonal results more than any other performance measure, having each participant train at the same time each session minimized diurnal variations (Galliven et al., 1997; Sedliak et al., 2007; Sedliak et al., 2009).

This investigation presented a novel research question using a true strength training range according to the NSCA, whereas a majority of the high- vs. low-load literature uses a hypertrophy range. When considering the group differences using the wearables and the training volume, it is interesting there were no further group differences in any of the performance or measures following the cessation of the training program. Similar to the findings of the current investigation, other research using 1-RM unilateral leg extensions with 30 vs. 80% showed muscle usage was found to be significantly greater in the 80% 1-RM group, with measures of muscle hypertrophy and volume being similar (Jenkins et al., 2015).

CHAPTER VI

CONCLUSION

The purpose of this investigation was to examine and determine significant differences in strength, body composition, and hormonal markers over nine weeks of high- or low-load resistance training. Secondary purposes of the current investigation were to assess and quantify training load for resistance training using EMG sensor-embedded compression shorts. It was hypothesized the 30% group would result in greater hypertrophy, higher muscle usage as recorded by the wearables, and a more robust cortisol response. Further, it was hypothesized the 85% group would present greater increases in strength as well as greater increases in testosterone over time and following training.

Our results suggest similar hypertrophy occurred regardless of training volume and training load. While SMM was found to significantly increase in the 85% group, %BF did not change significantly, suggesting overall there were no differences in body composition. Although while there were no significant results in the isometric peak torque values, there were several significant decreases in the isokinetic values in the 30% group, reflecting small declines in strength at $60°\cdot s^{-1}$ and $120°\cdot s^{-1}$ while the 85% group maintained their strength. From a practical perspective, the 85% group improved more in a majority of their predicted maxes for each lift. Despite training to failure in each training session, this still reflects the heavier loads to result in greater improvements in strength.

The endocrine data revealed no significant changes in both basal cortisol and testosterone. This suggests similar stress and recovery overall. Additionally, while nonsignificant for differences pre-post in either marker, the pattern for testosterone of slight decreases may be an effect of receptor uptake and additional monitoring over a longer time interval should be used to track the changes over a full recovery window. Finally, the use of the sEMG compression shorts in the current investigation indicated the ability to differentiate between training intensity as reflected as “muscle load”. However, this was found in the overall training session data, and the division into individual lifts did not show consistent variations.

Overall, this study suggests training to failure at 30% or 85% 1-RM results in similar hypertrophy and body composition changes, but larger increases in strength particularly when using field methods. The monitoring of hormones can provide better insight into the physiological response, but more frequent or specific time-course monitoring is needed in recovery. It should be acknowledged the current investigation used recreationally-trained lifters; therefore, the results may not be translated to athletic populations or novice lifters. Future research should target both of these populations, as there may be more discrepancies in newer lifters that typically benefit from novice gains or may provide a novel stimulus by changing up the training style of advanced lifters.

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APPENDIX A

TABLES

Table A1

Subject Demographics

CHARACTERISTIC	30%	85%
Age (yrs)	20.3 ± 1.6	20.5 ± 3.7
Weight (kg)	85.4 ± 14.6	69.4 ± 15.0
Height (cm)	176.39 ± 9.34	173.99 ± 6.22
Years Training	2.7 ± 1.1	2.0 ± 1.2

Data are presented as mean ± standard deviation for both groups.

Table A2

Order of Exercises

DAY 1	**DAY 2**
Back Squat	Deadlift
Deadlift	Back Squat
Bench Press	T-Row
T-Row	Bench Press
Biceps Curl	Skullcrushers
Skullcrushers	Biceps Curl

Exercises were completed with 120 seconds of rest between sets. Two warm-up sets were used prior to each exercise with 5 repetitions in the first set and 3 repetitions in the second set. The 30% group completed one warm up set at 20% 1-RM, and the second at 25% 1-RM. The 85% group completed the first warm up set at 55% 1-RM and the second at 75% 1-RM. Three working were completed for back squat, deadlift, bench press, and T-row. Two working sets were completed for bicep curls and skullcrushers.

Table A3

Body Composition

MEASURE	GROUP	T1	T2	T3	T4
Body Mass (kg)	Overall	77.88 ± 16.54	78.36 ± 16.24	79.02 ± 16.77 *	79.10 ± 16.10 *
	85%	69.40 ± 15.04	70.34 ± 14.76	70.92 ± 14.98	71.54 ± 15.31
	30%	85.42 ± 14.60	85.50 ± 14.66	86.22 ± 15.56	85.82 ± 14.34
Body Fat (%)	Overall	16.6 ± 7.4	16.0 ± 7.21	16.4 ± 7.07	16.6 ± 6.9
	85%	13.6 ± 8.31	13.1 ± 7.98	13.9 ± 7.60	13.5 ± 7.1
	30%	19.2 ± 5.6	18.6 ± 5.7	18.7 ± 6.1	19.3 ± 5.7
SMM (kg)	Overall	36.85 ± 6.33	37.31 ± 6.26	37.37 ± 6.16	37.46 ± 6.01
	85%	33.84 ± 5.06	34.50 ± 4.92 *	34.52 ± 4.98 *	35.02 ± 5.12 *
	30%	39.53 ± 6.37	39.82 ± 6.50	39.90 ± 6.23	39.64 ± 6.17

Data are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. There was a significant group x time interaction for SMM ($p < 0.05$), and a significant time effect in body mass ($p < 0.05$). * Significantly different from T1 ($p < 0.05$).

Table A4

Muscle Thickness

MUSCLE	GROUP	T1	T2	T3	T4
Biceps (cm)	Overall	3.16 ± 0.70	3.27 ± 0.57	3.35 ± 0.68 *	3.46 ± 0.58 *
	85%	2.95 ± 0.64	3.13 ± 0.63	3.23 ± 0.68	3.34 ± 0.56
	30%	3.35 ± 0.73	3.39 ± 0.51	3.47 ± 0.70	3.58 ± 0.61
Triceps (cm)	Overall	3.37 ± 0.92	3.43 ± 0.84	3.51 ± 0.81	3.62 ± 0.85 *
	85%	2.88 ± 0.76	3.08 ± 0.64 *	3.26 ± 0.75 *	3.32 ± 0.69 *
	30%	3.81 ± 0.85	3.75 ± 0.91	3.74 ± 0.83	3.89 ± 0.92
Chest (cm)	Overall	2.09 ± 0.71	2.11 ± 0.70	2.11 ± 0.56	2.05 ± 0.54
	85%	1.75 ± 0.39	1.85 ± 0.43	1.84 ± 0.44	1.85 ± 0.39
	30%	2.39 ± 0.82	2.34 ± 0.83	2.34 ± 0.57	2.23 ± 0.61
Hamstrings (cm)	Overall	3.20 ± 0.52	3.33 ± 0.48 *	3.38 ± 0.46 *	3.42 ± 0.50 *
	85%	3.02 ± 0.42	3.20 ± 0.42	3.36 ± 0.43 *	3.27 ± 0.43
	30%	3.37 ± 0.61	3.44 ± 0.52	3.39 ± 0.51	3.55 ± 0.56
Quadriceps (cm)	Overall	2.23 ± 0.44	2.39 ± 0.47 *	2.37 ± 0.40 *	2.25 ± 0.44
	85%	2.07 ± 0.37	2.18 ± 0.41	2.23 ± 0.44	2.07 ± 0.47
	30%	2.37 ± 0.48	2.58 ± 0.45	2.49 ± 0.34	2.42 ± 0.36

Data are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. There were significant changes over time in biceps, triceps, hamstrings, and quadriceps ($p < 0.05$). There were no group differences, but a significant group x time interaction for triceps ($p < 0.05$). * Significantly different from T1 ($p < 0.05$).

Table A5

Isometric Elbow Extension/Flexion

SIDE	GROUP	T1	T2	T3	T4
Left Extension	Overall	71.29 ± 23.60	57.94 ± 16.63	60.18 ± 20.79	62.71 ± 16.53
(N·m)	85%	62.00 ± 17.10	52.38 ± 12.69	49.63 ± 12.68	58.13 ± 16.36
	30%	79.56 ± 26.35	62.89 ± 18.80	69.56 ± 22.66	66.78 ± 16.52
Right Extension	Overall	71.18 ± 23.05	57.94 ± 16.63	60.06 ± 16.43	58.76 ± 14.00
(N·m)	85%	60.00 ± 17.82	53.88 ± 11.91	49.63 ± 12.68	54.50 ± 17.00
	30%*	81.11 ± 23.44	65.56 ± 18.53	61.22 ± 16.18	63.11 ± 12.33
Left Flexion	Overall	80.35 ± 20.50	75.29 ± 18.82	72.12 ± 20.00	72.88 ± 14.64
(N·m)	85%	68.25 ± 13.66	66.88 ± 14.36	61.63 ± 18.28	67.63 ± 15.24
	30%*	91.11 ± 20.01	82.78 ± 19.85	81.44 ± 17.31	77.56 ± 13.16
Right Flexion	Overall	80.59 ± 18.84	76.47 ± 17.62	76.53 ± 19.71	75.18 ± 14.93
(N·m)	85%	72.00 ± 16.36	69.25 ± 11.45	69.25 ± 16.97	68.63 ± 11.40
	30%	88.22 ± 18.34	82.89 ± 20.20	83.00 ± 20.62	81.00 ± 15.84

Peak torque values are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. All units are N·m. There were no significant changes over time for any measure. There were significant group differences for right extension and left flexion ($p < 0.05$; denoted by *), with the 30% group demonstrating higher peak torque values overall. There were no significant group x time interactions.

Table A6

Isometric Knee Extension/Flexion

SIDE	GROUP	T1	T2	T3	T4
Left Extension	Overall	293.65 ± 80.61	286.82 ± 78.88	276.47 ± 68.02	273.71 ± 62.59
(N·m)	85%	239.75 ± 66.43	249.00 ± 76.19	244.38 ± 57.40	257.75 ± 74.64
	30%*	341.56 ± 60.40	320.44 ± 68.28	305.00 ± 66.51	287.89 ± 49.79
Right Extension	Overall	292.18 ± 70.99	302.59 ± 64.33	291.76 ± 64.34	301.24 ± 56.90
(N·m)	85%	245.13 ± 62.63	275.50 ± 57.89	266.38 ± 61.22	288.19 ± 61.68
	30%*	334.00 ± 49.66	326.67 ± 62.91	314.33 ± 61.50	312.89 ± 53.11
Left Flexion	Overall	102.00 ± 36.16	97.47 ± 25.96	104.41 ± 40.71	105.47 ± 30.65
(N·m)	85%	86.13 ± 43.66	88.75 ± 31.57	93.25 ± 44.54	91.00 ± 25.47
	30%	116.11 ± 21.72	105.22 ± 18.21	114.33 ± 36.66	118.33 ± 30.26
Right Flexion	Overall	102.29 ± 35.47	102.88 ± 30.65	114.47 ± 35.81	115.00 ± 28.27
(N·m)	85%	85.75 ± 42.89	95.50 ± 35.50	96.63 ± 34.95	106.38 ± 29.95
	30%	117.00 ± 19.75	109.44 ± 25.95	130.33 ± 29.92	122.67 ± 25.93

Peak torque values are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. All units are N·m. There were no significant changes over time for any measure. There were significant group differences for left and right extension ($p < 0.05$; denoted by *), with the 30% group demonstrating higher peak torque values overall. There were no significant group x time interactions.

Table A7

Isokinetic Elbow Extension/Flexion

SIDE/SPEED	GROUP	T1	T2	T3	T4
Left Extension	Overall	55.76 ± 15.94	46.59 ± 13.07	47.35 ± 14.18	46.35 ± 10.45
60°·s^{-1}	85%	49.13 ± 14.22	41.63 ± 11.86	40.13 ± 11.78	41.00 ± 8.64
(N·m)	30%	61.67 ± 15.74	51.00 ± 13.12	53.78 ± 13.50	51.11 ± 9.96
Right Extension	Overall	58.06 ± 15.69	47.24 ± 13.33 *	45.00 ± 10.80 *	45.53 ± 10.67 *
60°·s^{-1}	85%	51.75 ± 16.44	42.00 ± 12.86	40.38 ± 10.38	40.13 ± 9.91
(N·m)	30%	63.67 ± 13.44	51.89 ± 12.60	49.11 ± 9.93	50.33 ± 9.30
Left Flexion	Overall	55.35 ± 15.34	54.29 ± 14.08	52.53 ± 14.71	53.53 ± 13.50
60°·s^{-1}	85%	47.25 ± 14.74	47.13 ± 13.11	45.28 ± 14.16	49.00 ± 12.71
(N·m)	30%	62.56 ± 12.51	60.67 ± 12.21	59.00 ± 12.53	57.56 ± 13.57
Right Flexion	Overall	59.71 ± 15.17	56.24 ± 13.45	55.71 ± 13.48	55.24 ± 11.70
60°·s^{-1}	85%	51.50 ± 15.91	51.50 ± 13.78	50.75 ± 14.08	50.13 ± 12.80
(N·m)	30%	67.00 ± 10.56	60.44 ± 12.37	60.11 ± 11.97	59.78 ± 9.00
Left Extension	Overall	48.94 ± 17.56	40.94 ± 10.09	41.53 ± 12.94	40.94 ± 10.58
120°·s^{-1}	85%	42.38 ± 17.06	37.00 ± 11.07	35.75 ± 8.78	35.75 ± 7.81
(N·m)	30%	54.78 ± 16.75	44.44 ± 8.19	46.67 ± 14.30	45.56 ± 10.93
Right Extension	Overall	51.29 ± 15.87	41.41 ± 11.15 *	38.65 ± 7.95 *	40.24 ± 9.66 *
120°·s^{-1}	85%	45.38 ± 16.31	38.00 ± 12.47	37.25 ± 9.18	35.63 ± 8.94
(N·m)	30%	56.56 ± 14.30	44.44 ± 9.51	39.89 ± 7.01	44.33 ± 8.75
Left Flexion	Overall	46.71 ± 16.97	45.82 ± 11.03	45.41 ± 12.81	46.12 ± 10.65
120°·s^{-1}	85%	38.75 ± 14.68	41.13 ± 10.64	39.63 ± 10.84	43.13 ± 10.89
(N·m)	30%	53.78 ± 16.22	50.00 ± 10.12	50.56 ± 12.74	48.78 ± 10.31
Right Flexion	Overall	51.94 ± 14.29	47.18 ± 10.07	46.82 ± 10.02	47.71 ± 9.43
120°·s^{-1}	85%	46.00 ± 12.54	44.75 ± 11.99	45.00 ± 12.34	45.38 ± 10.58
(N·m)	30%	57.22 ± 14.30	49.33 ± 8.12	48.44 ± 7.83	49.78 ± 8.35

Peak torque values are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. All units are N·m. There were significant changes over time for right extension at both 60 and 120°·s^{-1}. There were significant group differences for left/right extension and right flexion for 60°·s^{-1} ($p < 0.05$) and left extension for 120°·s^{-1} ($p < 0.05$). There were no significant group x time interactions. * Significantly different from T1 ($p < 0.05$).

Table A8

Isokinetic Knee Extension/Flexion

SIDE/SPEED	GROUP	T1	T2	T3	T4
Left Extension	Overall	211.53 ± 53.00	183.94 ± 44.93 *	177.18 ± 52.40 *	172.94 ± 39.69 *
60°·s^{-1}	85%	175.00 ± 41.01	170.88 ± 43.14	157.39 ± 46.56	160.50 ± 44.59
(N·m)	30%	244.00 ± 40.33	195.56 ± 45.68	194.78 ± 53.42	184.00 ± 33.45
Right Extension	Overall	223.76 ± 55.21	189.71 ± 47.70 *	185.82 ± 50.53 *	198.06 ± 51.53
60°·s^{-1}	85%	194.75 ± 31.20	178.75 ± 45.37	167.13 ± 40.83	171.00 ± 41.02
(N·m)	30%	249.56 ± 60.45	199.44 ± 50.23	202.44 ± 54.66	222.11 ± 49.56
Left Flexion	Overall	121.63 ± 30.87	109.76 ± 25.72	111.00 ± 32.09	111.76 ± 26.17
60°·s^{-1}	85%	109.25 ± 31.72	102.75 ± 26.08	100.88 ± 27.60	105.63 ± 31.81
(N·m)	30%	132.11 ± 27.36	116.00 ± 25.20	120.00 ± 34.62	117.22 ± 20.33
Right Flexion	Overall	131.47 ± 29.36	115.88 ± 28.92 *	116.94 ± 30.17 *	114.71 ± 27.27 *
60°·s^{-1}	85%	119.00 ± 22.56	109.25 ± 21.02	109.38 ± 23.42	110.38 ± 23.45
(N·m)	30%	142.56 ± 31.38	121.78 ± 34.69	123.67 ± 35.10	118.556 ± 31.17
Left Extension	Overall	164.00 ± 47.68	150.24 ± 35.53	143.76 ± 44.20	148.18 ± 33.38
120°·s^{-1}	85%	137.00 ± 34.56	137.25 ± 37.07	125.25 ± 35.33	136.50 ± 36.81
(N·m)	30%	188.00 ± 46.09	161.78 ± 31.70	160.22 ± 46.57	158.56 ± 28.03
Right Extension	Overall	168.00 ± 41.01	157.53 ± 34.21	144.82 ± 34.06 *	167.41 ± 38.90
120°·s^{-1}	85%	150.13 ± 24.55	146.00 ± 28.09	132.50 ± 28.71	149.13 ± 31.52
(N·m)	30%	183.89 ± 47.25	167.78 ± 37.41	155.78 ± 36.22	183.67 ± 39.05
Left Flexion	Overall	97.18 ± 24.90	95.74 ± 23.07	91.47 ± 27.43	96.59 ± 23.52
120°·s^{-1}	85%	84.38 ± 20.94	89.88 ± 29.18	84.75 ± 28.79	90.00 ± 27.45
(N·m)	30%	108.56 ± 23.38	100.44 ± 16.15	97.44 ± 26.34	102.44 ± 19.12
Right Flexion	Overall	108.00 ± 25.19	102.41 ± 21.42	95.41 ± 21.36	99.24 ± 27.33
120°·s^{-1}	85%	97.88 ± 27.59	92.38 ± 17.27	90.88 ± 21.92	92.88 ± 26.69
(N·m)	30%	117.00 ± 20.25	111.33 ± 21.59	99.44 ± 21.28	104.89 ± 28.19

Peak torque values are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. All units are N·m. There were significant changes over time for left/right extension and right flexion for 60°·s^{-1}, as well as right extension for 120°·s^{-1}. There were significant group differences for left/right extension and right flexion for 60°·s^{-1} ($p < 0.05$) and left extension for 120°·s^{-1} ($p < 0.05$). There were no significant group x time interactions.
* Significantly different from T1 ($p < 0.05$).

Table A9 *Dietary Intake*

INTAKE	T1	T2	T3	T4
Total (kcal)	2355 ± 901	2269 ± 724	2222 ± 712	2282 ± 820
Carbohydrates (g)	246 ± 102	231 ± 62	242 ± 85	245 ± 98
Fat (g)	92 ± 42	90 ± 41	80 ± 39	89 ± 37
Protein (g)	122 ± 39	131 ± 48	120 ± 36	115 ± 42

Data are presented as mean ± standard deviation for both 30% an 85% 1-RM, as well as overall testing values. There were no significant differences across time, between groups, or a group x time interaction.

Table A10 *Strive Sense3 Loads and Muscle Groups*

Exercise	Group	Measure	Week 1	Week 2	Week 3	Week 4	Week 5
Total Session	85%	TL	58.7 ± 11.4	60.8 ± 10.7	56.9 ± 9.6	55.6 ± 8.0	55.6 ± 8.4
		ML	136.0 ± 66.9	204.8 ± 254.7 *	116.6 ± 50.5	171.3 ± 155.5	106.9 ± 53.4
		Quads	119068 ± 72982	186502 ± 247861 *	111621 ± 74106	102385 ± 73128	69269 ± 52464
		Hamstrings	115844 ± 87106	127366 ± 92040	90243 ± 53576	96768 ± 67695	67538 ± 36456
		Glutes	122340 ± 55583	160551 ± 211485	103084 ± 56493	152078 ± 140770	88276 ± 64053
	30%	TL	62.2 ± 19.3	67.6 ± 9.2	62.3 ± 8.5	64.2 ± 10.0	62.6 ± 8.4
		ML	169.8 ± 127.2	139.3 ± 67.3	117.5 ± 63.3	102.5 ± 77.0 *	99.1 ± 65.2 *
		Quads	195851 ± 145130	124885 ± 65351 *	111818 ± 57844 *	84386 ± 66199 *	85625 ± 81164 *
		Hamstrings	171923 ± 124207	135103 ± 86328	122422 ± 60004	108459 ± 80448 *	101085 ± 80953 *
		Glutes	180777 ± 138332	165047 ± 105321	118566 ± 79040 *	105839 ± 73901 *	103404 ± 78756 *
Squat	85%	TL	6.2 ± 1.4	5.8 ± 1.4	4.3 ± 2.1	5.6 ± 1.0	6.0 ± 1.0
		ML	31.4 ± 21.8	36.9 ± 40.6	15.3 ± 13.8	26.1 ± 16.7	22.3 ± 14.7
		Quads	17145 ± 12981	18158 ± 21572	8730 ± 9503	12140 ± 10066	8691 ± 8355
		Hamstrings	14881 ± 13878	16370 ± 22813	6924 ± 6685	8273 ± 5087	7691 ± 5418
		Glutes	13360 ± 7465	12985 ± 12163	6885 ± 6472	11866 ± 10137	9773 ± 10746
	30%	TL	8.7 ± 1.9	8.0 ± 1.8	8.1 ± 1.8	7.6 ± 1.8 *	8.4 ± 2.0
		ML	64.6 ± 27.4	43.6 ± 26.4 *	45.4 ± 31.1 *	30.5 ± 24.6 *	33.2 ± 17.7 *
		Quads	42017 ± 19803	18629 ± 11348 *	19789 ± 13299 *	14077 ± 13358 *	14358 ± 12792 *
		Hamstrings	28390 ± 14412	16791 ± 10865 *	23469 ± 22523	15586 ± 12862 *	14364 ± 9490 *
		Glutes	26574 ± 14866	24566 ± 19768 *	16120 ± 8523 *	14294 ± 12203 *	15989 ± 9639 *

Table A10 (continued)

Exercise	Group	Measure	Week 6	Week 7	Week 8	Week 9
Total Session	85%	TL	55.8 ± 8.4	53.2 ± 10.8	51.3 ± 15.4 *	53.2 ± 10.4
		ML	122.3 ± 72.8	167.4 ± 150.6	136.9 ± 102.8	142.8 ± 102.4
		Quads	104124 ± 59470	119049 ± 103820	108771 ± 85216	114244 ± 91760
		Hamstrings	100054 ± 76632	158433 ± 129524	126247 ± 103732	117746 ± 90756
		Glutes	98022 ± 58693	124321 ± 124898	88015 ± 66550	117248 ± 80735
	30%	TL	62.3 ± 11.2	62.1 ± 10.9	63.4 ± 14.6	68.9 ± 8.4
		ML	124.9 ± 76.8	120.5 ± 74.0	111.1 ± 79.2	94.6 ± 61.7 *
		Quads	101639 ± 66393 *	116457 ± 98953 *	108633 ± 87476 *	92793 ± 69387 *
		Hamstrings	117361 ± 96713 *	100657 ± 67215 *	97282 ± 73700 *	86870 ± 45875 *
		Glutes	114983 ± 74173 *	113857 ± 71907 *	90495 ± 63978 *	106101 ± 81710 *
Squat	85%	TL	6.3 ± 1.0	5.9 ± 1.1	5.8 ± 0.8	6.0 ± 1.3
		ML	26.0 ± 16.2	30.0 ± 26.9	26.4 ± 19.3	27.7 ± 17.9
		Quads	11298 ± 9443	12740 ± 14133	13753 ± 12193	13029 ± 11357
		Hamstrings	12144 ± 10456	15400 ± 13635	12645 ± 10594	12180 ± 6538
		Glutes	11272 ± 7165	12419 ± 16363	8520 ± 6057	11282 ± 9134
	30%	TL	5.6 ± 3.7 *	8.5 ± 1.4	8.6 ± 2.2	9.4 ± 2.2
		ML	25.6 ± 22.3 *	33.7 ± 20.1 *	34.0 ± 25.1 *	38.1 ± 19.7 *
		Quads	12012 ± 10164 *	16922 ± 13010 *	17673 ± 17241 *	20806 ± 17165 *
		Hamstrings	10683 ± 10548 *	14293 ± 9762 *	13241 ± 13560 *	14827 ± 8465 *
		Glutes	12343 ± 13083 *	14925 ± 9699 *	14301 ± 9378 *	16942 ± 9929 *

Table A10 (continued)

Exercise	Group	Measure	Week 1	Week 2	Week 3	Week 4	Week 5
Deadlift	85%	TL	4.8 ± 1.9	6.0 ± 1.6	4.4 ± 2.6	6.2 ± 1.7	5.9 ± 1.7
		ML	25.6 ± 15.9	26.7 ± 17.2 *	17.6 ± 15.1 *	31.9 ± 34.0 *	22.2 ± 15.1 *
		Quads	13255 ± 9707	14128 ± 11837 *	9973 ± 10302 *	15679 ± 21771 *	8387 ± 6922 *
		Hamstrings	12675 ± 9372	12074 ± 9073	7660 ± 6318 *	10436 ± 8211	8544 ± 6161 *
		Glutes	10601 ± 6039	12332 ± 7883	8220 ± 7366 *	12260 ± 11763 *	10778 ± 10010 *
	30%	TL	10.9 ± 4.8	12.2 ± 5.0	10.0 ± 5.4	11.2 ± 4.2	9.7 ± 3.1
		ML	64.0 ± 29.5	58.3 ± 35.6	32.9 ± 21.2	45.5 ± 37.2	40.6 ± 28.7
		Quads	36277 ± 19483	22488 ± 12354	15001 ± 11895	18225 ± 18188	17123 ± 17396
		Hamstrings	31430 ± 12378	26919 ± 20330	16738 ± 11217	24256 ± 22429	20303 ± 16529
		Glutes	31236 ± 20015	30436 ± 22274	15579 ± 12155	22746 ± 22455	18350 ± 16436
Bench Press	85%	TL	2.5 ± 1.0	2.3 ± 1.7	2.4 ± 1.2	2.7 ± 0.7	2.6 ± 1.0
		ML	18.9 ± 15.3	16.5 ± 14.5	17.8 ± 17.3	15.1 ± 15.6	17.3 ± 18.7
		Quads	5952 ± 5516	5498 ± 6516	7961 ± 9360	5381 ± 4872	5199 ± 5604
		Hamstrings	9528 ± 10000	7151 ± 6892	6746 ± 6289	4729 ± 5935	8328 ± 12000
		Glutes	8596 ± 6932	8976 ± 7938	8482 ± 9608	7439 ± 10270	7257 ± 7014
	30%	TL	3.3 ± 1.6	2.3 ± 1.5	2.0 ± 1.2 *	2.9 ± 1.0	2.6 ± 1.2
		ML	24.3 ± 28.4	11.5 ± 10.3	16.9 ± 14.6	15.3 ± 16.1	15.6 ± 15.7
		Quads	11888 ± 22166	4197 ± 4125	6231 ± 5423	3708 ± 4524	4611 ± 5426
		Hamstrings	10344 ± 15226	3830 ± 5088	6092 ± 6882	7594 ± 11578	5736 ± 8153
		Glutes	11866 ± 12349	5576 ± 6498	8741 ± 8153	6573 ± 6916	8628 ± 9899

Table A10 (continued)

Exercise	Group	Measure	Week 6	Week 7	Week 8	Week 9
Deadlift	85%	TL	4.9 ± 2.4 *	5.9 ± 1.6	6.1 ± 1.9	6.0 ± 2.0
		ML	21.0 ± 15.6 *	33.4 ± 25.6 *	29.0 ± 20.0 *	28.3 ± 16.2 *
		Quads	9569 ± 9949 *	15169 ± 12101 *	14101 ± 11807 *	13044 ± 9537 *
		Hamstrings	8287 ± 7486 *	15320 ± 12040 *	13744 ± 9425 *	14010 ± 8311 *
		Glutes	9570 ± 8809 *	14860 ± 15351 *	11861 ± 9976 *	10908 ± 6218 *
	30%	TL	8.7 ± 3.3	10.2 ± 2.7	10.8 ± 3.0	10.9 ± 3.0
		ML	34.5 ± 23.6	42.8 ± 25.2	38.3 ± 19.0	39.0 ± 21.9
		Quads	15822 ± 12049	20409 ± 14075	17646 ± 12974	16936 ± 13027
		Hamstrings	15598 ± 12742	16712 ± 12630	17671 ± 12044	17906 ± 10735
		Glutes	16365 ± 11740	18776 ± 13988	16133 ± 8676	18834 ± 12160
Bench Press	85%	TL	2.9 ± 0.8	2.7 ± 1.0	2.7 ± 1.0	2.2 ± 0.9
		ML	18.9 ± 14.6	22.5 ± 19.5	32.3 ± 45.8	11.0 ± 6.7
		Quads	8177 ± 5816	7961 ± 6761	15807 ± 25524	4455 ± 3419
		Hamstrings	9259 ± 8933	9838 ± 11909	9556 ± 8215	3661 ± 3264
		Glutes	6935 ± 6543	10840 ± 8915	15227 ± 26025	5729 ± 4612
	30%	TL	2.5 ± 1.4	3.1 ± 1.4	2.9 ± 1.2	2.8 ± 1.4
		ML	15.8 ± 16.5	16.9 ± 16.7	12.3 ± 11.5	18.8 ± 19.5
		Quads	6261 ± 7582	6299 ± 8573	4481 ± 5176	6240 ± 7749
		Hamstrings	7230 ± 9624	6726 ± 6719	4633 ± 4210	7473 ± 9554
		Glutes	7313 ± 8444	8171 ± 10065	6018 ± 7910	10716 ± 13157

Table A10 (continued)

Exercise	Group	Measure	Week 1	Week 2	Week 3	Week 4	Week 5
T-Row	85%	TL	5.2 ± 1.6	4.4 ± 2.1	2.9 ± 1.7	4.2 ± 1.0	4.2 ± 1.1 *
		ML	26.2 ± 17.4	27.2 ± 37.5	9.1 ± 9.8	19.4 ± 10.0	11.9 ± 6.7 *
		Quads	12709 ± 10644	16281 ± 25280	4317 ± 5561	6934 ± 5986	4089 ± 4400 *
		Hamstrings	12194 ± 9618	8127 ± 5901	3914 ± 4666	6795 ± 4999	5084 ± 3629 *
		Glutes	12944 ± 8202	11642 ± 15178	4544 ± 5504	10183 ± 7234	5449 ± 4460 *
	30%	TL	3.9 ± 1.4	4.6 ± 1.5	4.6 ± 0.9	4.4 ± 1.5	5.3 ± 1.3 *
		ML	30.0 ± 20.9	24.4 ± 17.4	22.5 ± 18.2	13.8 ± 12.5 *	17.3 ± 15.3 *
		Quads	13520 ± 11436	9340 ± 7663	10359 ± 10706	5026 ± 5350 *	6116 ± 7013 *
		Hamstrings	13910 ± 10641	11195 ± 10228	10712 ± 10250	6148 ± 5746 *	8492 ± 9716
		Glutes	16898 ± 13557	13274 ± 11537	10078 ± 8543 *	6971 ± 7340 *	7088 ± 7913 *
Bicep Curls	85%	TL	1.7 ± 0.8	2.0 ± 0.8	1.9 ± 1.0	2.0 ± 0.7	2.0 ± 0.6
		ML	12.4 ± 7.9	21.0 ± 29.6 *	8.7 ± 8.1	16.6 ± 15.1	8.4 ± 7.2
		Quads	4671 ± 3730	9728 ± 15786	3652 ± 3946	4535 ± 5687	2528 ± 2826
		Hamstrings	5835 ± 5058	6337 ± 7359 *	3770 ± 4210	4462 ± 4659	3084 ± 2556
		Glutes	6311 ± 4482	9609 ± 16765	4191 ± 4371	9085 ± 8238	3703 ± 5494
	30%	TL	1.9 ± 1.2	2.2 ± 1.1	2.5 ± 0.8	2.3 ± 0.9	2.5 ± 0.9
		ML	16.6 ± 15.0	12.6 ± 12.1	11.0 ± 9.7	7.5 ± 8.0 *	8.9 ± 9.3 *
		Quads	7908 ± 11747	4783 ± 4905	4705 ± 4475	2402 ± 2412	3450 ± 4838
		Hamstrings	7412 ± 7147	6323 ± 7751	5718 ± 6214	3918 ± 5570 *	3718 ± 5157 *
		Glutes	8332 ± 7504	6442 ± 7227	5151 ± 5346	3292 ± 3889	3683 ± 4728 *

Table A10 (continued)

Exercise	Group	Measure	Week 6	Week 7	Week 8	Week 9
T-Row	85%	TL	4.1 ± 1.2 *	4.2 ± 1.4 *	3.9 ± 1.2 *	3.9 ± 1.1 *
		ML	21.0 ± 15.0	25.4 ± 15.7	21.1 ± 16.6	22.4 ± 16.7
		Quads	8288 ± 5023	10569 ± 7521	8373 ± 7503	9651 ± 8719
		Hamstrings	10680 ± 10188	12870 ± 8744	11317 ± 10989	8741 ± 7708
		Glutes	9389 ± 7898	11221 ± 10473	7590 ± 7391	10618 ± 6695
	30%	TL	3.8 ± 2.3 *	5.6 ± 1.2 *	5.1 ± 1.6 *	5.5 ± 1.1 *
		ML	14.3 ± 19.4	23.1 ± 17.8	18.8 ± 16.6 *	13.5 ± 10.0 *
		Quads	5286 ± 6163	10154 ± 10293	8733 ± 8016	5663 ± 5535 *
		Hamstrings	6491 ± 12992	8917 ± 8940	8330 ± 8727 *	4983 ± 3481 *
		Glutes	6677 ± 7133 *	9592 ± 8870 *	8805 ± 8713 *	6589 ± 6298 *
Bicep Curls	85%	TL	1.9 ± 0.5	2.0 ± 0.8	2.0 ± 0.7	2.0 ± 0.7
		ML	10.4 ± 7.6	18.7 ± 15.7	14.0 ± 10.5	16.3 ± 18.0
		Quads	5030 ± 4548	5274 ± 4049	6728 ± 7329	6603 ± 10997
		Hamstrings	5191 ± 4905	10691 ± 10630	6811 ± 4941	5392 ± 6142
		Glutes	4418 ± 3031	8309 ± 8200 *	5844 ± 6083	6759 ± 8160
	30%	TL	1.9 ± 1.2	3.1 ± 1.8 *	3.3 ± 1.9 *	3.5 ± 2.5 *
		ML	7.3 ± 7.5	10.7 ± 10.9	9.8 ± 10.6	11.4 ± 11.4
		Quads	3199 ± 4635	4525 ± 6345	4799 ± 6832	3334 ± 3565
		Hamstrings	2483 ± 3224	4273 ± 4455	4641 ± 4409	4178 ± 4746 *
		Glutes	3665 ± 3747 *	4773 ± 5426	3489 ± 3946	5945 ± 7952

Table A10 (continued)

Exercise	Group	Measure	Week 1	Week 2	Week 3	Week 4	Week 5
Skullcrushers	85%	TL	1.4 ± 0.8	1.4 ± 0.9	1.1 ± 0.6	1.6 ± 1.2	1.5 ± 0.7
		ML	11.6 ± 7.4	18.7 ± 32.0	8.1 ± 7.4	13.5 ± 12.1	9.8 ± 12.3
		Quads	4196 ± 3641	9956 ± 17737 *	3157 ± 3429	3082 ± 2698	3989 ± 10313
		Hamstrings	5505 ± 4382	4826 ± 3153	3831 ± 4196	4852 ± 4874	3463 ± 3837
		Glutes	6079 ± 4923	8278 ± 17781	4057 ± 4147	7160 ± 7301	4233 ± 4741
	30%	TL	1.4 ± 1.5	1.4 ± 0.7	1.5 ± 0.8	1.4 ± 0.8	1.6 ± 0.6
		ML	15.2 ± 18.0	11.2 ± 9.8	11.4 ± 10.4	7.3 ± 8.4	12.5 ± 12.8
		Quads	7362 ± 14714	4933 ± 4539	4144 ± 3753	1674 ± 2061 *	4707 ± 6104
		Hamstrings	6629 ± 9591	4761 ± 5532	4836 ± 4555	3870 ± 5811	5886 ± 8242
		Glutes	7031 ± 6843	5368 ± 5720	5816 ± 6426	3593 ± 3982	5150 ± 5553

Table A10 (continued)

Exercise	Group	Measure	Week 6	Week 7	Week 8	Week 9
Skullcrushers	85%	TL	1.4 ± 0.5	1.7 ± 0.8 *	1.3 ± 0.6	1.4 ± 0.6
		ML	11.5 ± 9.3	16.8 ± 10.1	11.4 ± 8.1	15.3 ± 16.6
		Quads	4909 ± 4604	4974 ± 3433	4026 ± 4097	5798 ± 8735
		Hamstrings	4927 ± 5898	9088 ± 7225	6445 ± 5326	5608 ± 6785
		Glutes	4340 ± 3536	6691 ± 5526	4233 ± 4250	6278 ± 8459
	30%	TL	1.4 ± 0.8	2.0 ± 0.9	1.8 ± 0.8	1.7 ± 0.7
		ML	9.3 ± 10.0	11.7 ± 12.6	10.0 ± 11.0	9.4 ± 10.2
		Quads	2685 ± 3037	5063 ± 8117	5124 ± 7375	3871 ± 5961
		Hamstrings	3911 ± 5534	4013 ± 4887	3939 ± 3215	3723 ± 4313
		Glutes	4932 ± 5466	5134 ± 5723	3515 ± 3460	4524 ± 5191

Data are presented as mean ± standard deviation. There were significant group differences for all variables in squat and deadlift, in TL for T-row, in TL, ML, and glutes usage for bicep curls, and in TL and ML for total training session (p <0.05). There were significant time effects for TL in deadlift and bicep curls; for ML in squat, deadlift, and T-row; for quad usage in squat, deadlift, T-row, and total session; in hamstring usage for squat, deadlift, T-row, bicep curls, and total session; and in glute usage for squat, deadlift, T-row, and total session (p <0.05). There were significant group x time interactions for the following: quad usage during squats; all variables except TL in deadlift; TL for T-row; quad usage in bench press; TL, ML and quad usage in bicep curls; and hamstrings for total session. * Significantly different from Week 1 (p < 0.05). TL = training load, ML = muscle load.

Table A11 *Average and Total Training Volume*

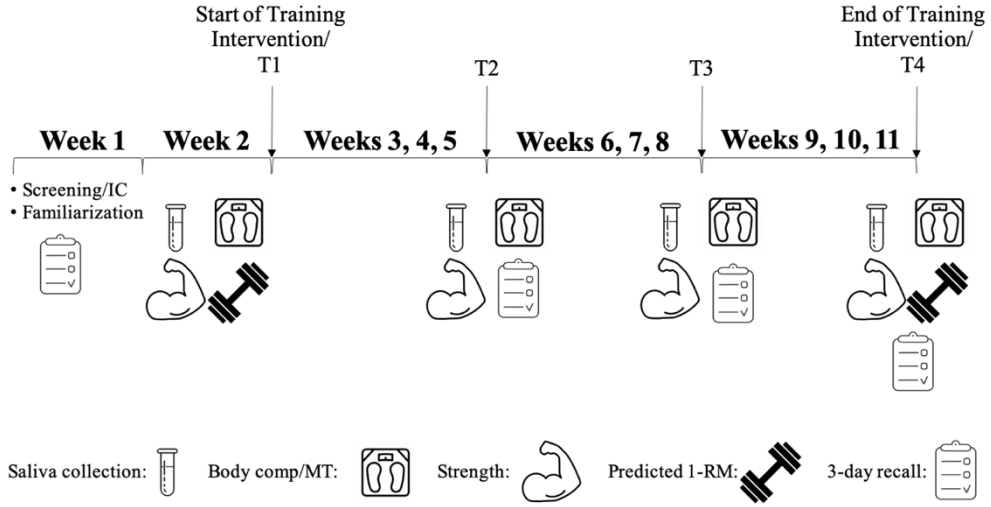
Exercise	Group	Block 1 (Weeks 1-3)				Block 2 (Weeks 4-6)				Block 3 (Weeks 7-9)			
		Avg (lbs)		Total (lbs)		Avg (lbs)		Total (lbs)		Avg (lbs)		Total (lbs)	
Squat	85%	2856 ± 761		20824 ± 4870		3358 ± 855		23088 ± 6638		3349 ± 1057		24644 ± 7032	
	30%	7353 ± 1502		54787 ± 11489		7728 ± 2188		53802 ± 15963		7302 ± 2365		55178 ± 20182	
Deadlift	85%	3430 ± 908		24006 ± 6669		3633 ± 842 *		26526 ± 7525		4070 ± 986		28030 ± 5758	
	30%	9066 ± 2806		66201 ± 25503		8042 ± 2152		57168 ± 12210		8373 ± 2425		59847 ± 19957	
Bench Press	85%	2205 ± 602		15790 ± 4594		2417 ± 704		17306 ± 5996		2437 ± 705		17508 ± 5174	
	30%	6191 ± 2050		46404 ± 18705		6881 ± 2425		48971 ± 17999		6992 ± 2220		51302 ± 14846	
T-Row	85%	1887 ± 828		13210 ± 5454		2044 ± 896 *		14728 ± 7510		2104 ± 811 *		15085 ± 5691	
	30%	3302 ± 997		24367 ± 8360		4019 ± 1434		28952 ± 11689		4319 ± 1446		31262 ± 8907	
Bicep Curls	85%	757 ± 195		5336 ± 1429		859 ± 188		6188 ± 1762		896 ± 210		6423 ± 1392	
	30%	1978 ± 531		14456 ± 4291		2132 ± 660		15239 ± 4913		2299 ± 758		16713 ± 5299	
Skullcrushers	85%	872 ± 210		6326 ± 1545		997 ± 322		6962 ± 2386		944 ± 334		6846 ± 2620	
	30%	2650 ± 734		19917 ± 6529		3054 ± 683		21532 ± 5525		3018 ± 585		22359 ± 4595	

Data are presented as mean ± standard deviation. Volume was calculated as sets x repetitions x load. There were significant group differences for all lifts in average and total training volume (p <0.05) with the 30% being higher. There were significant time effects for average training volume in bench, T-row, bicep curls, and skullcrushers (p <0.05). There was a significant group x time interaction in average training volume for deadlift and T-row (p <0.05). For total training volume, there was a significant effect across time for T-row. There were no group x time interactions for total training volume in any lift. * Significantly different from Block 1 (p < 0.05).

APPENDIX B

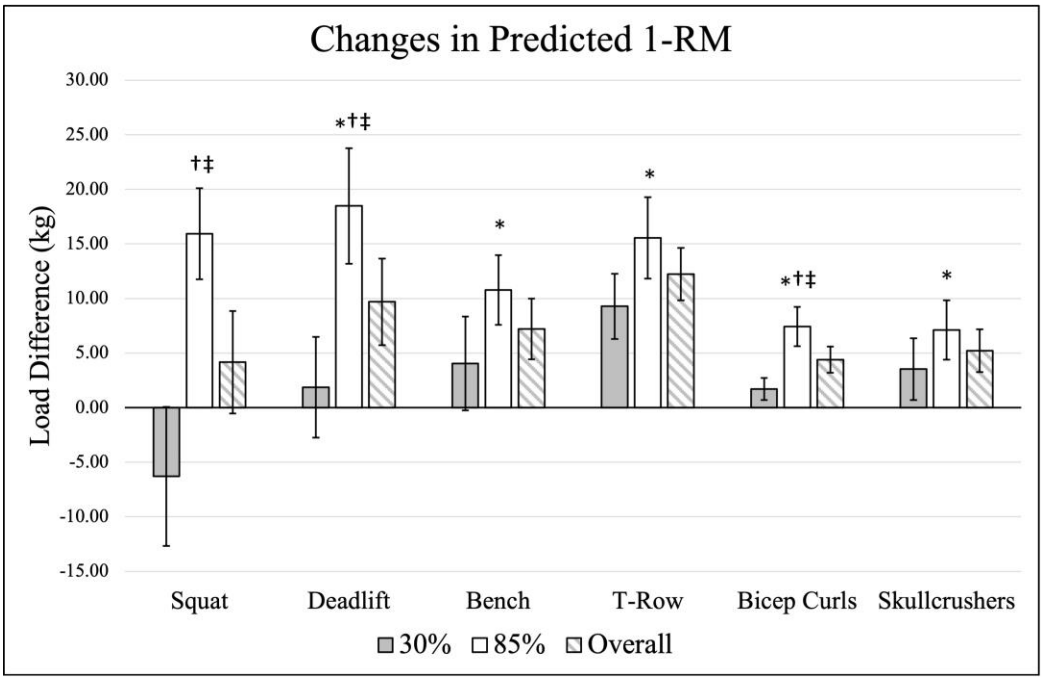
FIGURES

Figure B1.
Schematic Overview of Experimental Protocol and Procedures



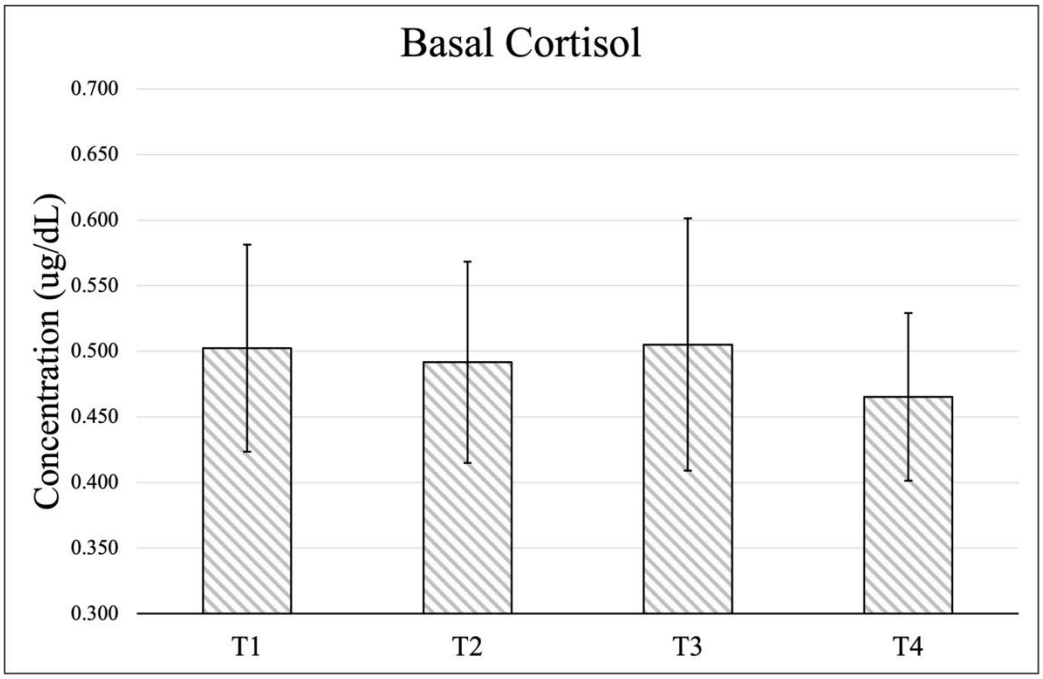
The figure represents the overall timeline of the investigation. Two groups (30% and 85%) completed the same training protocol of six exercises with three sets to failure in all compound movements, and two sets in accessory exercises. MT = muscle thickness, IC = informed consent.

Figure B2.
Changes in Predicted 1-RM from Pre- to Post-Training Program



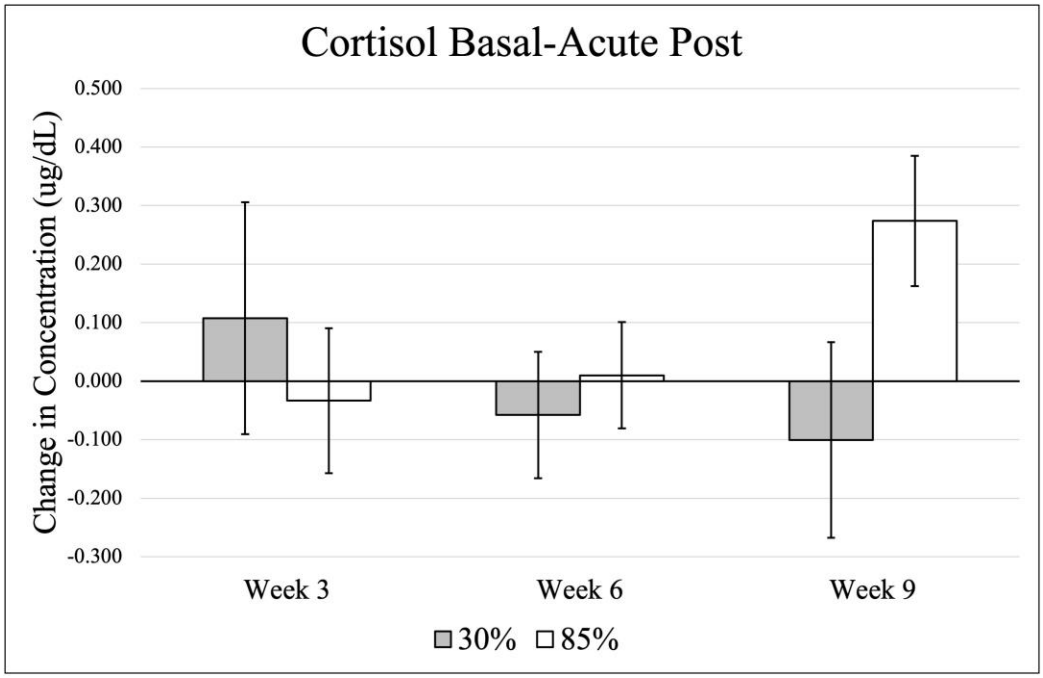
Data are presented as mean ± standard error for both 30% an 85% 1-RM, as well as overall testing values. ∗ Significantly different from pre to post ($p < 0.05$). † Significantly different between groups ($p < 0.05$). ‡ Significant group x time interaction ($p < 0.05$). The 85% group saw greater improvements in predicted 1-RM for squat, deadlift, and bicep curls. Overall, there were increases for both groups in all lifts apart from squats.

Figure B3.
Changes in Basal Cortisol Over Course of the Training Program



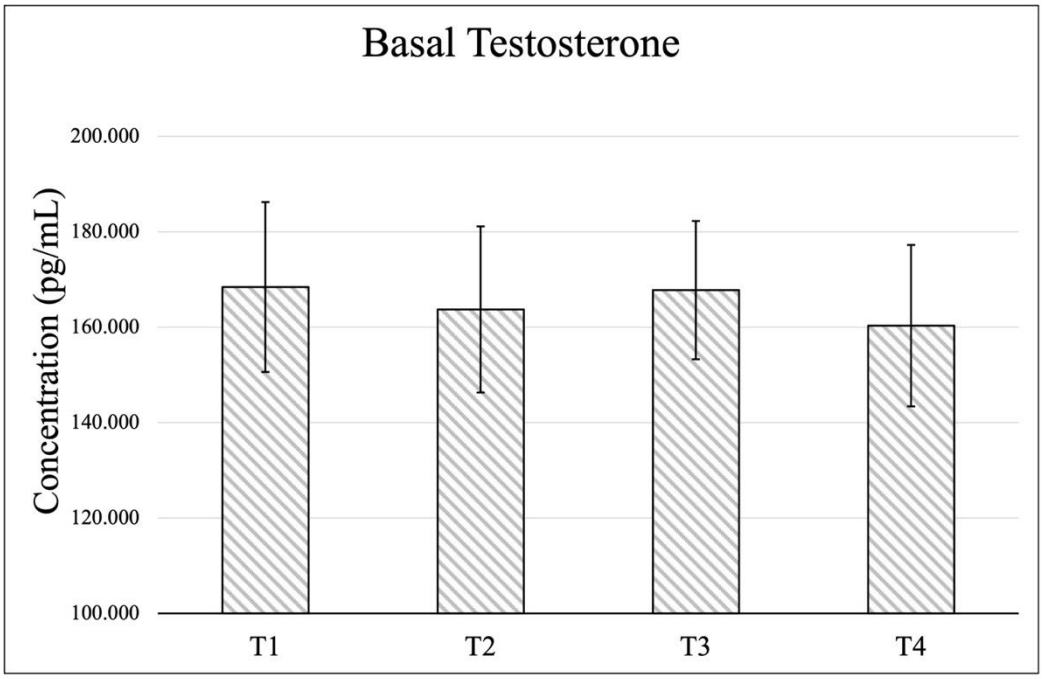
Data represent basal cortisol concentrations throughout the course of the training program. There were no significant differences between groups, over time, and no interactions.

Figure B4.
Cortisol Differences from Pre-Post Training Sessions at Testing Timepoints Throughout the Training Program



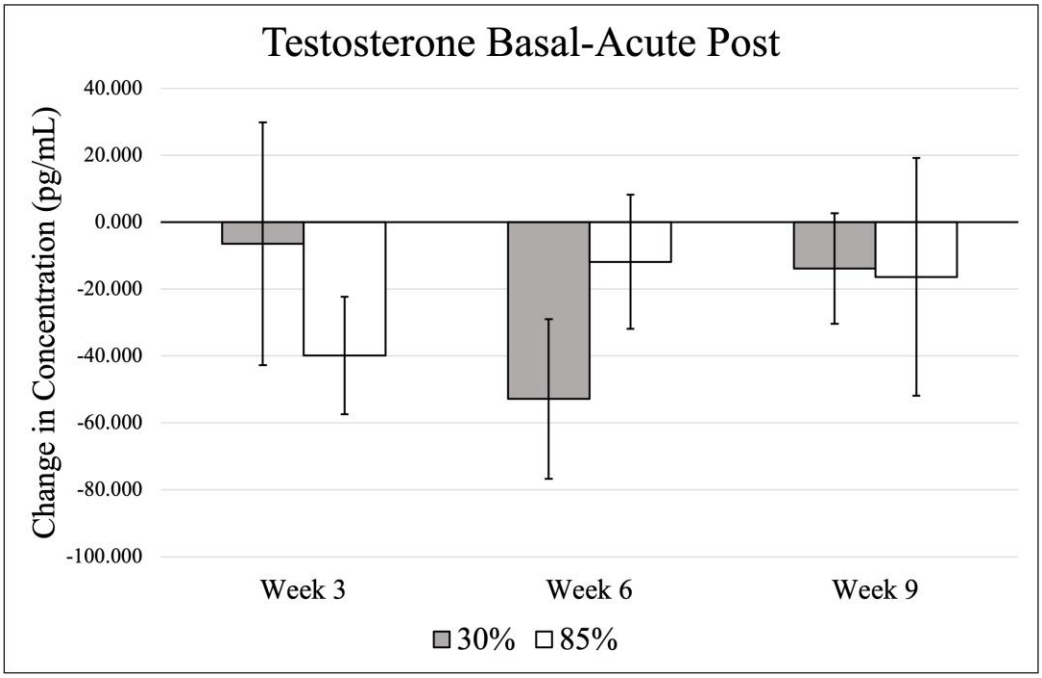
Data represent changes in cortisol concentrations from basal to acute post-exercise at weeks 3, 6, and 9 of the training program. There were no significant differences between groups, over time, and no interactions.

Figure B5.
Changes in Basal Testosterone Over Course of the Training Program



Data represent basal testosterone concentrations throughout the course of the training program. There were no significant differences between groups, over time, and no interactions.

Figure B6.
Testosterone Differences from Pre-Post Training Sessions at Testing Timepoints Throughout the Training Program



Data represent changes in cortisol concentrations from basal to acute post-exercise at weeks 3, 6, and 9 of the training program. There were no significant differences between groups, over time, and no interactions.

APPENDIX C

INFORMED CONSENT & IRB APPROVAL

Subject: Do Not Reply: Approval Notice for Study # IRB-20-486, Impacts of High- vs Low-Load Resistance Training on Measures of Muscle Activation, Strength, Body Composition, Cortisol, and Testosterone

Date: Wednesday, February 17, 2021 at 9:17:43 PM Central Standard Time

From: nrs54@msstate.edu

To: Smith, JohnEric, Kelly, Kathy, Shepherd, Brandon, Fountain, Brent, Wax, Ben, Anglin, Derick, Bello, Marissa, Wood, Morgan, Brown, Stanley, Smith, Brighton, Gillen, Zack

Protocol ID: IRB-20-486
Principal Investigator: JohnEric Smith
Protocol Title: Impacts of High- vs Low-Load Resistance Training on Measures of Muscle Activation, Strength, Body Composition, Cortisol, and Testosterone
Review Type: EXPEDITED
Approval Date: February 17, 2021
Expiration Date:January 06, 2026

This is a system-generated email. Please DO NOT REPLY to this email. If you have questions, please contact your HRPP administrator directly.

The above referenced study has been approved. *For Expedited and Full Board approved studies, you are REQUIRED to use the current, stamped versions of your approved consent, assent, parental permission and recruitment documents.*

To access your approval documents, log into myProtocol and click on the protocol number to open the approved study. Your official approval letter can be found under the Event History section. All stamped documents (e.g., consent, recruitment) can be found in the Attachment section and are labeled accordingly.

If you have any questions that the HRPP can assist you in answering, please do not hesitate to contact us at irb@research.msstate.edu or 662.325.3994.

Please take a minute to tell us about your experience in the survey below. When logging in, please use your MSU email (ex: abc123@msstate.edu) and login credentials:
https://forms.office.com/Pages/ResponsePage.aspx?id=sNtR7YavokWcI3P7OTXfF9uShqNaQAdCIfXwiCnibYZURUtWVDRRN1pRMEhHUzBCT1RGUFRZRkdLSy4u

Mississippi State University
Informed Consent Form for Participation in Research

IRB Approval Number:

Title of Research Study: Impacts of High vs Low Load Resistance Training on Measures of Muscle Activation, Strength, Body Composition, Cortisol, and Testosterone

Study Site: Applied Physiology Lab in McCarthy Gymnasium, Holliman Athletic Center

Researchers: JohnEric Smith, Mississippi State University

Purpose

The purpose of the proposed study is to examine the impact of high vs low load resistance training (85 vs 30% of 1-RM) and its effects on muscle activation, muscle thickness, body composition, strength, and hormonal markers including cortisol and testosterone.

Procedures

There will be three sessions per week, each lasting 1 hour. Total duration of participation in this study will be 3 hours per week for 11 weeks. Your total time of commitment is 33 hours.

The first two weeks of the study will be used to assess your baseline values and perform preliminary testing. During week one, you will fill out a medical history form to screen for any potential medical conditions that may prevent you from participating in this study and sign an informed consent. You will then complete an activity questionnaire to evaluate training experience and a food recall to establish your daily caloric/nutrient intake. A familiarization protocol will be conducted to explain the isokinetic dynamometer and proper form for each of the exercises you will be performing during training sessions. The isokinetic dynamometer will be used to measure your strength by isolating a part of your body, in this case your elbow or knee joint, and assesses your strength by how much force is produced through the range of motion at a controlled speed. This will also be used to perform a maximal voluntary contraction, or a single contraction with maximum effort against an immovable resistance.

On the second week of preliminary/baseline testing, you will complete two separate sessions prior to starting the training intervention. On Day 1 you will provide a salivary sample using the passive drool method. You will be given a saliva collection aid, and without any help will drool into the container to the marked line. This will be used to assess your levels of testosterone and cortisol. Your muscle thickness will be measured using a portable ultrasound machine that is non-invasive and measures by imaging the muscles. Body composition will be measured bioelectrical impedance analysis, where you will stand on two electrodes and hold on to two handles, while it sends a current through your body. You will not be able to feel this current, and there are no risks associated with it. Following these measures you will complete strength testing using the isokinetic dynamometer for lower and upper body extension/flexion movements, as well as the maximum contraction. For upper body, your elbow joint will be used and you will push against and pull against the dynamometer for three trials. For lower body, your knee joint will be used and you will push against and pull against the dynamometer for

three trials. For the maximal contraction, three trials will be performed. On Day 2, separated from Day 1 by a minimum of 48 hours, a second measure of maximal strength will be performed using a 2-10-repetition predicted maximal test. After a warm-up with light resistance that easily allows 5-10 repetitions, the weight will be increased and you will rest for 1 minute. You will then complete 3-5 repetitions followed by a 2 minute rest. The third set will include another increase in weight to approximately 85% of your perceived 1-repetition maximum, or the amount of weight you can lift one time. This third set will be as many repetitions as you can perform with proper technique. The amount of repetitions completed will then be used to estimate your 1-repetition maximum. These predicted maximal efforts will be used to calculate the prescribed load used during training sessions. A predicted max will be completed for each of the exercises performed in the training program.

You will complete resistance training 3 days per week, for 9 weeks. You will be randomized into either low- or high-load training group. The low-load training group will work at 30% of 1-repetition maximum, and high-load group will work at 85% of 1-repetition maximum. Each session will be completed at the same time of day, with 48 hours between training sessions, on a Monday/Wednesday/Friday or Tuesday/Thursday/Saturday split. During each session, you will wear an assigned pair of Strive shorts to monitor muscle activation and training load. The shorts are a compression material and can be worn independently or under a pair of gym shorts, but they are the base layer. The shorts have built-in sensors that monitor and interpret your muscle activation or the changes in timing and magnitude of the force produced during exercise. There are three locations of sensors on the shorts located on the glutes (buttocks), the hamstrings (back of the legs), and the quads (front of the leg/thigh). These shorts will be given to you for the duration of the study.

Prior to each workout, you will be asked to arrive at the lab at least 4 hours after having a meal. You will also be asked to refrain from consuming caffeine in any form (coffee, energy drink, preworkout) within 6 hours before each training session. You may consume water as you need throughout each session. Following the training session we will provide you a shake containing of 30 g of protein. Each training session will include session rating of perceived exertion where you rate the difficulty of each movement on a scale of 1-10, where 10 is the most difficult and failing repetitions. Every third session of the week will include a questionnaire to measure your current stress levels.

Training sessions will include 3 working sets at the prescribed load with repetitions performed until failure. The order of exercises will alternate between two protocols throughout the duration of the program and are listed below. Week 1 would start in the order of 1, 2, 1, and week 2 would start with day 2 and continue the pattern (2, 1, 2).

Day 1:	Day 2:
Squat	Deadlift
Deadlift	Squat
Bench press	T row
T row	Bench press
Bicep curls	Triceps extension
Triceps extension	Bicep curls

On the third session (Friday/Saturday) of every third week, measures of: muscle thickness, body composition, and strength will be taken prior to the training session. Strength will be assessed using the isokinetic dynamometer. Salivary cortisol and testosterone will be measured immediately post-training. A 3-day dietary recall will also be assessed during the third week to ensure there are no significant changes in dietary intake. You will be asked to make no large changes in dietary intake or supplementation.

Risks or Discomforts

The exercise carries standard associated risks. There may be pain, soreness, discomfort, and you may experience shortness of breath and increased heart rate. Participants can discontinue participation in the study at any time if they experience these symptoms and feel they cannot continue. CPR/first aid certified and certified strength and conditioning specialists will be present to assist and report any discomfort to.

Benefits

You will be provided feedback regarding their measures of muscle activation, strength, and body composition. This knowledge can be used to potentially enhance performance while training and competing.

Incentive to participate

You will be provided with your respective strength, body composition, and hormonal (testosterone and cortisol) values. This information is useful knowledge for athletic performance, training and competition.

You are responsible for paying any state, federal, Social Security or other taxes on the payments you receive exceeding $600. You will receive a form 1099 in January of the year following your participation in this study. This form is also sent to the IRS to report any money paid to you. No taxes are kept from your payment.

Confidentiality

- Your participation in this study is voluntary. You can withdraw or refuse to participate or answer any questions at any time without consequence.
- You will be assigned a participant number that will allow us to remove your personal identifying information from data. Your data, including data sheets and computer files, will only be identified by your participant number during the study.
    - The physical activity readiness questionnaire will be destroyed once completed and the investigator clears you to participate in the study
    - Once the participant completes all sessions of the study (or immediately after dropping from the study, should they decide to discontinue their participation), your name connecting you to your specific participant number will be destroyed.
- The participant's identity will be kept in a separate data file after each participant's completion of all data collection sessions in the study.
- All electronic data will be protected by passwords and is coded/filed using the participant number as the identifier.

- All data from the wearable will be uploaded into the company's cloud software. This data will be de-identified so the only information the company will have will be the subject number.
- All hard copy data will be kept in a locked file cabinet. Only Dr. JohnEric Smith will have access to the room and data files. If the data are reported at a scientific meeting or published in a scientific journal, only the group data will be reported.
- The researchers reserve the right to terminate training if there are potential hazards to participant's safety or well-being.
- Please note that these records will be held by state entity and therefore are participant to disclosure if required by law. Research information may be shared with the MSU Institutional Review Board (IRB) and the Office for Human Research Protections (OHRP) and others who are responsible for ensuring compliance with laws and regulations related to research. The information from the research may be published for scientific purposes; however, your identity will not be given out.

Please note that these records will be held by a state entity and therefore are subject to disclosure if required by law. Research information may be shared with the MSU Institutional Review Board (IRB) and the Office for Human Research Protections (OHRP) and others who are responsible for ensuring compliance with laws and regulations related to research. The information from the research may be published for scientific purposes; however, your identity will not be given out.

Questions

If you have any questions about this research project or want to provide input, please feel free to contact JohnEric Smith at 941-592-5575.

For questions regarding your rights as a research participant or to request information, please feel free to contact the MSU Human Research Protection Program (HRPP) by e-mail at irb@research.msstate.edu, or visit our participant page on the website at https://www.orc.msstate.edu/human-subjects/participant-information.

To report problems, concerns, or complaints pertaining to your involvement in this research study, you may do so anonymously by contacting the MSU Ethics Line at http://www.msstate.ethicspoint.com/.

Research-related injuries

MSU has not provided for any payment to you or for your treatment if you are harmed as a result of taking part in this study.

In addition to reporting an injury to JohnEric Smith at 941-592-5575 and to the Research Compliance Office at 662-325-3994, you may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the University Police Department at *MSU UNIVERSITY POLICE DEPARTMENT, Williams Building, Mississippi State, MS 39762, (662) 325-2121*.

Voluntary Participation
Please understand that your **participation is voluntary.** Your **refusal to participate will involve no penalty or loss** of benefits to which you are otherwise entitled. You **may discontinue your participation** at any time without penalty or loss of benefits.

Options for Participation
Please initial your choice for the options below:

___The researchers may contact me again to participate in future research activities.

___The researchers may NOT contact me again regarding future research.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

_____ _____
Participant Signature Date

_____ _____
Investigator Signature Date

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.
https://forms.office.com/Pages/ResponsePage.aspx?id=sNtR7YavokWcI3P7OTXfF9uShqNaQAdClfXwiCnibYZUOTM4NDUzMDIyUEhTM0NFNEVWNUc3TEw2Vy4u

APPENDIX D

RECRUITMENT FLYER

MISSISSIPPI STATE UNIVERSITY

MSU HRPP Full Accreditation

Approved: 1/7/2021 Expires: 1/6/2026

IRB # 20-486

PARTICIPANTS WANTED FOR A 11-WEEK TRAINING STUDY

Who can participate?

- Males 18+ who have been consistently resistance training for 2-4 days per week for at least the last 6 months

What's the purpose of the study?

- The purpose of the study is to examine the impact of low- vs high-load resistance training (30% vs 85% of 1-RM). This study aims to examine the effects on muscle activation, muscle thickness, body composition, strength, and hormonal markers including cortisol and testosterone

What will you be doing?

- Total duration of participation is 11 weeks
- You will complete preliminary and baseline testing over 2 weeks to assess your current body composition, strength, and hormonal markers
- Under direct supervision, for 9 weeks you will complete a training program 3 days/week at either low- or high-loads for each lift
  - Low-load is 30% of your 1-repetition maximum
  - High-load is 85% of your 1-repetition maximum
  - All exercises will be 3 working sets to fatigue
  - Each session will be completed with a pair of compression shorts measuring muscle activation
- On the 3rd session of every 3rd week, measures will be assessed for body composition, muscle thickness, strength, and salivary cortisol/testosterone

How will you benefit from participating?

- Free testing for all measures
- Free resistance training programming and coaching for 9 weeks

If you are interested or have any questions, please contact

Marissa Bello, MS, CSCS*D
MLB1221@msstate.edu

APPENDIX E

SCREENING & DATA COLLECTION SHEETS

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or **NO**.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** _____	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

☑ **If you answered NO to all of the questions above, you are cleared for physical activity.**
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2020 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2020 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: _____

_____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

11-01-2019

2020 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

11-01-2019

General Health Questionnaire

Name: _____
Address: _____
_____
_____

Mobile Phone number: _____

Name of the responsible investigators for the study:

_____

Please answer the following questions. If you have any doubts or difficulty with the questions, please ask the investigator for guidance. These questions are to determine whether the proposed exercise is appropriate for you. Your answers will be kept strictly confidential

1.	What is your exact date of birth? Month_____ Day_____ Year _____ So your age is..... Years		
2.	When did you last see your doctor? In the: Last week Last month Last six months Year More than a year.....		
3.	Are you currently taking any medication? If you answered yes, please specify name, dose, and frequency:	YES	NO
4.	Are you currently taking any supplements? If you answered yes, please specify name, dose, and frequency:	YES	NO
5.	Has your doctor ever advised you not to take part in vigorous exercise?	YES	NO
6.	Has your doctor ever said you have "heart trouble"?	YES	NO
7.	Has your doctor ever said you have high blood pressure?	YES	NO
8.	Have you ever taken medication for blood pressure or your heart?	YES	NO

9.	Do you feel pain in your chest when you undertake physical activity?	YES	NO
10	In the last month have you had pains in your chest when not doing any physical activity?	YES	NO
11.	Has your doctor (or anyone else) said that you have raised blood cholesterol?	YES	NO
12.	Have you had a cold or feverish illness in the last month?	YES	NO
13.	Do you ever lose balance because of dizziness, or do you ever lose consciousness?	YES	NO
14.	a) Do you suffer from back pain b) if so, does it ever prevent you from exercising?	YES YES	NO NO
15.	Do you suffer from asthma?	YES	NO
16.	Do you have any joint or bone problems which may be made worse by exercise?	YES	NO
17.	Has your doctor ever said you have diabetes?	YES	NO
18.	Have you ever had viral hepatitis?	YES	NO
19.	Do you know of any reason, not mentioned above, why you should not exercise?	YES	NO
20.	Are you accustomed to vigorous exercise (an hour or so a week)?	YES	NO
21	a) Have you ever had an ECG? b) if so, have you ever been told you had a heart abnormality?	YES YES	NO NO
22	Do you have a history of heart disease (stroke, heart attack, or other) in your family?	YES	NO
23	On average, how many days per week do you resistance train?		
24	How many minutes on the average is each of your exercise workouts?		
25	Have you been resistance training consistently for the previous 6 months?	YES	NO
26	If so, how long have you been consistently resistance training?		
27	Has your bodyweight remained constant for the past 2 months (no greater difference than 40 lbs)?	YES	NO

I have completed the questionnaire to the best of my knowledge and any questions I had have been answered to my full satisfaction.

Signed: _____

Date: _____

FORM REVIEWED BY: ☐☐☐ INITIALS _____ INITIALS

☐☐☐ MONTH ☐☐ DAY ☐☐ YEAR

College Student Stress Scale (CSSS)

For the following items, report how often each has occurred using the following scale:

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

1. Felt anxious or distressed about personal relationships _____
2. Felt anxious or distressed about family matters _____
3. Felt anxious or distressed about financial matters _____
4. Felt anxious or distressed about academic matters _____
5. Felt anxious or distressed about housing matters _____
6. Felt anxious or distressed about being away from home _____
7. Questioned your ability to handle difficulties in your life _____
8. Questioned your ability to attain your personal goals _____
9. Felt anxious or distressed because events were not going as planned _____
10. Felt as though you were NO longer in control of your life _____
11. Felt overwhelmed by difficulties in your life _____

Daily Session Questionnaire

PARTICIPANT ☐☐☐☐☐☐				☐☐☐ MONTH	☐☐ DAY	☐☐ YEAR
		SECTION COMPLETED BY: ☐☐☐			_____ INITIALS	
COLLECTION TIME ☐☐ : ☐☐		☐ AM	☐ PM	☐☐☐ MONTH	☐☐ DAY	☐☐ YEAR
A	**SUBJECT ARRIVES**					
B	**COVID QUESTIONNAIRE:**					
1	Have any answers for the COVID questionnaire changed since before?					☐
C	**GENERAL SESSION QUESTIONNAIRE:**					
1	How many hours of sleep did you get last night?					☐
2	How many hours ago did you eat?					☐
4	Have you experienced any recent injuries?					☐
5	Have you completed any extra physical activity outside of the training?					☐
6	Have you consumed alcohol within the last two days?					☐
8	Is there anything else that might affect your training today?					☐
D	**SUBJECT BEGINS WARMUP**					
1	High Knees in place x 30sec					☐
2	Jumping Jacks x 20					☐
3	Body weight squats x10					☐
4	Inch Worms x 5					☐
5	Glute bridges x 10, 1 second pause					☐
6	Scapula Pushup x 10 Pushups x 10					☐
E	**SUBJECT BEGINS TRAINING SESSION**					☐
G	**SUBJECT COMPLETES TRAINING SESSION**					☐
H	**SUBJECT CONSUMES PROTEIN**					☐
I	**SUBJECT LEAVES**					☐

Daily Training Session Collection Sheet Day A

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐
MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐
INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐
AM PM MONTH DAY YEAR

BACK SQUAT	REPETITIONS	LOAD	RPE
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
DEADLIFT	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
BENCH PRESS	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
T-ROW	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
BICEP CURL	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
TRICEP EXTENSION	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐

Daily Training Session Collection Sheet Day B

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐
MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐ INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ AM ☐ PM ☐☐☐ MONTH ☐☐ DAY ☐☐ YEAR

DEADLIFT	REPETITIONS	LOAD	RPE
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
BACK SQUAT	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
T-ROW	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
BENCH PRESS	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
SET THREE	☐☐ reps	☐☐☐ lb	☐.☐
TRICEP EXTENSION	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐
BICEP CURL	**REPETITIONS**	**LOAD**	**RPE**
SET ONE	☐☐ reps	☐☐☐ lb	☐.☐
SET TWO	☐☐ reps	☐☐☐ lb	☐.☐

Testing Data Sheet

PARTICIPANT ☐☐☐☐☐☐		☐☐☐ MONTH	☐☐ DAY	☐☐ YEAR
SECTION COMPLETED BY: ☐☐☐				INITIALS
COLLECTION TIME ☐☐ : ☐☐ ☐ AM ☐ PM		☐☐☐ MONTH	☐☐ DAY	☐☐ YEAR

1	SALIVARY SAMPLE (RESTING)			☐
2	MUSCLE THICKNESS	TRIAL 1	TRIAL 2	TRIAL 3
A	BICEPS	☐	☐	☐
B	TRICEPS	☐	☐	☐
C	PECTORALIS MAJOR	☐	☐	☐
D	HAMSTRING	☐	☐	☐
E	QUADRICEPS	☐	☐	☐
3	BIA MEASUREMENT			
A	TOTAL BODY MASS			
B	FAT FREE MASS			
C	% BODY FAT			
D	URINE SPECIFIC GRAVITY			
4	ISOMETRIC CONTRACTION	TRIAL 1	TRIAL 2	TRIAL 3
A	ELBOW FLEXION	☐	☐	☐
B	ELBOW EXTENSION	☐	☐	☐
C	KNEE FLEXION	☐	☐	☐
D	KNEE EXTENSION	☐	☐	☐
5	ISOKINETIC STRENGTH	TRIAL 1	TRIAL 2	TRIAL 3
A	ELBOW FLEXION	☐	☐	☐
B	ELBOW EXTENSION	☐	☐	☐
C	KNEE FLEXION	☐	☐	☐
D	KNEE EXTENSION	☐	☐	☐
6	SALIVARY SAMPLE (IMMEDIATELY POST)			☐
7	PROTEIN SHAKE CONSUMED			☐
8	QUESTIONNAIRES/ SURVEYS FULLY COMPLETED			☐

Predicted 1-RM Data Sheets

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ MONTH ☐☐ DAY ☐☐ YEAR

SECTION COMPLETED BY: ☐☐☐ _____ INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ AM ☐ PM ☐☐☐ MONTH ☐☐ DAY ☐☐ YEAR

BACK SQUAT	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐

MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐

INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐

AM PM MONTH DAY YEAR

DEADLIFT	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐

MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐

INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐

AM PM MONTH DAY YEAR

BENCH PRESS	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐

MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐ _____ INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐

AM PM MONTH DAY YEAR

T-ROW	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐
MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐ INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐
AM PM MONTH DAY YEAR

BICEP CURL	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg

PARTICIPANT ☐☐☐☐☐☐ ☐☐☐ ☐☐ ☐☐

MONTH DAY YEAR

SECTION COMPLETED BY: ☐☐☐

INITIALS

COLLECTION TIME ☐☐ : ☐☐ ☐ ☐ ☐☐☐ ☐☐ ☐☐

AM PM MONTH DAY YEAR

SKULLCRUSHERS	REPETITIONS	LOAD
SET ONE (WARM UP)	☐☐ reps	☐☐☐ kg
SET TWO	☐☐ reps	☐☐☐ kg
SET THREE	☐☐ reps	☐☐☐ kg
ESTIMATED 1RM		☐☐☐ kg
PRESCRIBED LOAD		☐☐☐ kg