Acute Hormone Response to Slow Velocity and Traditional Velocity Resistance Training Sessions

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CHAPTER 1

ACUTE HORMONAL REPSPONSE TO TRADITIONAL VELOCITY VERSUS SLOW VELOICTY RESISTANCE TRAINING SESSION

INTRODUCTION

The acute hormonal response to resistance exercises has been studied in various forms, from free weights to machines, kettle bells, heavy resistance exercise protocols, and tempo training (3,16,17,19,24). These studies have examined both acute and chronic changes in hormone concentrations, as well as changes in cellular receptor content. Resistance exercise research is a field which has an immense variety of exercise protocols and performance variables to examine.

Slow velocity resistance exercise includes a large range of tempos. Some protocols range from 2-3 seconds to 10 seconds for the eccentric portion of the lift (2,11,13). Those in favor of slow velocity claim benefits such as caloric burn, strength gains, more time under tension, and increased work production over traditional velocity all within one set of exercises once or twice per week. Some of these claims disagree with basic biomechanical principals. Previous research and unpublished pilot data by Dietz, et al. 2015 (25) are able to examine these claims.

In previous studies and pilot research from our laboratory, slow velocity free weight exercise has been compared to traditional velocity free weight exercise for kinematic data and acute endocrine response (5,25). Both studies were able to prove some of the basic principal of resistance exercise biomechanics. Although time under tension (TUT) was significantly higher for the slow velocity; power production, work and force were all significantly lower during the slow velocity exercise protocol.

Testosterone plays a key role in reproduction, but also aids in increased lean muscle mass. Testosterone increases in response to an acute resistance training session if the resistance exercise power and relative intensity are high. With light loads or increased inter-set rest intervals during resistance exercise, testosterone levels are shown to decrease (19). Cortisol helps insure the availability of energy when under physical or psychological stress by increasing production of glucose, and is also an indicator of stress. The acute cortisol response following a resistance training session is shown to be affected by volume more than the intensity or load (12, 18). Growth hormone is produced by the pituitary and is under hypothalamic control. Physiological factors such as exercise, sleep, diet, & stress can affect circulating concentrations. Additionally, growth hormone can be increased with physical exercise such as resistance exercise (16). The acute growth hormone response is dependent on the type of resistance training, and is greatly influenced by the total work performed and the inter-set rest intervals.

Purpose

The purpose of this study is to measure the acute hormonal responses to traditional velocity vs. purposely slow velocity resistance exercise in healthy resistance trained men. Additionally, lactate, and plasma volume shifts due to each type of resistance exercise will be determined.

Hypotheses

The primary hypothesis is traditional velocity resistance exercise protocol will produce significantly larger responses in testosterone, cortisol, and growth hormone concentrations when compared to the slow velocity protocol. A secondary hypothesis is the lactate responses will be similar for both resistance exercise protocols.

Independent Variables

The independent variable for this study will be the type of resistance training protocol used, traditional velocity or slow velocity. Both protocols will utilize the free weight squat followed by the free weight bench press. For the purpose of this study, traditional velocity will be performed using 3 sets of 10 repetitions at 70% of 1 repetition maximum (1 RM) with 1 min inter-set rest intervals and 2 min of rest between exercises. The lifting velocity for the traditional protocol will be a controlled eccentric phase, and a maximal velocity concentric phase. The slow velocity protocol will be 1 set of 10 repetitions at 28% of 1 RM with 2 min rest between the squat and bench press exercises, using a tempo of 10 seconds eccentric and 10 seconds concentric of each phase.

Dependent Variables

Dependent variables for this study will include serum testosterone, cortisol, and growth hormone levels, as well as lactate and plasma volume shifts. Also included will be training performance variables such as mean repetition velocities and powers for each exercise and each protocol.

Delimitations

This study will be delimited to college age males, who have previous weight experience. Additionally, this study will only examine the barbell high bar back squat and bench press exercises, using the previously described set and repetition protocols. Rather than to equate the training protocols for volume or intensities, these protocols have been selected to somewhat mimic typical training protocols commonly used for each type of training.

Assumptions

All subjects are assumed to be free from any hormonal supplement or medication, refrained from caffeine during the days of the testing, and have not participated in strenuous physical activity the 24-48 hours prior to the testing sessions.

Definitions

SuperSlow®: An exercise protocol whereby the positive phase is executed in 10 seconds and the negative in 10 seconds.

HIT: (High Intensity Training) Exercises performed at a high level of effort, usually in a slower manner.

Intensity: Amount of resistance used for the exercise or percentage of 1 repetition maximum.

Eccentric: The phase of the exercise where the primary muscles are lengthened during contraction.

Concentric: The phase of the exercise where the primary muscle is shortened during contraction.

Tempo: The pace or cadence of the exercise takes to perform each repetition.

Traditional Resistance Exercise: For this investigation, traditional velocity will be prescribed to the subjects as controlled eccentric (lowering) phase of the exercise and as fast as possible in the concentric (upward) phase of the exercise to return to starting position.

Slow Velocity Resistance Exercise: There is not a specific definition of slow velocity, therefore for this study, slow velocity will be a controlled tempo of 10 second eccentric (lowering) and 10 second concentric (upward) phase of the exercise.

CHAPTER 2

REVIEW OF LITERATURE

The development of resistance training workouts have evolved over-time. Designing a program involves several considerations for what an individual requires for their goals. In most cases a needs assessment will provide key information such as exercise movements, energy system requirements, and injury prevention considerations. After the information is reviewed and understood it should be combined with knowledge of resistance training to develop the best program for the individual. Kramer and Fleck have simplified acute training program variables into five categories: 1) choice of exercise, 2) order of exercise, 3) number of repetitions, 4) rest periods, and 5) load or intensity (16). Let's focus on one of the acute training variables, exercise choice, specifically movement velocity.

Acute training variables are the resistance exercise factors which can be altered in a single workout to change the outcome. These variations are important training considerations when designing exercise programs. Most workouts are designed for a specific purpose whether it is strength, power, hypertrophy, weight loss, coordination, or athletic performance. In "Optimizing Strength Training" by Kraemer and Fleck, the authors outline 5 acute training variables: exercise choice, exercise order, number of sets and reps (training volume), training intensity (% 1 RM), and length of rest periods between sets and exercises (16).

Exercise selection: Various exercises require the use of different muscle groups. Exercises can be selected based on the portion of muscle mass being utilized to move powerfully. Exercises which primarily use muscles of the upper body such as bench press are drastically different than exercises that predominantly use the lower portion of the body. A larger portion of the body is included in exercises such as the squat in comparison with the bench press. Biomechanical properties can change because a larger percentage of the body is involved during the movement of the lift. Exercise selection includes considerations such as range of motion (ROM) during the movement. Larger multi-joint exercises use more muscle mass than single joint movements. As reviewed by Kawamori and Haff, previous research has demonstrated the differences between single joint movements and multiple joint movements. As an example of exercise selection comparison, the optimal power output for single joint exercises is reportedly at 30-45% 1 RM, whereas multi-joint movements range from 10-70% of 1 repetition maximum (1 RM) (31). Variability in the way exercises are performed is important when reviewing literature and study design because although researchers may describe the exercises. There are multiple ways to perform each exercise and a slight change may play a large role when analyzing movement.

Ballistic exercises, also commonly referred to as power training can be used to demonstrate power output, but it should be noted ballistic exercises differ from traditional tempo exercises because they are done with a different purpose. An example of ballistic exercise vs. a traditional exercise would be a bench press throw versus a regular bench press exercise. Newton et al. reported the highest peak and average power was produced at 15-30% and 30-45% of the 1 RM in the bench press throw vs the traditional bench press, respectively. Similarly the squat has a ballistic version of the exercise; the squat jump. During a squat jump the body accelerates through the end range of motion before the take-off from the ground. If the subject performs a ballistic exercise there is not a deceleration factor until after take-off. In traditional exercises a deceleration happens toward the end range of motion. This strategy is used to protect the joints and the stress that powerful movements place on joints and connective tissue (14).

Olympic lifts, such as the clean & jerk and the snatch are high power output exercises which require high force and high velocity. Optimal loads for power production for Olympic lifts appear to be higher compared to traditional resistance training exercises such as the bench, squat and deadlift (37). Exercise selection aside, the training level of the athletes is very important. Strength levels, experience with resistance training, and experience/familiarity with the technical aspects of the exercise are all contributing factors. If the exercise is highly technical, experience alone will have an effect on efficiency of movement no matter the starting strength. Optimal training load may change if the exercise is designed to be a measure of strength or power. Another consideration is the specificity of the exercise kinetically and how it relates to athletic performance. Power can have a large impact on sport performance (64). It is trainable and can be improved several ways for individuals based on their goals. Yet power is still just one component to athletic performance. Skill development, effort, and genetics play large roles as well.

Exercise choice is an important consideration because selection of exercises will affect what muscle groups are utilized in training. Free weight exercises or machine weight exercises are factors within exercise choice. For example, working on a machine may limit range of motion, but some believe weight machines increase safety when compared with free weight training exercises (7), although data does not support this claim (52). Multiple joint exercises, such as the squat, power snatch, and clean pull, involve a large muscle mass and complex neural activation and coordination of the involved muscle mass. Because a large muscle mass is involved, it is possible to use heavier resistances than single joint exercises where smaller muscle mass is involved" (1,36). The selection of exercises should also depend on the muscle and muscle fiber recruitment pattern the program designer wants from the workout. The specific exercise determines what and how many motor units are recruited (1,36).

Exercise choice should also consider if the movement should be bilateral or unilateral. Bilateral movements are exercises in which both limbs are being used simultaneously. Unilateral movements are exercises in which single limbs are used. Unilateral exercises can be critical in maintaining equal strength in both limbs as well as teaching and improving balance and coordination (1,36).

The last consideration in exercise choice is to use machine resistance or free weights, and single joint or multiple joint exercises. Depending on the individual or the goal of the training program, exercise choices may change. When training for a competition, rehabilitation, general fitness, or weight loss, each situation requires a specific program to each individual and his or her strengths and weaknesses.

Exercise Order

Another acute variable in resistance training programs would be exercise order. The original rationale for exercise order suggested using large muscle, multi-joint exercises followed by small muscle group, single joint exercises. The rationale was that performing large muscle multi-joint exercises early in a workout is preferred because these movements are the most neurologically, metabolically, hormonally demanding and create the largest circulation response in the human body. For this reason, when performing these exercises, repetitions are sometimes kept relatively low to be able to maintain power. Minimizing fatigue is an important safety as well issue when training large multi-joint exercises. Exercises later in the daily routine would be affected by fatigue; therefore it may be best to use smaller muscle, single joint exercises to improve safety and reduce the risk of injury, as well as receive the most benefits from the resistance training program (1,36).

Number of Sets & Repetitions

The third consideration when designing a program is the number of sets and repetitions for exercises, also known as the exercise volume. All exercises do not have to follow the same set and repetition protocols, but should be used to calculate the volume of exercise (sets x reps). "Multiple sets and repetitions have been found to be superior for improvements in strength, power, hypertrophy, and high –intensity endurance." (36)

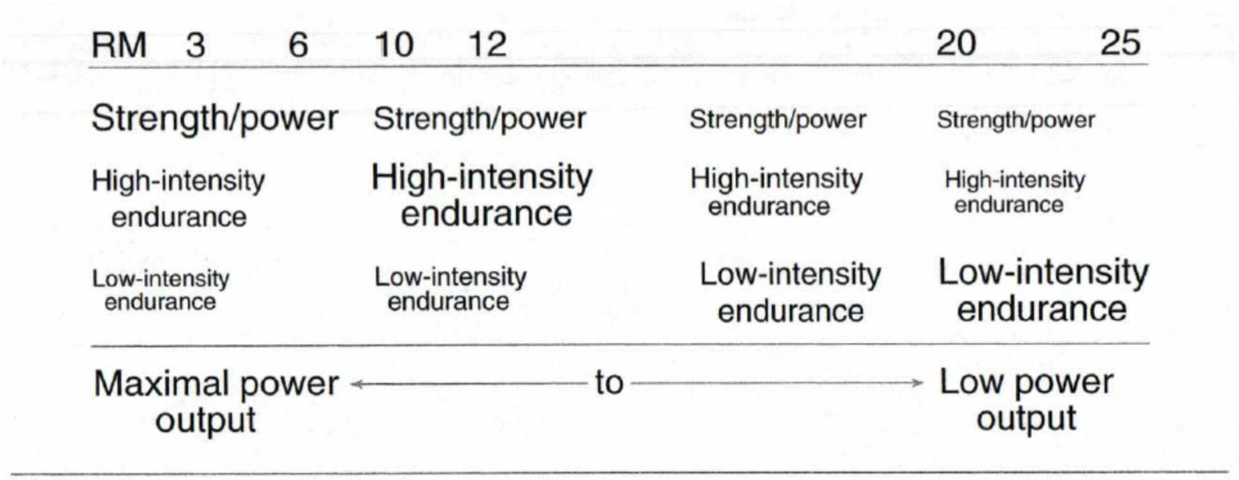
> "Number of sets and reps does affect the nervous, metabolic and muscular acute response to resistance training. For example, acute growth hormone response is greater with multiple-sets than with single-set training sessions. Gains in strength and muscle hypertrophy have been shown with single-set and multiple set training programs" (36).

Rest Periods

Defining rest periods for a training program could include rest days or periods of lower training volume or more specifically the amount of time between each rep and each set also known as inter-set rest periods. The ability to modify rest periods with in a single workout session, can alter which energy system is being utilized within the body during resistance training.

Training Intensity

Training intensity or amount of resistance may be the most important factor in training adaptation. Repetition maximum or (RM) is the resistance amount that an individual uses to determine the training load to use for exercises. As strength improves, the training intensity will need to be increased to account for the increased strength to keep making improvements. Fleck and Kramer, developed a training continuum that ranges from maximal power output to low power output (see below). According to the continuum, training intensity should also follow with the repetition maximum. Three repetition maximum training intensity coincides with the maximal power output and as the repetition maximum increases, the load will decrease and the focus will shift to lower power output and low intensity endurance (16, 36).



(16) Figure 1 Literature Review

Fleck and Kramer's resistance exercise training continuum ranging from maximal power output to low power output.

Let's focus on one of the acute training variables, exercise choice, specifically movement velocity.

Movement Velocity

Super slow is a popular method of resistance exercise training used in the field of exercise and fitness. This type of training has gained popularity over the last few decades but due to its unique characteristics continues to be controversial (25). Although the term is widely used, the specific definition or exact protocol has not clearly been identified. Super slow, or controlled velocity resistance exercise, is a when the person performing the exercise purposefully controls the tempo of the eccentric and concentric parts of each repetition. Although the exact protocol differs depending on the practitioner, extreme examples incorporate a 10 second eccentric phase couples with a 5 to10 second concentric phase for each repetition of each exercise (7,28,32,57, 61). Traditional resistance training is a broad term as well. Some people consider traditional resistance exercise as a maximum velocity lift, ≤1 second eccentric to ≤1 second concentric, while others simply consider traditional velocity as where the resistance is lifted at a volitional velocity. Others propose lifting with a 2 second eccentric to 4 second concentric lifting tempo, although this is considerably slower than what is typically volitional (44). The terminologies, as well as a definition for each term, are confusing. Some terms that may be associated with super slow include slow burn, controlled velocity, or high intensity training.

Super slow resistance training was first introduced to the exercise community by Ken Hutchins in 1982. He originally developed SuperSlow® as a way for elderly osteoporotic women to resistance train at safe speeds (48,60). This new method of resistance training began to be used with other populations. The super slow tempo made the exercise very taxing, so to account for the difficulty and total time under tension, most super slow workouts consist of only one set per exercise (60). A previous standard training protocol, which super slow borrowed, was from a Nautilus program. This program was characterized by a 2 second concentric contraction 1 second pause and a 4 second eccentric contraction. Westcott stated “more resistance can be handled in the eccentric (negative) or lowering phase of a movement compare to the concentric (positive) or pushing phase, a repetition should be performed so that the concentric phase is longer than the eccentric phase”. This description helps explain the reasoning for the variances among different super slow tempo protocols. It is also one of the key tenets of super slow training that does not necessarily follow principles of Newtonian physics if muscular force production is desired. It must be remembered that muscular strength has been defined as the force produced by a muscle or muscle group at a known or given velocity (33).

Skeletal Muscle Physiology

To gain further understanding of SuperSlow® training, we will first examine the underlying physiology behind resistance exercise. Skeletal muscle is one of three types of muscle found in the human body (skeletal, cardiac and smooth) but is the only of these three that functions under voluntary control. This review will focus solely on skeletal muscle. Muscle fibers contract and relax based on signals from the nervous system. Muscle contraction occurs when an action potential is sent from the nervous system to the axon terminal and is transmitted via signal transduction to the muscle fibers at the neuromuscular junction. Muscle fibers consist of myofibrils which are in turn made up of sarcomeres located in myofibrils. Sarcomere are often considered the functional unit of skeletal muscle since this is where the contractile apparatus is located.

Each sarcomere consists of thin and thick filaments which give it a banded appearance. The thick filaments consist of myosin molecules, whereas the thin filaments consist of f-actin, the filamentous form of g-actin. When filaments slide past each other the muscle is contracting. Within the sarcomere there are specific regions of the sarcomere, also known as bands, which represent different areas within the sarcomere. The full sarcomere runs Z disc (line) to Z disc (line) and act as book ends to the sarcomere. Each side of the sarcomere mirrors the other with the M line directly in the center. The I-band is adjacent to the Z disc and consists of just actin filaments. The next area is the A Band and consists of the myosin filaments. At the center of the sarcomere and in the middle of the A band is the M line. On either side of the M line is the H zone which represents the portion of the sarcomere between the ends of opposing actin filaments. When the muscle is activated, the myosin attaches to the actin and pulls the filaments to slide past each other. The actin filaments are actually sliding by the myosin, thus the name for the sliding filament theory (1, 41).

The sliding filament theory was introduced by Huxley in 1958(30). Although very early in muscle physiology and with crude instruments from our standards today, it was theorized that there was movement within the sarcomere and the distance from the H zone to the Z line to the beginning of the next H zone remained approximately the same length. The filaments would then crumple, fold, or coil as they overlapped (30). A sarcomere can shorten without changing the thick and thin filament length. It is now known that during contraction myosin actually pulls actin along its length, but does not affect the length of actin and myosin. In essence they slide past one another.

The structures of actin and myosin differ in shape. The thick filament is made of multiple myosin proteins, with one myosin looking similar to a golf club. It has a long base with two nodules on one end. These are referred to as the S1 heavy chain and S2 light chain sub-units (41). Research has shown a relationship between myosin heavy chain and muscle fiber type in human limb musculature (19). Altogether many individual myosin proteins are attached together with the multiple myosin heads extending from the periphery making a column-like structure. The actin looks like tiny molecules all attached to each other in a helical formation. Actin is associated with the troponin protein complex and tropomyosin. Tropomyosin wraps around the actin and acts to block the myosin from attaching on the binding sites.

Calcium

Calcium has to be present for muscle contractions to occur, When sufficient calcium is present, tropomyosin shifts away from the binding sites, thus to allowing myosin to bind to the actin. Calcium is vital for muscle contraction. An electrical impulse travels from the nervous system down axon terminals to the neuromuscular junction causing the molecules to release and bind to receptors which depolarizes the membrane of the muscle fiber. This causes the electrical impulse to travel down the T-tubules and open calcium stores. Those calcium molecules then bind to troponin and help shift the protecting tropomyosin off the binding site for actin (1, 41).

Neuromuscular Junction

The neuromuscular junction (NMJ) has been studied to determine its morphology, and to determine if chronic resistance training has an effect. In exercised animals, there is a significant total length of branches and greater complexity of branching patterns in both fast and slow twitch muscle fibers. This was not seen significantly in non-exercised animals which means that both increased and decreased activity are capable of significantly altering NMJ structure (14). Another study looked at resistance training and neuromuscular junction remodeling. Exercised induced expansion of endplate area is directly related to evidence that even under normal conditions Ach receptors are packed together as densely as possible (13).

Power Stroke

When bound ATP changes to ADP-P_i on the myosin, this causes the myosin head to attach to a binding site on the actin forming a cross bridge. During the power stroke is an action in which the myosin head pulls the actin toward the M-line or center of the sarcomere, thus shortening the sarcomere's total length. The sliding filament theory states actin filaments slide toward the center of the sarcomere past the myosin filaments. The net result is the Z lines get closer to one another and shorten the length of the sarcomere. When the actin is sliding over the myosin, the H zone and I band get shorter (1).

The actual shift of the myosin head from the cocked position to resting position (i.e. power stroke) happens when the cross bridges are attached the myosin and actin. This power stroke occurs because when the cleaved phosphate molecule is released causing the head of the myosin to shift from the cocked position to the resting position. Myosin ATPase is an enzyme on the myosin head which hydrolyzes the ATP to ADP and P_i causing the myosin to release and prepare for another cross bridge cycle. If remaining detached the muscle will relax (1,38).

Force-Velocity Curve

The force that can be generated by a muscle is related to its velocity. Force is generated when the myosin binds to actin forming cross bridges. These cross bridges cycle during contraction. The number of cross bridges that can form is dependent upon the amount of time allowed to bind. When the muscle filaments slide past each other quickly the muscle shortens, increasing velocity. If the velocity is too fast, all cross bridges cannot attach which decreases the total amount force that can be produced. As velocity decreases it gives more time to allow more cross bridges to form, thus increasing the amount of force that can be produced.

The force velocity curve can also be studied mechanically and will be discussed further in the paper. The force velocity curve has a very important role in power production. Power can be calculated by multiplying the force x velocity (23,38). Force used in this calculation is the mass of the resistance, multiplied by the acceleration due to gravity (-9.81 m/s^2) + any acceleration to overcome inertia. The change of velocity is how fast the load is accelerated, which affects how much distance is covered. Depending on how it is measured, peak power is typically achieved with moderate to minimal force at an intermediate velocity (30). This statement fits with the concept of the force-velocity curve which illustrates that as force increases, velocity will decrease as long as maximal efforts are performed.

Stretch-Shortening Cycle

Muscles have elastic properties. When a muscle is stretched there is an immediate signal in the muscle spindle fibers back to the nervous system. This signal will provide information about the stretch, resulting in a concentric muscle contraction to prevent potential damage. The stretch-shortening cycle is a natural part of most movements and refers to the eccentric lengthening of the muscle followed by the immediate concentric contraction (16).

Motor Units

According to Lieber, motor units are defined as a α-motoneuron plus the muscle fibers it innervates. Motor units consist of a cell body in the root of the spinal cord with a long projection from the cell body called the axon. The axon extends to innervate a particular muscle. When the axon gets close to the muscle the axon branches out, similar to how a tree branches out, with each branch typically innervating a single muscle fiber. Therefore a whole muscle can contain many motor units which each contain a single motor neuron and its composite fibers (41). Different motor units have different thresholds for activation. The "all or none" principle describe show when a single motor unit is stimulated all the muscle fibers that motor unit innervates are simulated, otherwise none of the muscle fibers are stimulated.

Motor Units are generally classified in three categories similar to the three fiber types in humans. Motor unit have been classified as fast fatigable (FF) and are associated with fast glycolytic muscle fibers (FG), fast fatigue-resistant (FR) associated with fast oxidative glycolytic (FOG) muscle fibers, and slow (S) associated with slow oxidative muscle fibers (SO). Commonly these muscle fiber types identified in humans are called fiber types IIX, IIA, and I. (41) Motor units also function on a size principal, which is the larger the axon the greater the amount of stimulation required to recruit and the greater amount of force it can produce. Smaller motor units have lower recruitment thresholds and are recruited first. These are the most sustainable but produce lower levels of force. But each skeletal muscle has a ratio of muscle fibers to motor units according to the physiological functions it performs. The number of motor units recruited highly affects the magnitude of force and power production because it dictates the amount of muscle cross sectional area recruited and the corresponding amount of cross-bridges activated (38).

Muscle fibers

Muscle fibers are specific such that the fiber type and the fiber cross sectional area of the activated fibers will affect the potential for force and power. Athletes often rely largely on their ability to produce power. Skeletal muscle fiber type, size, and number of fibers have a large effect on the total power production ability (38). Endurance athletes primarily have more type I muscle fibers, whereas an Olympic lifter will most likely have more Type II muscle fibers (17).

Possible training effects on muscle fiber content was investigated in a study involving a 6 week sprint cycle training protocol. While a significant fiber type conversion was not seen from type I to type II skeletal muscle, there was an appearance of a suggested conversion within type II fiber types from IIX to IIA (1,17). Other factors which may be affected include fiber cross-sectional area, fiber type distribution, and muscle architecture, all of which contribute to force and power output (31).

Mechanical Power

Many sports or athletic events require athletes to produce powerful movements that require large amounts of force to be produced very rapidly. Power is often calculated to describe the mechanical and physiological characteristics of an exercise and is measured in Watts. Mechanical power calculated by muscle force multiplied by the velocity of movement. It can also be defined as work/time. Force can be increased by increasing overall strength through resistance training for strength. By increasing strength while maintaining velocity capacity, total power output is increased (31).

Increasing the load or the intensity of the exercise during training may have an effect on Type II muscle fibers, which is the muscle fiber type that produces the highest amounts of force and power (31). High threshold motor units are typically composed of type II muscle fibers. Improved threshold motor unit recruitment through resistance training has the may have the ability to improve one's force and power output production. Other important factors that are possible factors for increased force and power output are motor unit firing frequency (increased rate of force development; RFD), muscle cross sectional area, and fiber type distribution (31).

Contractile velocity is also a very important component to power output. In essence, it is half of the equation of power = force x velocity. By keeping the resistance constant and increasing the velocity, total power increases.

In 1997 Newton et al. looked into the influence of load and the stretch-shortening cycle (SSC) on the kinematics, kinetics, and muscle activation that occurs during maximal effort bench press throws. Average velocity, average and peak force and average and peak power were significantly higher for the SSC throws compared to the concentric only bench throw (49).

Optimal Training Load

There are schools of thought regarding the optimal training load for maximal power output. The "Eastern Philosophy" which uses lighter loads < 50% of 1RM, with the idea that high tensions limit the ability of muscles to move quickly (11). Some feel training should be performed at the maximal power load to increase your power output, whereas training should occur at higher % 1 RM to increase power outputs at various loads. The "Western Philosophy" utilizes heavier loads 50-70% of 1RM, with the reasoning that heavy loads have to be performed at maximal rate (11). The optimal training load will depend on the goal of training, which exercise is being used to train and to test, and if the goal is to improve at one specific load or to improve across a variety of loads (8).

McBride et al, examined an 8 week training program with heavy vs light load jump squats on various physical performance measures (46). Subjects were trained with either 30% or 80% of their 1 RM. There were significant increases in peak power output and peak velocity for

30, 55 and 80 % in the group that trained with 30%. The same group also significantly increased in the 1 RM with a trend toward improved 20 meter sprint times. The group that was trained with 80% of their 1 RM significantly increased in both peak force and peak power output at 55 and 80% but also ran significantly slower in the 20 meter sprint. This study suggests that training with light-load jump squats increase movement velocity capabilities and that velocity specific changes in muscle activity may play a key role (45).

Other studies have examined the jump squat exercise further and the impact of strength and power training on the load-power relationship for the jump squat. This was an interesting study because previous training studies did not equate the work performed for the different training protocols. Cormie and researchers concluded that lower-body strength-power training (body weight jumping and heavy squats) is effective as power training for improving maximum jump height and maximum power output in the jump squat. It is also more effective than power training at producing all-around improvements in the load-power relationship of the jump squat (10).

Previous research has also examined the optimal load to achieve peak power output for resistance training exercises. Dayne et al. looked at power output in the squat jump in adolescent male athletes and found that the load which maximized their power output was 0% of the 1 RM which means they were able to see peak power output at body weight during the jump squat exercise (12). Comfort et al., investigated peak power output during the power clean in collegiate athletes. Subjects performed power cleans at 30, 40, 50, 60, 70, and 80% of 1RM. Peak power occurred at 70% of 1 RM. A question that arises is what and how are we measuring power output? Peak power output can be measured as BW or mass of the subject, or the subject with external load (i.e. system mass). It can also be measured during various exercises, done in a variety of ways, with different exercise techniques for each. An example would be if the measurement is done measuring barbell only or system mass, bodyweight + barbell.

Power can have a large impact on sport performance (64). It is trainable and can be improved several ways for individuals based on their goals. Yet power is still just one component to athletic performance. Skill development, effort, and genetics play large roles as well.

Slow Velocity Resistance Training

Resistance exercise has been used for many years for health and performance. There is a wide variety of ways to resistance train including altering exercise, order of exercises, load being lifted and velocity of the lift to list only a few. Velocity of the exercise can be distinctly different by performing the movements very fast or very slow. Controlled velocity or purposely slow resistance training is a form of resistance training in which the speed of the exercise is drastically reduced or controlled to a certain tempo which is a distinct difference from a more traditional type of exercises which encourages movement to be as fast as possible. Over time slow velocity exercise has gained some popularity because of the simplicity of the program, the lack of time it takes to perform each training session, and claimed safety considerations and physiological training benefits (5,40,46).

Purposely slow resistance exercise is referred to by various names such as SuperSlow®, slow velocity, purposely slow, controlled velocity, high intensity (HIT) and tempo training. Each has a different guideline and tempo depending upon the designer of the program, although the premise is always similar, to lift the resistance slowly. One of the most widely recognized forms of controlled velocity resistance exercise is called SuperSlow® and was developed by Ken Hutchins based on Arthur Jones' philosophy of finding out how little exercise we require, instead how much we can tolerate (5,53).

Many individuals who advocate using slow velocity training promote the training as a way to "properly and safely build muscle and increase resting metabolism (improving weight loss)" (5,40,46). SuperSlow® as developed by Ken Hutchins, is a specific protocol which uses a 10 sec eccentric and 10 sec concentric movement for each repetition and uses the exercise to "fatigue the muscle beyond exhaustion and this can all be reached within a 2 minute timeframe" (5,40). Proponents for SuperSlow® claim this type of "SuperSlow resistance training exercise only needs to be performed 1-2 times per week depending on muscle size" (5,40,46). Regardless of the exact tempo, little scientific data is available concerning the biomechanical properties of this type of training (33).

There are discrepancies as to some of the claims being made. Additional stated benefits for slow velocity in the lay literature include improvements in strength, bone density, cardiovascular efficiency, flexibility, resistance to injury, blood pressure, as well as decreased body fat. Physiological changes such as increased muscular endurance for daily functions and sport performance (5,40,46).

Slow velocity and forms of controlled velocity resistance training commonly use resistance exercise machines, declaring use of machines decreases the risk of injury during exercise (5,40). There is not supporting data that the overall rates of injury are less when training with machines compared to free weights (51).

One of the arguments is about forces being produced. Force is a product of mass x acceleration (32). In SuperSlow® or slow velocity exercise a reduction in velocity and load should result in decrease in the amount of force produced. However proponents of slow velocity believe force one produces is increased during slow velocity because momentum is decreased compared to high velocity exercises. The argument is that during a traditional (fast) exercise momentum is increased, supposedly allowing the weight to contribute to the movement and reduce the effort the body must make (1,40,53,55). Thus, arguments regarding power would also be affected by the force discrepancy of the two protocols as well because force has a direct effect on power. A reduction in velocity would require force to be extremely high to increase power (32).

Load restrictions play a key role in controlled velocity lifting. However, those in favor of slow velocity fail to mention the load reduction required to lift at a very slow pace. The movement is slower than a traditional tempo of lifting. For the purpose of this study, the recommendation from the American College of Sports Medicine suggests explosive lifting as an effective way to enhance athletic performance (51). For this study, traditional lifting will be lifting through the full range of motion as quickly as possible. During slow velocity exercise each repetition and each set requires a longer duration to complete. The increased duration of time may increase the perceived difficulty of the exercise, also known as effort. Some refer to this as intensity stimulus (53). Intensity is defined as relative load at which percentage of momentary degree of effort required, (53) although training load is often used to describe an exercise's intensity (17). For slow velocity the load is decreased and the velocity is decreased. Therefore, slow velocity training is not high intensity training by the generally accepted definitions (18).

Previous studies have examined the appropriate load to be used for slow velocity training, but additional factors should be considered, such as; goal of the exercise, use of machines or free weights, which exercises, how many reps and sets will be performed, and at what velocity (17,18,28,47,57). Pilot work has found that 28% or 30% is a more accurate load to prescribe for the free weight controlled velocity exercises.

Supporters of controlled velocity resistance exercise claim slow velocity training increases the amount of work being performed (2), however there are differing kinds of work, mechanical and metabolic. During slow velocity the amount of time is increased, but the amount of mechanical work is actually likely to decrease. Mechanical work is a function of force produced x the distance moved (32,33). During controlled velocity and traditional resistance exercise, as long as the exercises are the same, the distance should be the similar if not the equal. However, the forces may vary amongst the two protocols (55). Previous research has suggested the total mechanical work should be calculated when comparing effects of resistance exercise training programs because it has been shown that total work is influenced when comparing different sets, reps, and intensities with resistance training (29).

In 2003 Hunter and colleagues were able to demonstrate that when a SuperSlow® protocol was compared to a traditional lifting protocol, the VO2 and heart rate responses were significantly higher in the traditional protocol. Total energy expenditure from the oxidative processes were 45% higher for the traditional as well. In addition post exercise lactate difference was almost 2x greater than the SuperSlow® protocol (28). Traditional resistance training was shown to increase energy expenditure more than SuperSlow® and thus may be a more beneficial protocol for weight control (RR). Slow velocity training has been shown to improve muscular strength, but not beyond traditional strength training. Muscular endurance was also improved with low velocity training but not above traditional strength training (47). Although many of the claims mentioned by those in favor of slow velocity seem to disagree with basic biomechanical principles, there are few studies that have directly examined the kinetic characteristics of this type of training (33,58). The purpose of this study was to analyze the biomechanical properties of slow velocity and traditional velocity resistance training sessions.

Velocity is the rate of change of the position of the object over time (V=Δ Position/time). Velocity of a resistance exercise can be constant, accelerated, decelerated, or controlled. Work is calculated by force multiplied by distance (W=F x D). Often times work and force are used interchangeably but should not be because they represent two different components (47,53,56). Mechanical work is different than metabolic work. Mechanical work involves the physics and produces force outside the body, while metabolic work is a measure of work, energy and power as they relate to calorimetry. In the figure below Shilling et al. provided a helpful chart to understand some of the biomechanical relationships in three resistance training protocols (53).

Simplistic impulse-momentum relationship in various forms of resistance training.

Basic impulse-momentum relationship	$F\Delta t = m\Delta v$
Weightlifting	$\uparrow F = \frac{\leftrightarrow m \uparrow \Delta v}{\downarrow \Delta t}$
Powerlifting	$\uparrow F = \frac{\uparrow m \leftrightarrow \Delta v}{\leftrightarrow \Delta t}$
Purposefully slow training	$\downarrow F = \frac{\downarrow m \downarrow \Delta v}{\uparrow \Delta t}$

F = force, v = velocity, m = mass, t = time, ↑ = large, ↓ = small, ↔ = moderate.

Figure 2 Literature Review

Shilling et al, Impulse-momentum relationships for different forms of resistance exercise.

Super slow is a form of resistance training involves very slow speeds of movement for example raising the weight for 10 seconds and lowering the weight for 10 seconds (29,58). The idea behind super slow is that by moving the mass lifted at a slower rate than normal will cause a greater time under tension and increased muscle fiber recruitment. The goal of super slow is to increase strength.

Brzycki, one of the proponents of super slow, states “low velocity movements produce longer periods of continuous muscle tension during both the concentric and eccentric phases, thereby placing heavier demands on the target muscles. As, such high velocity movements are less productive producing maximal tension within a muscle” (2). Tension may be used interchangeably with force in this statement. Previous research has shown traditional speed (higher velocity) training improved strength beyond low velocity training, as well as muscular power, maximal O_2 consumption and body composition (50).

Super slow does increase the amount of time a person is performing each rep and set. Work, as discussed previously mentioned is calculated by force x distance, and force is calculated as mass x acceleration (47). During a super slow exercise acceleration is at a constantly very low level. Therefore force, by definition, should be low in a super slow. If force is low, then work would be low, because work is a product of force and distance. If the distance is constant and the force is less, the amount of work is decreased. Power is calculated by work divided by time (47). Super slow training uses a slow, controlled velocity, thus increasing total amount of time under tension (amount of time it takes to lift the mass (2,48,57,58,59). SuperSlow's® limitation is that the amount of weight used for the exercises must be drastically decreased from a maximum weight to allow for completion of one set.

Supporters of super slow training have stated that during weightlifting exercises (i.e. cleans, jerks, snatches), or explosive lifts, there is less work being completed (59,63). They state that although explosive lifts use heavier loads, the initial force the applied by the lifter to start moving the bar is so great that the barbell will have so much momentum that no additional forces are needed to complete the lift. In essence, they claim the lifter is not actually lifting the weight, but is instead relying on momentum to complete the exercise repetition. Super slow purportedly decreases the momentum of the barbell, requiring the lifter to remain contracting at a constant force throughout the whole movement (2,60).

In 2001, Westcott et al., studied the effect of regular and slow speed resistance training on muscle strength. In this study, subjects, both male and female, were given directions to follow either a regular speed tempo for each resistance exercise on a 13 exercise Nautilus circuit, or a slow velocity circuit. The regular speed tempo was 2 seconds to lift, a 1 second pause, and 4 seconds to lower. The slow speed group was instructed to use a tempo of 10 seconds to lift followed by a 4 second lowering phase. Each resistance program was carried out 2 to 3 times per week during an 8 to 10 week program. There was a 50% greater increase in strength with the super slow protocol in both the men and women than the regular speed protocol (60).

Factors to consider are the population that was utilized for this study. The subject pool was a mid to older population. This population typically has decreased strength, joint health, and mobility issues. Also, the subjects were a previously untrained population. Any type of resistance training program with appropriate stimulus and performed properly will improve strength with a sedentary or novice population. Efficiency of the movement during the exercise may have been an issue that was not discussed in detail for this study. The subjects may have been doing the exercise with incorrect form or because of lack of training. In this case the super slow tempo would allow extra time to focus on performing each exercise correctly. Until 2001, a majority of research surrounded around super slow resistance training, was conducted with beginning exercisers and performed on exercise machines (25). SuperSlow® training has transformed into a training protocol for individuals attempting to increase strength as well as muscle size. It should be noted that the original purpose of super slow training was to develop for a way to elderly to train safely. It is beyond the scope of this study to determine whether SuperSlow® is an appropriate manner for athletes to use for sport training. Further research is needed to determine the biomechanical relationships of slow velocity resistance training and traditional velocity resistance training sessions.

Hormones

Hormones are chemical compounds that are secreted by endocrine tissues and travel via the circulation to help regulate biological functions in different tissues in the body (6). Hormones function in the body every day to help maintain, up-regulate, or down-regulate biological processes. Hormones act much like the thermostat in the house or the gas and brake pedals in a moving car. Increased production occurs when more is needed, and decreased production occurs when the need is reduced.

Hormones are transported throughout the body in several ways. The first transportation route is called autocrine, these types of hormones remain within the same cell where they are produced and influence the activity within a cell. An example of an autocrine hormone is Insulin-like Growth Factor (IGF-1). IGF1 is produced in many cells and helps with the actions of growth hormone (6). Another method for hormone transportation is paracrine. Paracrine hormones can leave the endocrine cells, but never enter into the circulation. These types of hormones travel to adjacent cells where they influence activity in the new cell. The last method of hormone distribution, and most familiar, is endocrine. Endocrine hormones are released into the bloodstream or lymph system following the stimulation of the nervous system. The goal of the endocrine system is to get from the tissue of release to the target tissue via the circulation or lymph system (6).

All hormones are classified based on their chemical structure. Steroid hormones all share a four carbon ring structure. There are several types of steroid hormones. Although all have a different structure, they all share a similar 4 carbon ring structure (6). An example of a steroid hormone is cortisol. Peptide hormones consist of chains of amino acids. Bonds between certain amino acids help to configure the structure of the peptide hormone. An example of a peptide hormone in growth hormone. The third type of hormone is amine hormones. Amine hormones are derived from amino acids as well but the common factor of amine hormones is that they possess an amine ring (6). An example of an amine hormone is epinephrine.

Hormone concentrations in the body vary constantly because of several factors. These include the rate of hormone synthesis, the amount of hormone released and how the release occurs, binding proteins, plasma volume shifts, binding receptors and affinity, receptor sensitivity, breakdown (or metabolism) of hormones, and receptor second messenger system receptor adaptations. Some hormones vary in concentration because they are released in periodic bursts. When collecting hormone samples, a very important consideration to when sampling and being aware of the specific hormone's characteristics. Daily (or diurnal) fluctuations, as well as pulsatile release characteristics, can result in changes in hormonal concentrations (6).

Circadian rhythms are daily cycles which are affected by time of day. Hormone concentrations vary throughout the day which means they have a diurnal variation. Throughout a 24 hour period there are times of the day when a hormonal concentration is higher or lower and gradually changes through the day. This is unlike pulsatile hormones, where levels spike and drop rapidly. Certain hormones have diurnal variation increase and decrease in a smooth manner throughout a 24 hour period. For example, for the stress hormone, human peak cortisol levels are occur typically in the early morning and drop dramatically mid-morning and remain lower throughout the remainder of the day and evening. After midnight the levels begin to climb again (6).

The body can also have a hormonal response based on anticipation of an event, occurrence, or situation. The hormones that are related to stress help the body get ready for a stressful situation. Fight or flight is a great example of the anticipatory hormone response. If a perception of imminent danger exists, an increase in epinephrine will help in biological functions such as slowing digestion and increasing heart rate and circulation to prepare to run, or to confront or fight. This is an example of an anticipatory response (6).

Hormones and Exercise

In a classic paper, Kraemer et al. hypothesized there are several acute resistance training variables that affect hormone concentrations, such as the relative intensity of the exercise, the amount of work performed, and the inter-set rest intervals. Testosterone, cortisol and the testosterone-cortisol ratio are hormones commonly associated with the acute (immediate) and chronic (long-term) resistance exercise response (34).

Growth Hormone

Growth Hormone, originating from the pituitary and under cybernetic regulation by the hypothalamus via growth hormone-releasing hormone, is essential for normal growth of skeletal muscle. Physiological stimuli such as exercise, sleep, diet, and stress can stimulate a growth hormone response (34). Previous studies have reported that intensity of the exercise is an important factor for production of increased growth hormone. Heavier loads (70-85%) of 1RM increased growth hormone concentrations (43). Additionally, short rest intervals and total work performed during resistance exercise contribute greatly to the acute growth hormone response (35). A recent study found that for the bench press slow eccentric velocity had a significant higher mean values for peak blood lactate and blood lactate removal than the fast eccentric velocity. This is one case using slow eccentric velocity resulting in greater metabolic stress and hormone response (4).

Testosterone

Testosterone is a steroid hormone responsible for sexual development and contributing to skeletal muscle growth (62). Men and women have base levels of testosterone that are very different, with women having only 10% of the amount of testosterone compared to men. In men, the Leydig cells in the testes are responsible for the production of testosterone. In women, the female reproductive organs, the ovaries, produce the female steroids estrogen, testosterone, and progesterone. The low concentrations of testosterone found in women originate somewhat from the ovaries, but primarily from the adrenal cortex. The hypothalamus detects circulating levels of testosterone and then secretes luteinizing hormone-releasing hormone (LHRH) is testosterone concentrations are low. This signals release of luteinizing hormone (LH) from the anterior pituitary, which in turn stimulates release of testosterone from the testes. The released testosterone then binds with sex-hormone-binding globulin (SHBG) which is the primary testosterone binding protein (6). The portion of circulating testosterone not bound to SHBG (1-3%) is called free testosterone, and is biologically available for binding at the androgen receptor sites.

Cortisol

Cortisol is another steroid hormone and is released from the adrenal cortex. Cortisol is responsible for the availability of energy when under physical or psychological stress. Cortisol is often called a stress hormone because it helps the body prepare by increasing production of glucose from fat or protein in the liver, decreases glucose uptake, increases glycogen production in muscle, and causes amino acids to mobilize, which in some cases causes skeletal muscle degradation. Cortisol is also a catabolic hormone and has been used as an indicator or marker of training stress (6).

Testosterone-Cortisol Ratio

Testosterone levels can increase in response to resistance exercise, whereas cortisol levels can exhibit a relatively larger increase (62). This means the ratio of testosterone to cortisol may decrease post-resistance exercise. This change in the testosterone cortisol ratio can also be seen over multiple sessions of stressful training. The testosterone-cortisol ratio is thus used as a marker of training stress and could possibly be used as measure to monitor recovery (62).

As previously discussed, certain hormones can be affected just by the anticipation of an impending situation. Mason et al. examined the hormonal response from anticipation of exercise, more specifically the plasma cortisol response (44). The first exercise protocol was moderate exercise at 40% VO_2 max, and the second protocol was intense exercise bout at 70% VO_2 max. Their results indicated an increase in cortisol in both groups post-exercise. However, prior to the intense exercise, higher plasma cortisol levels were observed compared to the moderate exercise group.

Cook et al. (2012) conducted a study to examine testosterone and cortisol levels in elite and non-elite female athletes over a 12 week period. The baseline free testosterone of the elite female athletes was consistently double the levels of the non-elite group. In the same study cortisol levels were 25% higher in the elite group vs. the non-elite group. It was assumed this was due to a greater metabolic demand in elite athletes vs. non-elite (9).

Differences in cortisol and testosterone can be seen after 1 year of training. Fry and colleagues examined the endocrine response before and after 1 year of training, and in response to a week of high volume stressful training each year. Findings from this study revealed a decrease in the testosterone-cortisol ratio after stressful training the first year. The second year there was a reduction from baseline testosterone-cortisol ratio, but decrease in the ratio was not significant. It was concluded that after 1 year of additional weightlifting training and prior exposure to high volume stressful training, the subjects were able to better maintain their level of testosterone-cortisol ratio. Training age and weightlifting experience appeared to contribute to the subject's ability to maintain their testosterone-cortisol ratio (21).

In a short-term four week lifting program consisting of one week high relative intensity followed by three weeks normal intensity workouts, what would be the difference in elite and non-elite athletes? Fry et al. found that elite athlete were able to handle the high volume training with no real changes in testosterone/cortisol ratio, but during normal training the elite athletes actually improved their levels (20). However in non-elite athletes high training volume had an adverse effect decreasing the testosterone-cortisol ratio. Under normal training those same non elite athletes slightly improved the testosterone/cortisol ratio. This study suggests there is an improved tolerance to stressful training in elite athletes vs. non-elite athletes. Therefore, being an elite athlete and also having trained several years would improve the hormone response and tolerance to intense training.

Another study designed to look at relationships between training volume, physical performance capacity, and serum hormone concentrations during prolonged training in elite weight lifters. In 1987 Häkkinen reported an increased resting testosterone-cortisol ratio after 16-20 weeks of heavy resistance training and a subsequent decrease over a 12 week detraining period. Through this study Häkkinen and co-workers were "able to demonstrate a significant relationship between maximal isometric leg extensor strength and testosterone-cortisol ratio during the last 4 weeks of a 24 week training program" (27).

In 1993, Häkkinen and Pakarinen looked at the acute hormone response to two different heavy resistance protocols. The protocols were either performing 20 sets of 1 RM in the squat and the other protocol was the squat exercise doing multiple sets of 10 RM. Results show testosterone levels had a gradual decrease following the heavy 1 RM protocol. The 10 RM protocol had an initial increase in testosterone during the training session followed by a significant decrease in levels post-workout. Cortisol levels increased immediately from the 10 RM protocol and actually decreased gradually in the 1 RM protocol (26).

The acute testosterone and cortisol responses to high power resistance exercise was examined to determine the endocrine response when resistance exercise power is optimized. The high power exercise was 10 sets of 5 repetitions of a speed squat at 70% of the system mass 1 RM (body mass + bar mass). Conclusions from this study show that "acute increases in testosterone may be seen if the resistance exercise power is great enough and that elevated testosterone may be an adaptation for this type of exercise" (22). It was also concluded that one workout using high power resistance exercises, as in this study, did not acutely alter the testosterone- cortisol ratio. An interesting direction to examine would be the hormonal response of repeated bouts or a prolonged high power training program.

To examine the hormonal and growth factor responses to numerous heavy resistance exercise protocols, Kraemer, et al., looked at 6 different heavy resistance exercise protocols (HREP) which consisted of identically ordered exercises; 5 RM vs. 10 RM loads, 1 vs 3 min inter-set rest periods, and high vs. low total work performed. All resistance exercise protocols significantly increased testosterone concentrations, although the protocols using heavier loads had a larger testosterone response. Not all resistance exercise protocols produced increases in serum growth hormone (35).

When the hormonal response to resistance exercise modality (free weights vs. machines) was examined, free weights elicited a greater response in testosterone, growth hormone, cortisol, and lactate initially post- exercise, and continued 30 min after completion of the exercise (54).

A different type of resistance exercise, the kettlebell, is a tool used in many weight rooms for resistance training. Budnar and Duplanty examined the acute hormonal response to the kettlebell swing exercise. Participants performed 12 rounds of 30 sec kettlebell swings. Results show that testosterone increased immediately post- exercise, but decreased 15 and 30 min post-exercise. The growth hormone response was higher immediately post, and 15 and 30 min post-exercise. Cortisol was also higher immediately and 15 min post-exercise, compared to pre-exercise and 30 min post-exercise. Lactate levels were increased at all times after the exercise compared to pre-exercise (3).

What would the hormonal response be if the exercise prescription changes as well? Linnamo et al., studied the acute hormonal response to sub-maximal and maximal heavy resistance and explosive exercises in men and women. The three different types of resistance training for the testing were a sub-maximal heavy resistance exercise, a maximal heavy resistance exercise, and maximal explosive resistance exercise (43). This particular study looked at growth hormone, testosterone, blood lactate, and maximal force produced under each protocol. The testosterone increase was only statistically different in the maximal heavy resistance exercise protocol.

If there is a testosterone response after a heavy maximal resistance exercise, what is the response to purposely slow velocity resistance exercise? Goto et al., examined the hormone recovery response to purposely slow movement resistance exercise. The exercise protocol was 1 set of machine knee extensions until exhaustion at 80% 1 RM for the high intensity group and 40% for the low intensity group. Three protocols were used: high intensity normal movement velocity, low intensity slow movement velocity, and low intensity normal movement velocity. In the low intensity slow movement group, there was a significant increase in serum testosterone after exercise as compared to the other groups. The high intensity group saw a slight increase in testosterone 5 min post exercise and the low intensity normal movement velocity only decreased from pretesting levels. The cortisol levels did increase from pre to post exercise in the low intensity slow movement and slightly in the high intensity normal movement, but only decreased in in the low intensity normal movement group. To the author's knowledge, this project is the only one to examine endocrine responses to purposely slow resistance exercise (24).

It is important to understand all variables taken into account for a resistance exercise and endocrine studies. All of which have the possibility to produce dramatically different results. Population of trained or untrained subjects may elicit a larger initial endocrine response, but those of trained subjects may return to normal pre exercise condition quicker than those of untrained subjects. The exercise modality such as free weight or machines will change the muscles utilized and control during the exercise. As mentioned previously, free weights were able to elicit a greater response in testosterone, cortisol, and growth hormone as well as lactate levels (55). The exercise protocol is also a key variable as this includes intensity used for the exercise, the volume, and the tempo. Heavy resistance exercise produces a larger response, especially with shorter rest intervals. Although this is demonstrated, there are also large endocrine responses also shown by increasing the tempo or time during the eccentric phase of the exercise. Even with a reduced intensity, the endocrine response can still be significant.

Plasma Volume Shifts During Resistance Exercise

Exercise such as resistance exercise can cause a plasma volume shift in humans. This is due in part to postural changes, contracting muscles, and internal pressures due to Valsalva maneuvers that cause a shift of fluid from the circulation to interstitial spaces. Since hemoglobin is located in the red blood cells, the measurement of concentration of hemoglobin in the blood and the percentage of red blood cells in the blood (hematocrit; Hct) before and after exercise can be used to estimate the relative (%) shift in the fluid component of blood from the circulation. Hematocrit can be measured with a micro-hematocrit centrifuge and corrected for 4% plasma trapped with packed red cells. Hemoglobin can be measured by the cyanmethemoglobin assay method. Percent changes in plasma can then be calculated from hemoglobin and hematocrit using the methods of Dill & Costill (15). Often times, changes in plasma volume and reduction in clearance rates have been used to explain acute hormonal responses to exercise (40). Changes in the plasma volume due to the exercise session can profoundly affect the accompanying hormonal concentrations. Inclusion of this variable can sometimes provide helpful information when examining the mechanisms for changes in hormonal concentrations.

Except for the study by Goto (24), there is not an abundance of hormonal research examining the effects of "super slow", or controlled velocity resistance exercise. A possible direction to investigate further would be the testosterone, cortisol, growth hormone, and creatine kinase levels in relation to extreme differences in tempo during resistance training and muscle disruption. Further research may expand the body of knowledge currently available to researchers and practitioners.

Literature Review References

1. Baechle, RT, & Earle, RW. *Essentials of Strength and Training and Conditioning: National Strength and Conditioning Association.* Champaign, IL: Human Kinetics, 2008.

2. Brzycki M. *A practical approach to strength training*. Indianapolis, IN: Masters Press, 1995.

3. Budnar, RG, Duplanty, AA, Hill, DW, McFarlin, BK, Vingren, JL. The acute hormonal response to the kettlebell swing exercise. *Journal of Strength & Conditioning Research* 28: 2793-2800, 2014.

4. Calicto, RD, Verlengia, R, Crisp, AH, Carvalho, TB, Crepaldi, MD, Pereira, AA, Yamada, AK, Do Mota GR, Lopes, CR Acute effects of movement velocity on blood lactate and growth hormone responses after eccentric bench press exercises in resistance-trained men. *Biol. Sport* 31: 289-94, 2014.

5. Carpinelli, RN, Otto, RM. Strength training: single set versus multiple sets. *Sports Medicine.* 2: 73-84, 1998.

6. Chandler, T.J., & Brown, L.E. (2013). *Conditioning for Strength and Human Performance* Second Edition, Wolters Kluwer; Lippincott Willams & Wilkins, Philadelphia, PA

7. City Wide SuperSlow http://www.citywidesuperslow.com accessed Sept 22, 2014.

8. Comfort, P, Fletcher, C, & McMahon, JJ. Determination of optimal loading during the power clean in collegiate athletes. *Journal of Strength and Conditioning Research* 26: 2970-2974, 2012.

9. Cook, CJ, Crewther, BT, & Smith, AA. Comparison of Baseline Free Testosterone and Cortisol Concentrations between Elite and Non-Elite Female Athletes. *American Journal of Human Biology* 24: 856-858, 2012.

10. Cormie, P, McCaulley, GO, & McBride, JM. Power versus strength-power jump squat training; influence on the load-power relationship. *Medicine & Science in Sports & Exercise* 39: 996-1003, 2007.

11. Cronin, J, Sleivert, G. Challenges in understanding the influence of power training on improving athletic performance. *Sports Med,* 35: 213-234, 2005.

12. Dayne, AM., McBride, JM., Nuzzo, JL., Triplett, T., Skinner, J. & Burr, A. Power Output in the Jump Squat in Adolescent Male Athletes. *Journal of Strength and Conditioning Research,* 25: 585-589, 2011.

13. Deschenes, MR., Judelson, DA., Kraemer, WJ., Meskaitis, VJ., Volek, JS, Nindl, BC, Harman, FS, & Deaver, DR. Effects of resistance training on neuromuscular junction morphology. *Muscle and Nerve* 23: 1576-1581, 2000.

14. Deschenes, MR., Tenny, KA. & Wilson, M.H. Increased and decreased activity elicits specific morphological adaptations of the neuromuscular junction. *Neuroscience* 137: 1277-1283, 2006.

15. Dill, DB, and Costill, D.L. Calculation of percentage changes in volumes of blood, plasma & red cells in dehydration. *Journal of Applied Physiology* 37: 247-248, 1974.

16. Fleck, SJ, Kraemer, WJ. *Design Resistance Training Programs.* Champaign, IL: Human Kinetics, 2004.

17. Fry, AC. The role of resistance exercises intensity on muscle fiber adaptations. *Sports Medicine* 34: 663-679, 2004.

18. Fry, AC. *Overload & regeneration during resistance exercise in: Overload performance incompetence & regeneration in sport.* (M. Lehmann, J.M. Steinacker & U. Gastmann Editors.) New York: Kluwer Academic/Plenum Publishers. 149-162, 1999.

19. Fry, AC, Allemeier, CA, & Staron, RS. Correlation between percentage fiber type area and myosin heavy chain content in human skeletal muscle. *European Journal of Applied Physiology* 68: 246-251, 1994.

20. Fry, A.C., Kraemer, W.J., Stone, M.H., Koziris, L.P., Thrush, JT, & Fleck, SJ. Relationships between serum testosterone, cortisol, and weightlifting performance. *Journal of Strength and Conditioning Research* 14: 338-343, 2000.

21. Fry, AC, Kraemer, WJ., Stone, MH, Warren, BJ, Fleck, SJ, Kearney, JT, & Gordon, SE. Endocrine Responses to Overreaching Before and After 1 year of Weightlifting. *Canadian Journal of Applied Physiology* 19: 400-410, 1994.

22. Fry, AC, & Lohnes, CA. Acute Testosterone and Cortisol Responses to High Power Resistance Exercise. *Human Physiology* 36, (4) 457-461, 2010.

23. Garhammer, J. A review of power output studies of Olympic and powerlifting: methodology, performance, prediction, and evaluation tests. *Journal of Strength and Conditioning Research* 7: 76-89, 1993.

24. Goto, K., Takahashi, K., Yamamoto, M. & Takamatsu, K. Hormone Recovery Responses to Resistance Exercises with Slow Movement. *The Journal of Physiological Sciences* 58: 7-14, 2008.

25. Greer, B. The effectiveness of low velocity (superslow) resistance training. *Strength and Conditioning Journal* 27: 32-37, 2005.

26. Hakkinen, K., & A. Pakarinen. Acute hormonal responses to two different fatiguing heavy-resistance protocols in male athletes. *Journal of Applied Physiology.* 74 (2); 882-887, 1993.

27. Hakkinen, K., Pakarinen, A., Alen, M, Kauhanen, H., & Komi, PV. Relationships between training volume, physical performance capacity, and serum hormone concentrations during prolonged training in elite weight lifters. *International Journal of Sports Medicine.* 8, 61-65 (1987).

28. Hunter, G, Seelhorst, D, & Snyder, S. Comparison of metabolic and heart rate responses to super slow vs: traditional resistance training. *Journal of Strength and Conditioning Research* 17: 76-81, 2003.

29. Hutchins, K. Superslow: *The Ultimate Exercise Protocol* (2nd ed). Casselberry, FL: Media Support 1992.

30. Huxley, HE. The Contraction of Muscle. *Scientific American*. San Francisco & London W.H. Freeman and Company, 1958.

31. Kawamori, N. & Haff, G. The optimal training load for the development of muscular power. *Journal of Strength and Conditioning Research* 18: 675-684, 2004.

32. Keeler, L, Finkelstein, L, Miller, W, and Fernahall, B. Early-phase adaptations of traditional speed vs. Superslow resistance training on strength and aerobic capacity in sedentary individuals. *Journal of Strength and Conditioning Research,* 15: 309-314*,* 2001.

33. Knuttgen, WJ, Kraemer, WJ. Terminology and measurement in exercise performance. *Journal of Strength and Conditioning Research,* 1: 1-10, 1987.

34. Kraemer, W.J Endocrine responses to resistance exercise. *Medicine and Science in Sports and Exercise* 20: 1988.

35. Kraemer, WJ, Dziados, JE, Marchitelli, LJ, Gordon, SE, Harmon, EA, Mello, R. Fleck, SJ, Frykman, PN, Triplett, TN. Effects of different heavy-resistance exercise protocols on plasma β-ephidorphin concentrations. *Journal of Applied Physiology,* 74; 450-459, 1993.

36. Kraemer, WJ, Fleck, S. *Optimizing Strength Training: Designing Nonlinear Periodization Workouts.* Champaign, IL Human Kinetics, 2007.

37. Kraemer, WJ, & Kizoris, LP. Muscle strength training techniques and considerations. *Phys. Ther. Pract* 2.1, 54-68 1992.

38. Kraemer, WJ, Looney, DP. Underlying Mechanisms and Physiology of Muscular Power. *Strength and Conditioning Journal* 34: 13-19, 2012.

39. Kraemer, WJ, Marchitelli, L, Gordon, SE, Harman, E, Dziados, JE, Mello, R, Frykman, P, McCurry, D, Fleck, SJ. Hormonal and growth factor responses to heavy resistance exercise protocols*. Journal of Applied Physiology.* 69: 1442-1450, 1985.

40. Kraemer, WJ, & Ratamess, NA. Hormonal responses and adaptations to resistance exercise and training. *Sports Medicine;* 35: 339-361, 2005.

41. Lieber, RL. *Skeletal Muscle Structure, Function, and Plasticity: The Physiological Basis of Rehabilitation Third Edition*. Baltimore MD & Philadelphia, PA: Lippincott Willams & Wilkins, 2010.

42. Linnamo, V., Pakarinen, A., Komi, P.V., Kramer, W. & Hakkinen, K. Acute Hormonal Responses to Submaximal and Maximal heavy resistance and Explosive Exercises in Men and Women. *Journal of Strength and Conditioning Research* 19: 566-571, 2005.

43. Lukaszewska, J, Biczowa, B,Bobilewics, D, Obuchowicz-Fidelus, B. Effect of physical exercise on plasma cortisol & growth hormone levels in young weight lifters. *Endokrynol Pol.* 27: 149-57, 1976.

44. Mason, J, Hartley, H, Kotchen, T, Mougey, E, Ricketts, P, Jones, L. Plasma Cortisol, and Noreinephrine Responses in Anticipation of Muscular Exercise. *Psychosomatic Medicine* 35: 406-414 (1973).

45. McBride, JM, Triplett-McBride, T, Davie, A, & Newton, RU. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *Journal of Strength and Conditioning Research* 16: 75-82, 2002.

46. McBride, JM, McCaulley, GO, Cormie, P, Nuzzo, JL, Cavill, MJ, & Triplett, NT. Comparison of methods to quantify volume during resistance exercise. *Journal of Strength and Conditioning Research,* 23(1): 106-10, 2009.

47. McGinnis, PM. *Biomechanics of Sport and Exercise 2nd Ed.* Campaign, IL: Human Kinetics, 2005.

48. Nelson, J. & Kravitz, L. Super Slow Resistance Training. http://www.unm.edu/~lkravitz/Article%20folder/superslow.html accessed 10/16/2012.

49. Newton, R.U., Murphy, A.J, Humphries, B.J, Wilson, G.J, Kraemer, WJ, & Hakkinen, K. Influence of load and stretch shortening cycle on the kinematics, kinetics, and muscle activation that occurs during explosive upper-body movements. *European Journal of Applied Physiology* 75: 333-342. 1997.

50. Rana, SR, Chleboun, GS, Gilders, RM, Hagerman, FC, Herman, JR, Hikida, RS, Toma, K. Comparison of early phase adaptations for traditional strength and endurance, and low velocity resistance training programs in college-aged women. *Journal of Strength and Conditioning Research,* 22: 119-27, 2008.

51. Ratamess, NA, Alvar, BA, Evetoch, TK, Housh, TJ, Kibler, WB, Kraemer, WJ, Triplett, NT. Progression models in resistance training for healthy adults. *American College of Sports Medicine. Medicine and Science in Sports & Exercise,* 41: 687-708, 2009.

52. Requa, RK, DeAvilla, LN, Garric, JG. Injuries in recreational adult fitness activities. *American Journal of Sports Medicine* 21: 461-467, 1993.

53. Schilling, B, Falvo, M., & Chiu, L. Force velocity, impulse-momentum relationships: Implications for efficacy of purposefully slow resistance training. *Journal of Sports Science and Medicine* 7: 229-304, 2008.

54. Shaner, AA, Vingren, JL, Hatfield, DL, Budnar, RG, Duplanty, AA, & Hill, DW. The hormonal response to free weight and machine weight resistance exercise. *Journal of Strength & Conditioning Research* 28: 1032-1040, 2014.

55. Stone, MH, & O'Bryant, HS. *Weight Training: A Scientific Approach.* Minneapolis, Minnesota 55435: Bellwether Press, 1987.

56. Stone, MH. Plisk, SS, Stone, ME, Schilling, BK, O'Bryant, HS, Pierce, KC. Athletic performance development: volume load-1 set vs. multiple sets, training velocity and training variation. *Strength and Conditioning* 20: 22-33, 1998.

57. SuperslowofScottsdale, http://superslowofscottsdale.com/ *accessed Sept 22, 2014.*

58. Superslow Zone, http://slowzone.com 501 N. Orlando Ave., Ste 313-278, WinterPark FL 32789 *accessed Sept 22, 2014.*

59. Westcott, WL. The case for slow weight-training technique Available from htt://media.hometeamsonline.com/photos/football/THE_CASE_FOR_SLOW_REP_SPEED.pdf Accessed Nov 23rd 2014.

60. Westcott WL. Winett R.A., Anderson ES, Wojcik, J.R., L., Loud, RL Cleggett, E., Clover, S. The effects of regular and super slow repetitions on strength. *J Sports Med Phys Fitness* 41: 154–8, 2001.

61. Wickwire, PJ, McLester, JR., Green, JM, & Crews, TR. Acute heart rate, blood pressure, and RPE responses during super slow vs. traditional machine resistance training protocols using small muscle group exercises. *Journal of Strength and Conditioning Research,* 23: 72-9, 2009.

62. Wilson, JD & Foster, DW *Willams Textbook of Endocrinology 8th Ed.* Philadelphia, PA: Harcourt Brace Jovanovich, Inc. 1992.

63. Winnett, RA, Carpinelli, R.N. Review of potential health related benefits of resistance training. *Preventative Medicine,* 33: 503-513, 2001.

64. Zatsiorsky, VM, Kraemer, WJ. *Science & Practice of Strength Training 2nd Ed.* Campaign, IL: Human Kinetics 2006.

The following is a manuscript written for submission to the *Journal of Strength and Conditioning Research* guidelines.

Acute Hormonal Responses to Slow Velocity or Traditional Velocity Resistance Exercise in Men

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Abstract

Slow velocity resistance exercise uses purposely slow movement velocity (e.g., 10 s concentric and eccentric phases) which limits the loads that can be lifted. (e.g., <50% 1 repetition maximum [RM]). The purpose of this study was to determine the acute hormonal responses between slow velocity (Slow) and traditional resistance exercise (Trad) that uses maximal or near-maximal lifting velocities. Ten healthy resistance-trained men (X±SD; age = 24.7±4.4 yrs; height = 1.82±0.06 m; body mass = 93±11.7 kg) were tested for 1RM, and performed 2 randomized, crossover experimental exercise sessions consisting of; Slow velocity session (1 set x 10 repetitions at 28% 1 RM; 10-seconds for concentric and eccentric phases), and a Trad session (3 x10 at 70% 1 RM; maximum velocity muscle actions) with 7 days between experimental trials. Both Slow and Trad sessions included the barbell parallel squat and bench press exercises. Blood samples were collected before (Pre) and 5 min post-exercise (Post). Samples were analyzed for total testosterone (Tes), cortisol (Cort), and immunoreactive 22kDa growth hormone (GH) via ELISAs. Lactate (HLa) was also analyzed. Slow and Trad both increased GH and Cort ($p \leq 0.05$), but with no differences between protocols on post-exercise responses (GH: [Post - Slow = 5.62±3.70 $\mu g \cdot L^{-1}$ vs. Trad 5.00±3.10 $\mu g \cdot L^{-1}$; $p > 0.05$]; Cort: [Post - Slow = 258.5±122.9 $nmol \cdot L^{-1}$ vs. Trad = 284.7±142.0 $nmol \cdot L^{-1}$; $p > 0.05$]). Only Trad increased Tes above resting values (27.15±6.9 vs 32.40±8.5 $nmol \cdot L^{-1}$; $p < 0.05$). HLa increased after both protocols, but Trad produced a larger response (7.82±2.97 vs 13.81±2.07 $mmol \cdot L^{-1}$; $p < 0.05$). Contrary to reports in previous

literature, slow resistance exercise did not produce greater hormonal or lactate responses than the traditional resistance exercise session.

INTRODUCTION

Resistance training is a form of physical exercise which stimulates muscular contraction to oppose a resistance, usually gravity or external load. There are many benefits from resistance training, such as improved overall health, bone density, metabolism, cardiac function, increased tendon and ligament strength and elevated HDL, and reduced risk of injury. Resistance training can also increase anaerobic endurance and increase in the size of skeletal muscle. When developing a resistance training program, multiple factors must be considered to produce optimal results. The first consideration is the purpose of the training which determines the exercise selection. From the exercises selected; sets, repetitions, load, and lifting tempo can be manipulated to develop the proper training program (1). As such, an emerging form of resistance training consists of performing repetitions under a slow cadence (12). Despite the popularity of this type of training in some circles, data concerning the physiological responses to this type of resistance exercise are few and equivocal as to the benefits of such training.

Movement velocity or speed of movement is a factor that is being studied to determine if this component of training improves functional performance. In the 1970's, isokinetic equipment was developed. In 1982, a slow speed training technique was introduced for older women. This training technique consisted of 1 set per exercise and only 4-6 reps. Concentric and eccentric portions of the movement were performed with a 10 sec/10 sec cadence. This type of training was called SuperSlow® (15). The concept of SuperSlow® training was to purportedly create more tension in a muscle for a given workload (21). Westcott and colleagues sought to examine if super-slow is an effective method of resistance training strength. However, intensity can also be defined as a percent of the 1 rep max. Both protocols resulted in an increase in strength. The SuperSlow® group had a slightly greater increase in strength than the regular speed lifting group (28). The results suggested SuperSlow® does indeed increase strength. However, Westcott's study utilized subjects with no prior resistance training history, and therefore it is difficult to extrapolate inferences to those familiar with an extensive history of performing resistance exercise (28). Several researchers believe SuperSlow®, or purposely slow velocity resistance training, to be a superior type of training when compared to traditional weight lifting or Olympic style lifting because it eliminates momentum which purportedly aids in high velocity exercises. Anecdotal accounts suggest SuperSlow® training is a safer form of exercise because most slow velocity protocols are often performed on weight machines where some believe the risk of injury may be less than with free weights. Lastly, supporters of SuperSlow® training point out that although each exercise is performed for only one set, the amount of time taken to lift the weight is longer in duration. The concept of slower repetitions performed increased time under tension, and thus creates more "work" (2), although this definition of work differs from mechanical work (i.e., force x distance).

Previous work has examined the kinematic and kinetic properties of the slow velocity protocol used in the present study compared to the traditional velocity protocol. The results indicated that purposely slow velocity resistance exercise produced significantly less velocity, less force, less momentum, less work, and less power, but more time under tension compared to the traditional velocity (5). Although the time under tension was greater with the slow velocity resistance exercise, the external load was less. Since force = mass x acceleration, and work = force x distance, the lower masses used with slow velocity resistance exercise results in lower mechanical work. If greater time under tension is incorrectly interpreted to mean greater work, then the forces are being ignored. Schilling et al. (2008) examined the mechanical relationship between impulse and momentum when exercise is performed in a purposely slow manner for the barbell back squat. The results indicated normal speed back squats produced greater peak and mean propulsive forces than purposely slow lifting across all loads. However, time under tension was greatly increased in the purposely slow condition. The report indicated greater muscular forces are produced via traditional speed resistance exercise, suggesting it may be a superior modality for inducing neuromuscular adaptation (26).

Resistance training elicits acute physiological responses which are essential for increasing strength, power, and hypertrophy. Testosterone, cortisol, and growth hormone concentrations have been shown to increase acutely after resistance exercise. The responses in the degree of elevation of these hormones increases as the amount of muscle mass used in the exercise increases (19). Thus, large muscle mass exercises have been shown to induce large increases in lactate and suggest that a strong metabolic component may be one stimulus for testosterone and growth hormone (4,9,10,11,12,20).

Research conducted using slow velocity and endocrine responses have produced conflicting results which suggest that how much velocity is reduced may influence acute hormonal concentrations (11,18). Heavy resistance exercise protocols typically elicit an increase in lactate, testosterone, growth hormone, and cortisol, although some studies have reported acute decreases in testosterone or no significant changes in other hormonal concentrations (20). The inconsistent results may be due to variability in tempo or velocity, subject population, training age of subjects, different exercise modalities, variable rest periods, and varying intensities for resistance exercise, and are key to identifying and defining slow velocity. For resistance exercise it is also important to understand how these concepts for program design, periodization, and differences in training methods may influence hypertrophy and metabolic adaptation. Given this information, slow velocity resistance exercise warrants further investigation. The purpose of the current study was to examine the acute hormonal response to purposely slow velocity or traditional velocity resistance exercise in men.

METHODS

Experimental Approach to the Problem

This study used a controlled randomized cross-over design with a 1 week wash-out period, thus permitting each subject to serve as their own control. Each subject was randomly assigned to one of two resistance exercise protocols; slow velocity or traditional velocity. Velocities for the slow and traditional resistance training were based off previous research in the area of slow velocity resistance training and pilot work from our laboratory (5,15,16,24).

Participants

Ten healthy physically active males between the ages of 18-35 years old with at least 1 year of resistance training experience, volunteered to be subjects for the study. At the initial visit all subjects were informed of the study protocol and completed a health history questionnaire. At the second visit, subjects performed maximal strength tests for the free weight barbell high bar parallel squat and free weight barbell bench press. At the third visit, subjects participated in one of the two randomly assigned resistance exercise protocols, and seven days later the subjects returned for their fourth and final visit where they performed the protocol they did not perform the previous week.

Strength Testing

The one repetition maximum (1RM) strength tests were completed for both the bench press and squat exercises using previously described methods (20). Subjects were familiarized with proper back squat technique according to recommended guidelines (1), and were instructed to stand with feet approximately shoulder width apart, and to descend until the posterior thigh was parallel to the ground as assessed by a Certified Strength and Conditioning Specialist (25). Once proper depth was attained, subjects ascended to the starting position. Briefly, subjects performed a light warm-up of 5 to 10 repetitions at 40% to 60% of perceived maximum. After 1 minute subjects performed three to 5 repetitions at 60% to 80% of perceived maximum. A conservative increase in weight was made, and the subject attempted a 1RM lift. If the lift was successful, a rest period of 3 minutes was allowed prior to the next attempt. The 1RM was attained within three to five sets as to avoid excessive fatigue (18).

Resistance Exercise Protocols

Subjects were randomly assigned to one of two protocols. Each subject performed one resistance training protocol during their third visit, and the following visit performed the remaining protocol.

Slow Velocity - The slow velocity protocol consisted of 1 set of 10 repetitions performing the free weight squat with 2 min rest between exercises. Following the squat exercise, the subjects performed 1 set of 10 repetitions of the free weight bench press. Loads for the slow velocity squat and bench press were 28% 1 RM for each exercise based on previous research and pilot work in our laboratory (5,15,16,24). Subjects were instructed to perform each repetition at a tempo of 10 seconds to complete the eccentric phase and 10 seconds for the concentric. Subjects were given an auditory cue from a data collection assistant responsible for only for timing the tempo for the subjects using athletic stopwatch.

Traditional Velocity - The traditional velocity protocol consisted of 3 sets of 10 repetitions performing the free weight squat with 1 min rest between sets. Following the squat exercise the subject rested 2 mins, and then performed 3 sets of 10 repetitions of the free weight bench press. The traditional squat and bench press intensity was 70% of the individual's 1 RM for each of the exercises. Subjects were instructed to perform each repetition in a controlled descent followed by a concentric phase moving the barbell as fast as possible.

Kinematic Measurements

Kinematic data was measured during the resistance, company, exercise sessions using Tendo external dynamometers (Fitronics, Bratislava, Slovakia) attached to the barbells. The velocity of the bar was recorded for each repetition to record the actual barbell velocity for each repetition.

Blood Profiles

All blood samples were collected from an antecubital vein using venipuncture techniques and vacutainers. Samples were obtained at the same time of day (1300-1800 hours) for both lifting conditions to account for diurnal influences. Lactate (HLa) was immediately analyzed from unclotted blood using a calibrated Lactate Plus reader (Nova Biomedical, 41293B 01.2007, Waltham, MA). Hematocrit was also immediately determined using sodium heparin coated microcapillary tubes and centrifugation at 1000g for 5 min. The remaining whole blood was allowed to clot at room temperature and was centrifuged at 1000 g for 15 min at 4° C to obtain serum. Hematocrit and hemoglobin were determined in triplicate to account for plasma volume shifts from the exercise protocols (6). Reported hormonal concentrations were not adjusted for plasma volume shifts because the circulating concentration is what is actually interacting with target tissues and membrane receptors (8). Resulting serum was aliquoted and stored at -80° C for later analysis. Serum cortisol (C), immunoreactive growth hormone (GH), and total testosterone (T) were analyzed using standard enzyme-linked immunosorbent assay (ELISA) kits

(R&D Systems; Minneapolis, MN). ELISA plates were analyzed on a Synergy HT plate reader (Bio-Tek®, Winooski, VT) using KC4 software (Bio-Tek®, Winooski, VT). Intra-assay coefficients of variation were 5.9% for cortisol, 4.2% for growth hormone, and 5.2% for testosterone. All samples for each hormone were analyzed with one assay kit. Standard curves for all ELISAs were $r^2 > 0.99$.

Rating of Perceived Exertion

Rating of perceived exertion (RPE) was explained to each subject in the consent visit and was reviewed prior to the actual data collection. RPE measured for each subject after completion of the exercise protocol and prior to the blood draw. The RPE measurement was a measure on a scale of 1-10, 1 being very easy and 10 the most difficult. Subjects had the ability to report an 11 if the subject felt it exceeded the 1-10 scale of difficulty.

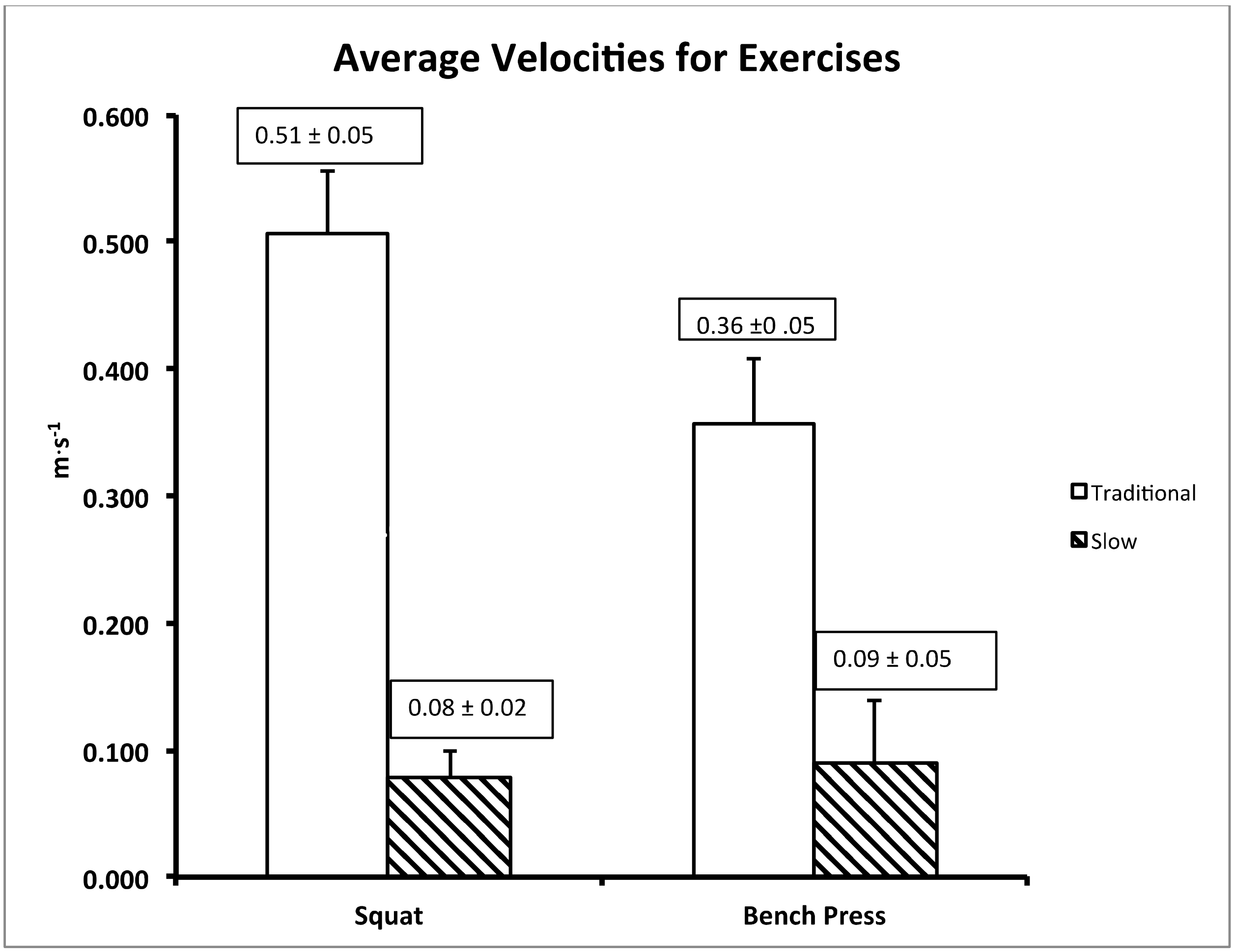
Statistical Analyses

All data were assessed for normality with a Shapiro-Wilks test. A two-way repeated measures analysis of variance (ANOVA; 2 conditions x 2 times) was used to analyze differences between protocols and acute exercise responses for the dependent variables (T, C, GH, & HLa). In the case of a significant interaction, follow up pairwise comparisons (paired T-tests) were performed using a Bonferroni adjustment to determine significant differences. Relative changes in the blood-borne variables (%△) were also analyzed for each hormone and were compared with paired samples T-tests. RPE and plasma volume shifts were also analyzed with paired samples T-tests. Analyses were performed with SPSS v22.0 (Armonk, NY). Significance was determined *a priori* ($p < 0.05$).

RESULTS

Mean barbell velocities for both the slow and traditional velocity resistance exercise squat and bench press exercises for all repetitions combined are shown in Figure 1.

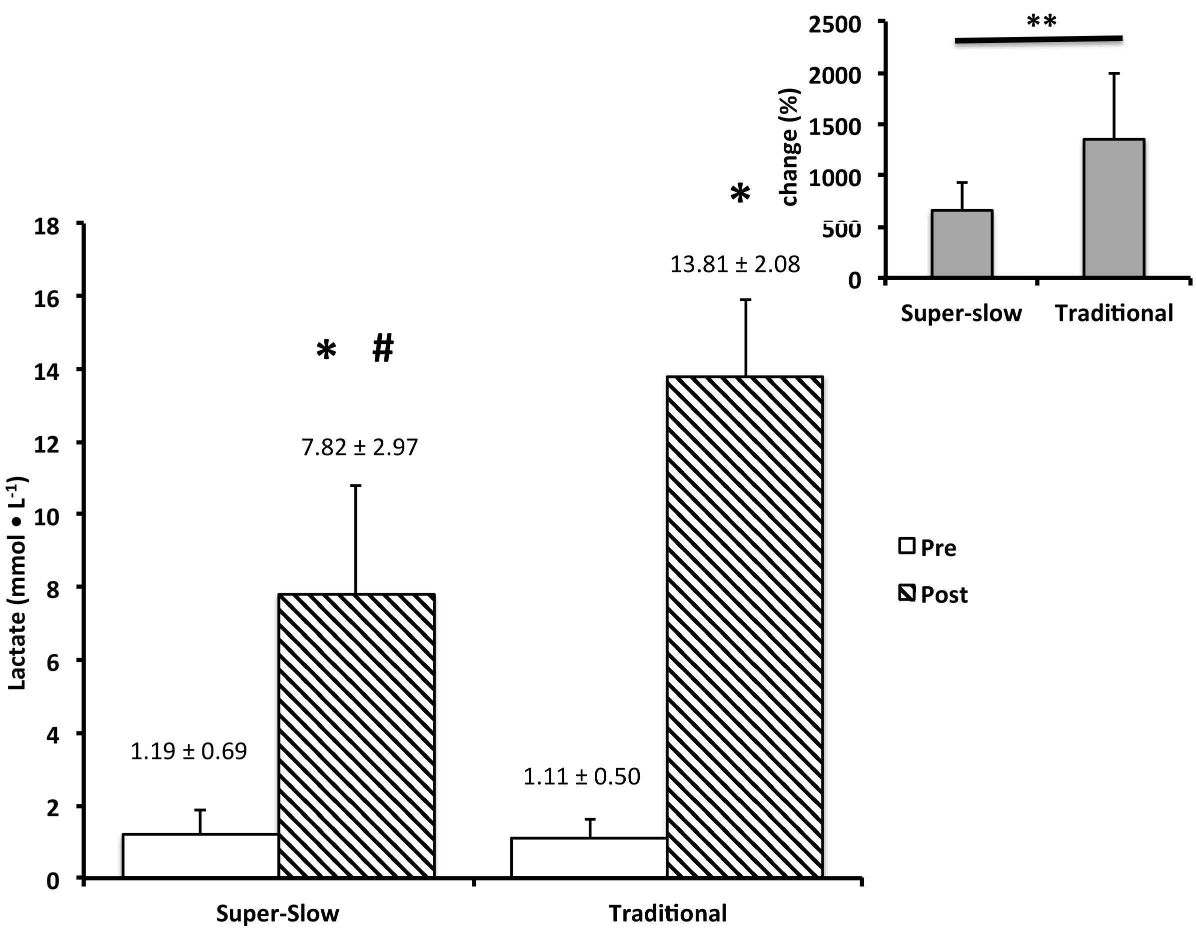
Figure 1



Mean barbell velocities for slow velocity and traditional resistance exercise protocols (n = 10; M±SD).
Solid bars indicate traditional velocity exercises and open bars indicate slow velocity

The results of the two-way repeated measures ANOVA indicated a significant interaction (trial X time) on lactate ($F_{1,9}$= 43.03; p<0.001). Follow up paired t-tests with Bonferroni corrections indicated both slow (t= -7.54; p<0.001) and traditional (t= -20.06; p<0.001) exercise protocols increased lactate concentrations. Traditional post-exercise concentrations were significantly higher compared to slow post-exercise concentrations (t= 6.54; p<0.001). These results are illustrated in Figure 1. The percent increase in lactate concentration between protocols was significantly higher after the traditional velocity protocol (t= -3.156; p= 0.012; Figure 2 inset)

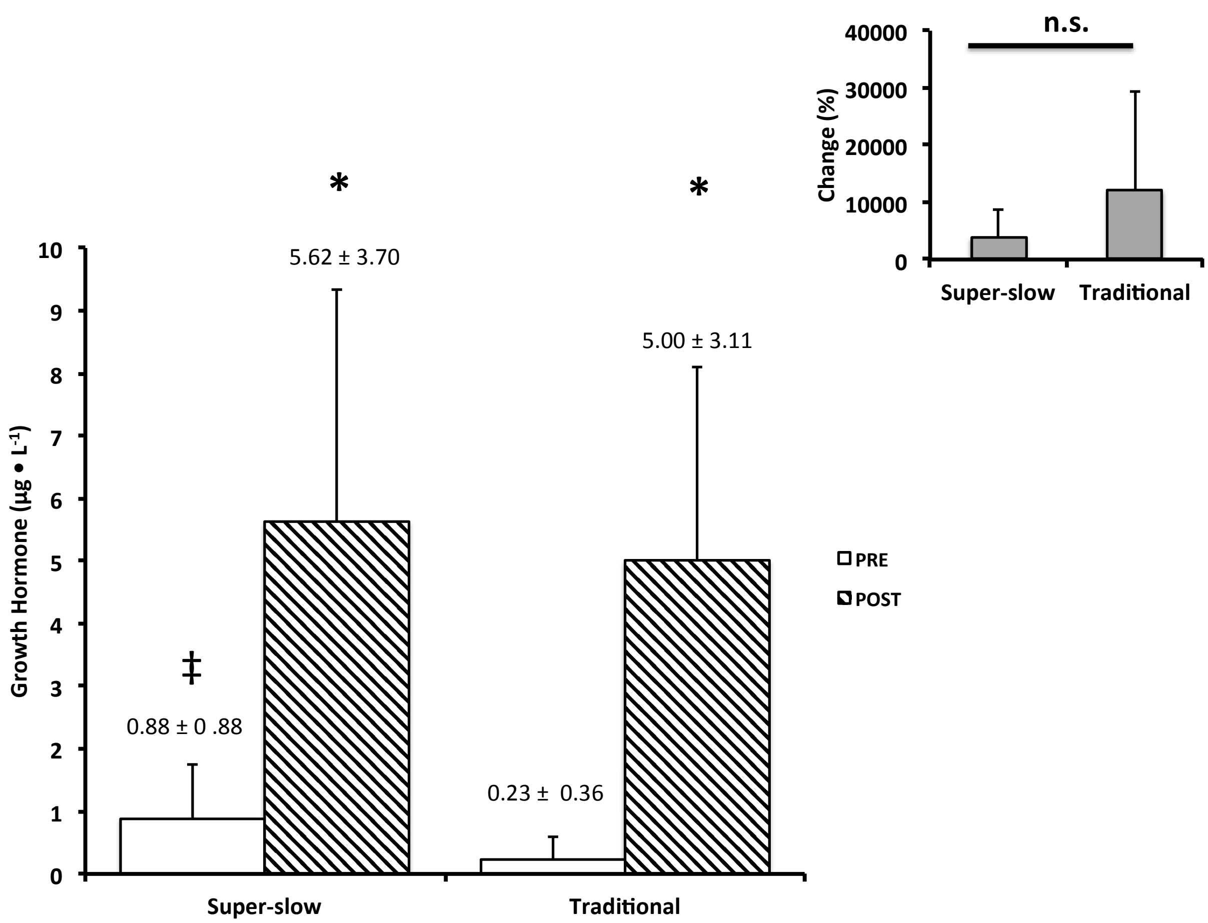
Figure 2



Lactate (mmol/L) responses from Super-slow and traditional resistance exercise protocols (n = 10; M±SD).
* indicates significantly different from corresponding PRE value.
** indicates significantly different percent change responses between protocols in inset figure (p ≤ 0.05).
# indicates significantly different from Traditional protocol POST exercise response (p ≤ 0.05).
Open bars indicate PRE exercise values, striated bars indicate POST exercise response.

There was no significant interaction on GH ($F_{1,9}$= 0.0; p= 0.983). There was a significant main effect of time ($F_{1,9}$=25.86; p<0.001), indicating that both slow velocity (t= -3.94; p= 0.003) and traditional velocity (t= -4.59; p=0.001) exercise conditions significantly increased GH concentrations. Pre-exercise GH concentrations were significantly different between exercise conditions (t= 2.082; p=0.025), with the slow velocity resting values being higher than traditional velocity, however both were within expected physiological ranges. These results are illustrated in Figure 3.

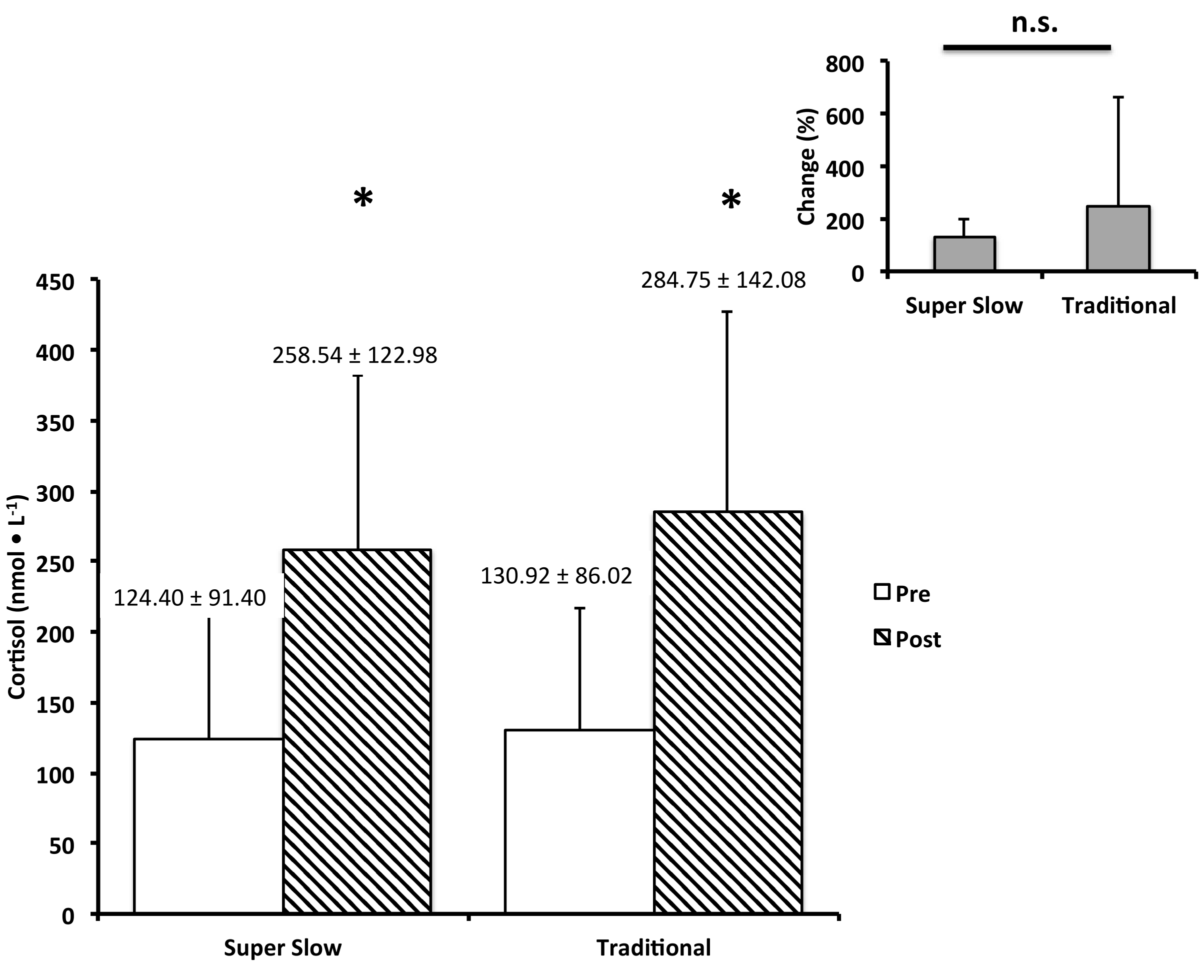
Figure 3



Immunoreactive growth hormone (µg/L) responses from Super-slow and Traditional resistance exercise protocols (n = 10; M±SD).
* indicates significantly different from corresponding PRE value.
‡ indicates significantly different from Traditional protocol PRE exercise value ($p \leq 0.05$).
n.s. Indicates responses are not significantly different ($p \geq 0.05$).
Open bars indicate PRE exercise values, striated bars indicate POST exercise response.

There was no significant interaction on Cortisol ($F_{1,9}$= 0.19; p= 0.669). There was a main effect of time ($F_{1,9}$= 50.31; p< 0.001) indicating both slow velocity and traditional velocity exercise conditions significantly increased cortisol concentrations. These results are illustrated in Figure 4. The percent increase in cortisol between protocols was not significantly different (t= -.837; p=0.425; Figure 3 inset) indicating both protocols increased cortisol concentrations similarly.

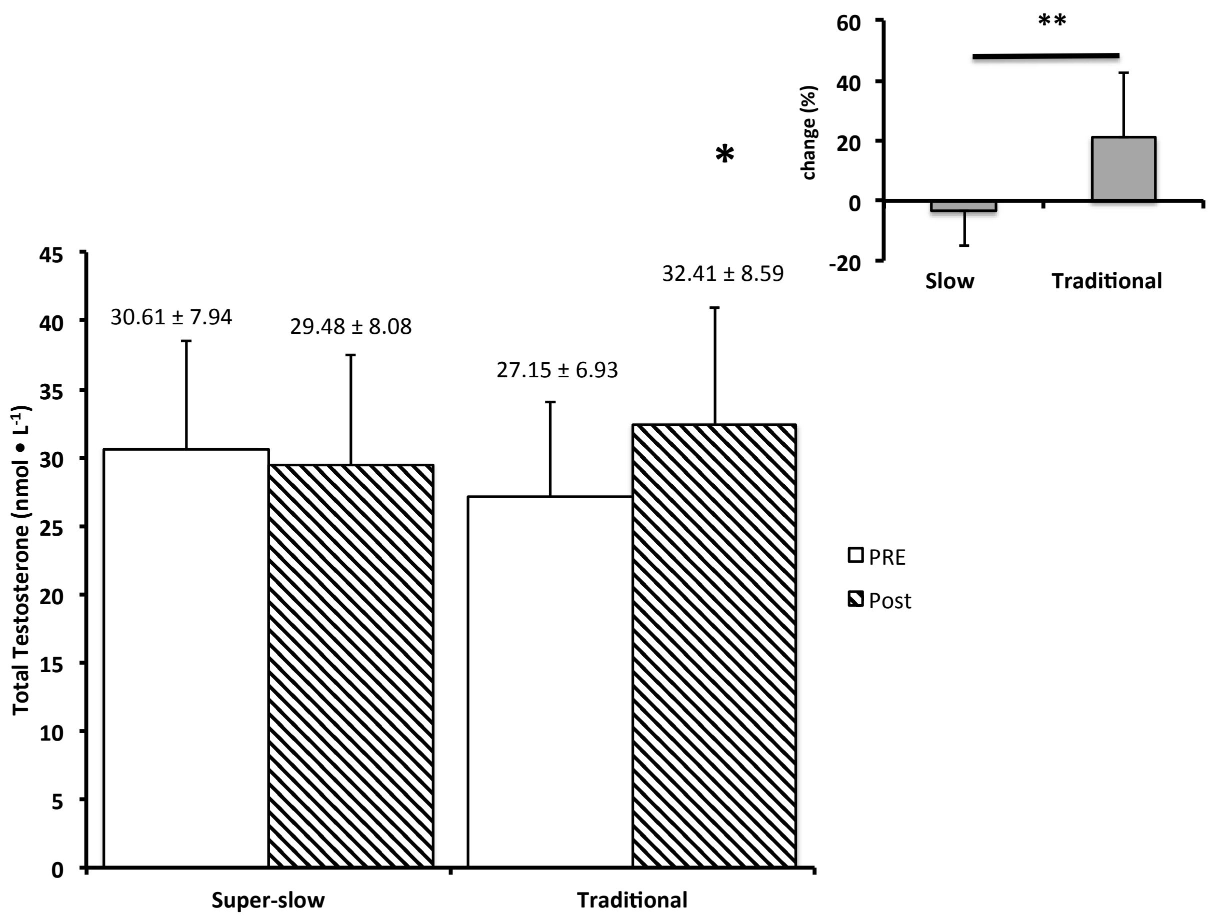
Figure 4



Cortisol (nmol/L) responses from Super-slow and Traditional resistance exercise protocols (n = 10; M±SD).
* indicates significantly different from corresponding PRE value ($p \leq 0.05$).
n.s. Indicates responses are not significantly different ($p \geq 0.05$).
Open bars indicate PRE exercise values, striated bars indicate POST exercise response.

There was a significant interaction of total testosterone ($F_{1,9}$= 18.09; p=0.002). Follow up paired t-tests with Bonferroni corrections indicated that only the traditional velocity condition increased testosterone concentration (t = -2.68; p= 0.025). Testosterone concentration in the slow velocity condition did not significantly change (t= 1.029; p= 0.330). Pre-exercise concentrations were not significantly different between conditions (t= 1.86; p= 0.10). Post exercise testosterone concentrations were not different (t= -1.84; p= 0.09). When the percent change between conditions were analyzed, the percent change in testosterone concentration from the traditional velocity condition was significantly higher than the slow velocity condition (t= -4.24; p= 0.002; Figure 5 inset).

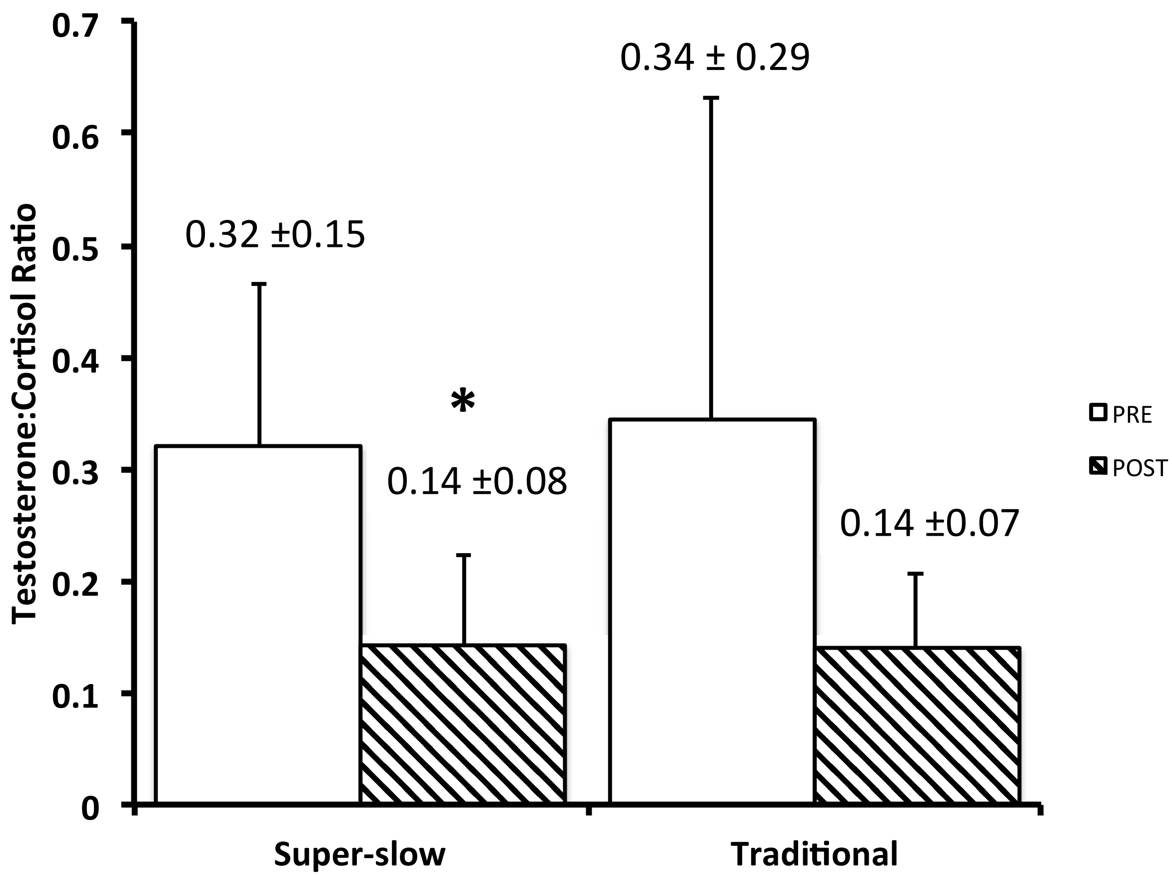
Figure 5



Total testosterone (nmol/L) responses from Super-slow and Traditional resistance exercise protocols (n = 10; M±SD).
* indicates significantly different from corresponding PRE value ($p \leq 0.05$).
** indicates significantly different percent change responses between protocols in inset figure ($p \leq 0.05$).
Open bars indicate PRE exercise values, striated bars indicate POST exercise response.

The ANOVA model indicated there was no interaction effect on the testosterone:cortisol ratio ($F_{1,9}$=0.066; p=0.803), however there was a main effect of time ($F_{1,9}$=17.2; p=0.002). Follow up paired t-tests indicated T:C decreased after the Slow protocol (t= 5.57; p<0.001) while there was a trend for a significant decrease after the Trad (t= 2.22; p=0.053; Figure 6)

Figure 6



Total Testosterone:Cortisol Ratio responses from Super-slow and Traditional resistance exercise protocols (n = 10; M±SD).

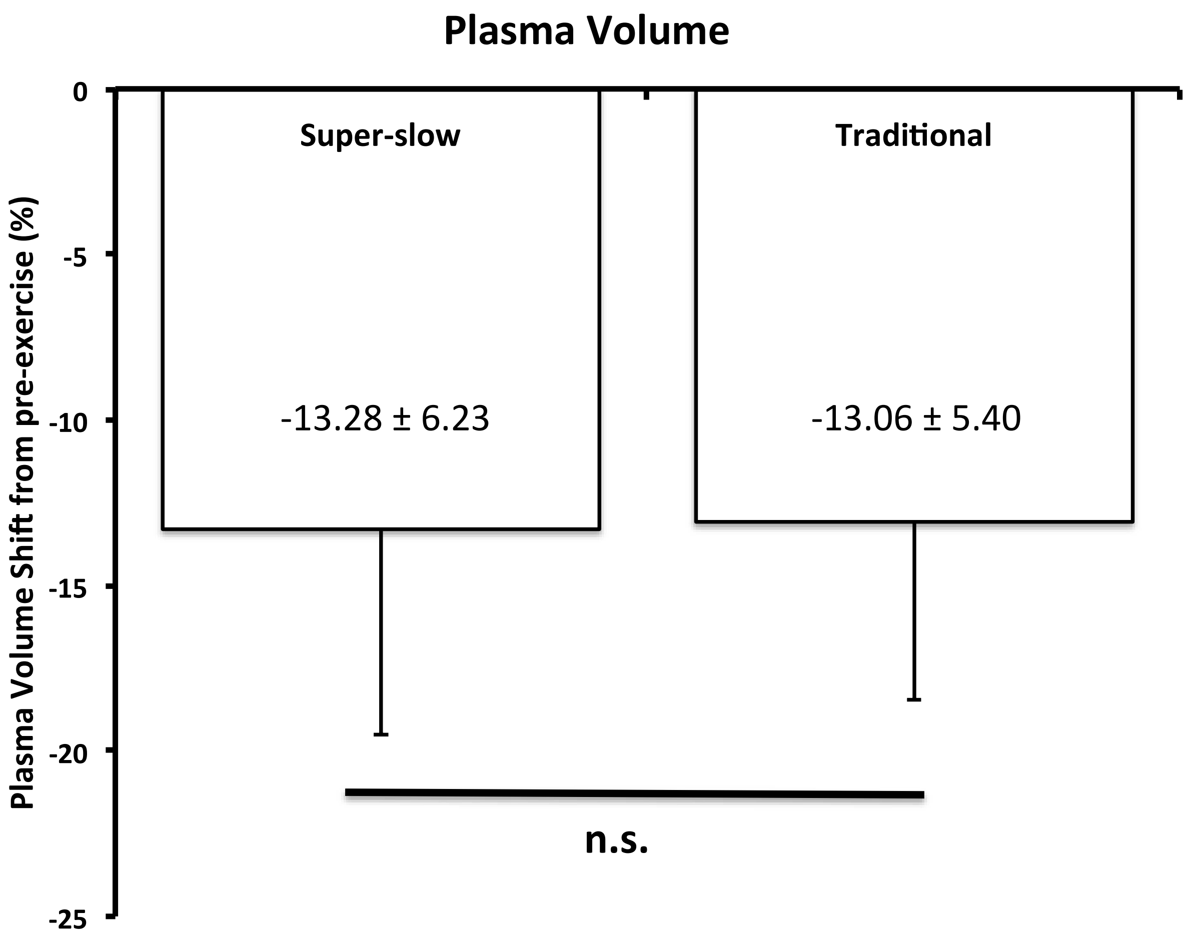
***** indicates significantly different from corresponding PRE value ($p \leq 0.05$).

^ indicates trend for significant decrease (p =0.053).

d indicates Cohen's d effect size. There was a large effect size d=0.982

Plasma volume shifts between protocols were analyzed with paired t-tests. There were no differences in plasma volume change between the two exercise protocols (t= -1.07; p= 0.917). These results are presented in Figure 7.

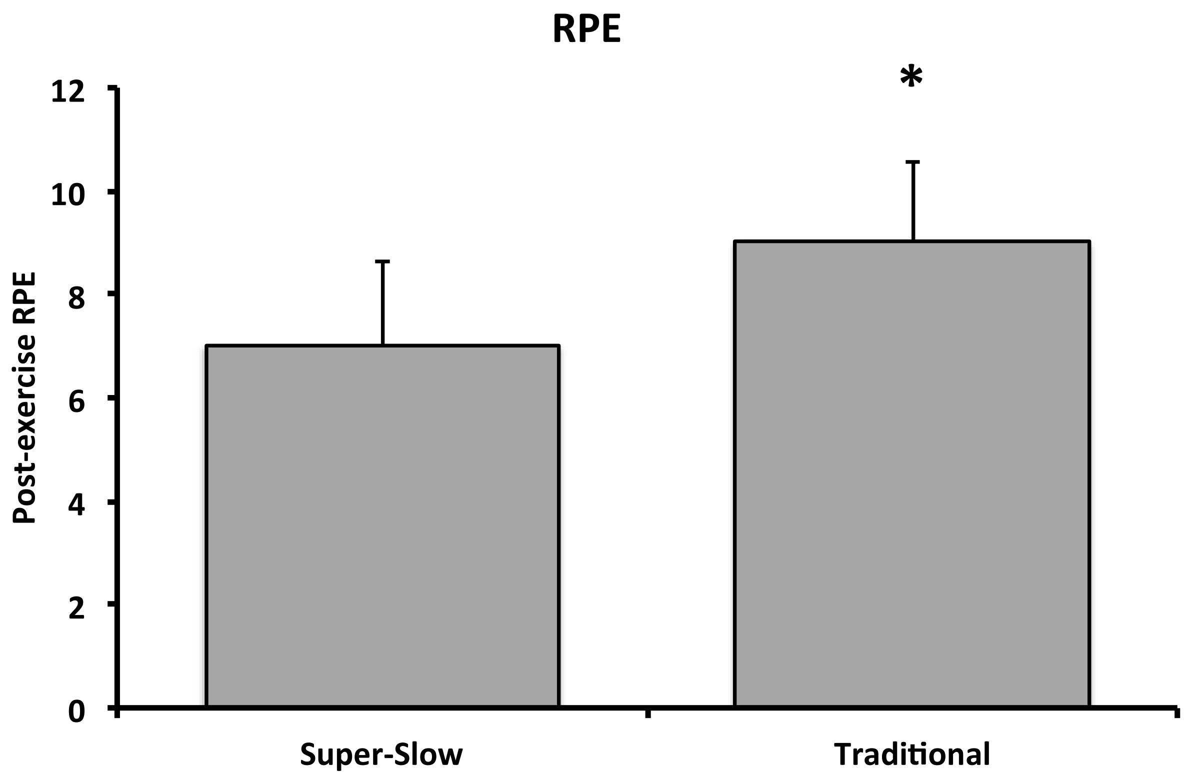
Figure 7



Post exercise plasma volume shifts between exercise protocols (n = 10; M±SD)
n.s. indicates not significantly different responses between protocols (p>0.05)

RPE at post exercise between protocols were analyzed with paired t-tests. The results indicated RPE was significantly higher after the traditional velocity protocol compared to the slow velocity protocol (t= -4.74; p=0.001). These results are presented in Figure 8.

Figure 8



Post exercise RPE values (n = 10; M±SD).
* indicates significant difference between exercise protocols ($p \geq 0.05$).

DISCUSSION

Kinematic results from this study were able to show subjects followed both protocols and that those protocols were different. Findings were similar to those found in a previous study (5). The results of the present study also demonstrated both the slow velocity and the traditional velocity protocols elicited significant acute increases in hormonal concentration. Several variables such as lactate and testosterone were significantly influenced by the exercise protocols, and these responses were specific to the exercise stressor. The increase in testosterone and lactate may be attributed to the substantially different load/intensity of the exercise protocols, which is consistent with previous research (18,19). On the contrary, Cortisol and GH responses were similar after both protocols. These results highlight the physiologic alterations of divergent velocity exercise protocols, and these responses may provide a physiologic rationale to the specific training adaptations associated with slow velocity resistance exercise, compared to resistance exercise preformed at traditional loads and velocity.

Lactate responses were significantly increased from exercise after both the traditional and slow protocols, however, there was a distinct difference in absolute and percent increase values between the two protocols. Kraemer et al. (1993) reported an increase in lactate profiles following 6 different heavy resistance exercise protocols (19). Similarly, Popov et al., 2014 reported lactate concentrations increased with resistance exercise at high intensity (~70% 1RM) more than moderate intensity loads (~50% 1RM). Popov and colleagues also reported lactate was greater than using a moderate intensity, high time-under-tension (i.e. no relaxation between repetitions) protocol compared to the same protocol that used relaxation of muscle tension between repetitions. These results highlight, greater time under tension produces significant metabolic perturbation, but a protocol utilizing a greater load will result in significantly greater lactate values. Phosphorylation of extracellular signal-regulated kinase 1/2 (ERK 1/2), which is an anabolic signaling protein, is sensitive to the degree of metabolic stress performed during resistance exercise (23). During super slow velocity resistance exercise, although low load, the contractions are of longer duration. While speculative, high time-under tension in conjunction with higher metabolic stress, similar to that which is performed during low load slow velocity training may thus provide a rationale in which this type of resistance exercise could induce hypertrophy of muscle tissue with chronic training. Low load, high volume stimulates muscle protein synthesis more than high load low volume resistance exercise in men. Burd et al., 2010 hypothesized from previous research that acute stimulation of muscle protein synthesis would occur if the exercise was done till failure (with concomitant metabolic stress), regardless of intensity. While the primary scope of this investigation was to elucidate the acute endocrine responses of super-slow training, future research should investigate training responses down stream of hormonal concentration and determine to what degree adaptations to chronic metabolic stress of this type of training and subsequent effects on muscle performance.

The traditional velocity protocol induced a significant increase in total testosterone indicated concentration from pre to post exercise, whereas the slow velocity protocol did not produce any significant alterations. While absolute post-exercise values were not different between protocols, there was much variability in the post exercise responses. As such, relative change was (i.e. percent change) was analyzed and exercise induced changes in testosterone concentration between the two protocols were significantly different (i.e. Slow: -3% ($p>0.05$). vs Traditional: 21% ($p<0.05$)). Kraemer et al, 1990 provided evidence heavy resistance exercise protocols produced increases in serum testosterone. On the contrary, Goto et al. (2008) which utilized low intensity and slow movement velocity resistance exercise reported a significant decrease in free testosterone (11). The slow velocity protocol utilized in the present study produced a non-significant decrease in testosterone. The disagreement between findings may be due to differences in the time under tension, exercises utilized, or analysis of bound vs. unbound fractions of hormone.

Cortisol produced a significant increase in concentration levels pre- to post-exercise in both protocols, however there was no significant differences between the two protocols. Kraemer et al. (1993) reported high total workloads were associated with an increase in serum cortisol levels. Goto et al. (2008) found that high intensity normal movement and the low intensity slow movement protocols both increased cortisol acutely. Our findings support the thesis, as well as corroborate pervious work (19) that duration of force, and short rest periods are key variables which increase cortisol concentration

Immunoreactive GH increased from the pre to post exercise in both exercise protocols. The pre-values were significantly different between each protocol. This could be in part due to the variability amongst subjects, but all pre values were within acceptable normal resting values. Previous literature states resistance exercise has been shown to elevate concentrations of GH through 30 minutes post exercise, but the magnitude of the increase depending upon exercise selection and muscle mass recruited (19). Kraemer et al. (1990) conducted a study using heavy resistance exercise protocols, (HREPs) which associated high levels of total work, short rest intervals, and high loads demonstrated significant changes in GH levels in subjects post exercise (18). Goto et al., (2008) also reported that with all RE protocols in his study there was an increase in GH concentrations. A similar investigation (10) a reported slow movement increased growth hormone, but the high intensity, normal velocity protocol did not induce a significant increase of GH. This is in disagreement with the current study which highlights Kraemer's assertion of high intensity, large muscle mass movements which subsequently increases systemic GH concentration (18, 20).

Plasma Volume was not different between the two resistance exercise protocols as well as RPE (Rate of Perceived Exertion) levels. Ploutzer-Snyder et al, 1995 found in their study that following immediately following the squat exercise there was a 22% decrease in plasma volume shifts with an increase in VS (vasti) muscle cross sectional area. The findings from that study support the idea that increased muscle size following resistance exercise is reflective primarily fluid movement. Rate of Perceived Exertion (RPE) and resistance training exercises was examined (7). In their protocol there were three different forms of resistance exercise used, slow, traditional, and power. Findings from that study show there different resistance training modes result in differences in perceived exertion, not directly to the loading used for the resistance exercise. They also found that traditional and super slow training RPEs did not differ from each other, but did when compared to the power training. The findings were similar to the observed RPEs from the current study.

Schoenfeld et al, 2014 found heavy weights for optimizing the post exercise muscle response. Light loads lifted to muscular failure may promote adaptations similar to heavy load training. This theory is the idea that momentary effort, regardless of magnitude of load will result in a full spectrum of available motor units and thereby have the potential for contributing to muscle hypertrophy. There is support that fatiguing contractions result in corresponding increased EMG activity, high threshold motor units utilized to maintain force output (27). In the case of slow velocity resistance exercise, this offers an intriguing hypothesis. During slow velocity the intensity is reduced, but the activation is for a longer duration. Thus the potential idea regarding high threshold motor units to be activated to maintain force output when the low threshold motor units have fatigued could be potentially correct.

Limitations for the present study were baseline controls. Although subjects were randomized and each subject was used as their own control, there is still variation day to day of each subject's resting hormonal levels. Although there were differences in some subjects pre resistance exercise values, all baseline levels were within normal range. Also, each subject completed each protocol fully, ideally each subject would be able to complete the protocols at the prescribed loads, because the loads were based directly of each subject's 1 rep maximum effort for the free weigh squat and bench press. During several of the testing sessions, and both protocols, subjects reached failure at the prescribed load. In order to complete the protocol fully loads were reduced slightly to allow subject to continue to complete remainder of the protocol. Lastly, equating the amount of total work as discussed previously, may be a contributing factor to increased growth hormone response. Previous pilot work (5) used the exact protocol for kinematic analysis showing mechanical work was greater for the traditional protocol, but the slow velocity protocol displayed significantly more time under tension although being just 1 set of 10 reps in comparison of the traditional protocol being 3 sets of 10 exercises. The previous work gave rationale for using the same protocol to look at acute hormonal responses.

CONCLUSIONS

Slow velocity resistance exercise does exhibit an acute effect on endocrine responses. Both protocols produced similar changes in circulating hormone concentrations in cortisol and growth hormone. However only the traditional velocity protocol induced significant increases in testosterone and lactate.

PRACTICAL APPLICATIONS

Exercise professionals and researchers should be aware and informed of new resistance exercise routines. The results from this study may be used when considering and writing training programs for various populations. Depending upon the goal of the coach/trainer and the health status of the client/participant. From this study, slow velocity may be an effective alternative to traditional velocity resistance exercise because of the increases in acute hormonal responses which were similar to traditional resistance exercise responses. All important factors should be considered when developing a resistance exercise program.

REFERENCES FOR MAUNSCRIPT

1. Baechle, RT, & Earle, RW. *Essentials of Strength and Training and Conditioning: National Strength and Conditioning Association.* Champaign, IL: Human Kinetics, 2008.

2. Brzycki M. *A practical approach to strength training*. Indianapolis, IN: Masters Press, 1995

3. Budnar, RG, Duplanty, AA, Hill, DW, McFarlin, BK, Vingren, JL. The acute hormonal response to the kettlebell swing exercise. *Journal of Strength & Conditioning Research* 28: 2793-2800, 2014.

4. Burd NA, West DWD, Staples AW, Atherton PJ, Baker JM, Moore, DR, Holwerda, AM, Parise, G, Renniez, MJ, Baker, SK, Phillips, SM. Low-Load High Volume Resistance Exercise Stimulates Muscle Protein Synthesis More Than High-Load Low Volume Resistance Exercise in Young Men. *PLoS ONE 5(8): e12033. doi:10.1371/journal.pone.0012033,* 2010.

5. Dietz, PR, Fry, AC, Herda, TJ, Andre, MJ, & Lane, MT. Kinematic properties of slow velocity and traditional velocity resistance training sessions. 2015 NSCA Abstract Poster Presentation July 9, 2015.

6. Dill, DB & Costill, DL. Calculation of percentage changes in volumes of blood, plasma, and red cells in dehydtration. *Journal of Applied Physiology* 37, 2, 1974.

7. Egan, AD, Winchester, JB, Foster, C, McCuigan, MR. Using session RPE to monitor different methods of resistance exercise. *Journal of Sports Sci Med.* 5(2) 289-295, 2006.

8. Fry, AC, Kraemer, WJ Resistance exercise overtraining & overreaching. *Sports Med.* 23(2):106-129, 1997.

9. Fry, A.C., Kraemer, W.J., Stone, M.H., Koziris, L.P., Thrush, JT, & Fleck, SJ. Relationships between serum testosterone, cortisol, and weightlifting performance. *Journal of Strength and Conditioning Research* 14: 338-343, 2000.

10. Goto, K, Ishii, N, Kizuka, T, Kraemer, R, Honda, Y, Takamatsu, K. Hormonal and metabolic responses to slow movement resistance exercise with different durations of concentric and eccentric actions. *Eur J Appl Physiol* 106: 731-739, 2009.

11. Goto, K., Takahashi, K., Yamamoto, M. & Takamatsu, K. Hormone Recovery Responses to Resistance Exercises with Slow Movement. *The Journal of Physiological Sciences* 58: 7-14, 2008.

12. Greer, B. The effectiveness of low velocity (superslow) resistance training. *Strength and Conditioning Journal* 27: 32-37, 2005.

13. Hakkinen, K., & A. Pakarinen. Acute hormonal responses to two different fatiguing heavy-resistance protocols in male athletes. *Journal of Applied Physiology.* 74 (2); 882-887, 1993.

14. Hunter, G, Seelhorst, D, & Snyder, S. Comparison of metabolic and heart rate responses to super slow vs: traditional resistance training. *Journal of Strength and Conditioning Research* 17: 76-81, 2003.

15. Hutchins, K. Superslow: *The Ultimate Exercise Protocol* (2nd ed). Casselberry, FL: Media Support 1992.

16. Keeler, L, Finkelstein, L, Miller, W, and Fernahall, B. Early-phase adaptations of traditional speed vs. Superslow resistance training on strength and aerobic capacity in sedentary individuals. *Journal of Strength and Conditioning Research,* 15: 309-314*,* 2001.

17. Kraemer, W.J. Endocrine responses to resistance exercise. *Medicine and Science in Sports and Exercise* 20: 1988.

18. Kraemer, WJ, Marchitelli, L, Gordon, SE, Harman, E., Dziados, JE, Mello, R., Frykman, P., McCurry, D., & Fleck, SJ. Hormonal and growth factor responses to heavy resistance exercise protocols. *Journal of Applied Physiology* 69 (4); 1442-1450 1990.

19. Kraemer, WJ, Dziados, JE, Marchitelli, LJ, Gordon, SE, Harmon, EA, Mello, R. Fleck, SJ, Frykman, PN, Triplett, TN. Effects of different heavy-resistance exercise protocols on plasma β-ephidorphin concentrations. *Journal of Applied Physiology,* 74; 450-459, 1993.

20. Kraemer, WJ, & Ratamess, NA. Hormonal responses and adaptations to resistance exercise and training. *Sports Medicine; 35: 339-361*, 2005.

21. Nelson, J. & Kravitz, L. Super Slow Resistance Training. http://www.unm.edu/~lkravitz/Article%20folder/superslow.html accessed 10/16/2012.

22. Ploutz-Snyder, LL, Convertino, VA, Dudley, GA, Resistance exercise-induced fluid shifts: change in active muscle size and plasma volume. *American Journal of Physiology* 269 (3), 1995.

23. Popov, DV, Lysenko, EA, Bachinin, AV, Miller, TF, Kurochkina, NS, Kravchenko, IV, Furalyov, VA, & Vinogradova, OL. Influence of resistance exercise intensity and metabolic stress on anabolic signaling and expression of myogenic genes in skeletal muscle. *Muscle Nerve* 51: 434-442, 2015.

24. Rana, SR, Chleboun, GS, Gilders, RM, Hagerman, FC, Herman, JR, Hikida, RS, Toma, K. Comparison of early phase adaptations for traditional strength and endurance, and low velocity resistance training programs in college-aged women. *Journal of Strength and Conditioning Research,* 22: 119-27, 2008.

25. Shaner, AA, Vingren, JL, Hatfield, DL, Budnar, RG, Duplanty, AA, & Hill, DW. The hormonal response to free weight and machine weight resistance exercise. *Journal of Strength & Conditioning Research* 28: 1032-1040, 2014.

26. Schilling, B, Falvo, M., & Chiu, L. Force velocity, impulse-momentum relationships: Implications for efficacy of purposefully slow resistance training. *Journal of Sports Science and Medicine* 7: 229-304, 2008.

27. Schoenfeld, BJ, Contreras, B, Willardson, JM, Fontana, F, Tiryaki-Sonmez, G. Muscle activation during low-versus high- load resistance training in well-trained men. European Journal of Applied Physiology 114:2491-2497, 2014.

28. Westcott, W.L., Winett, R.A., Anderson, E.S., Wojcik, J.R., Loud, R.L.R., Cleggett, E., and Glover, S. Effects of regular and slow speed resistance training on muscle strength. *Journal of Sport Medicine and Physical Fitness,* 41, 154-158, 2001.

Dill, DB & Costill, DL. Calculation of percentage changes in volumes of blood, plasma, and red cells in dehydtration. *Journal of Applied Physiology* 37, 2, 1974.

Appendix A

Table 1. Subject Descriptives

Table 1. Subject Descriptives

	Age (yrs)	Body mass (kg)	Height (m)	1-RM Back Squat (kg)	1-RM Bench Press (kg)
Mean	24.7	93	1.82	157.3	118.9
SD	4.4	11.7	0.06	49	25

Appendix B

Informed Consent with IRB approval number

University of Kansas IRB Approval

KU Lawrence IRB # STUDY00002613 | Approval Period 5/27/2015 – 5/26/2016

Informed Consent

Acute Hormonal Responses to Traditional or Controlled Velocity Resistance Exercise

INTRODUCTION

The Department of Health Sport and Exercise Sciences at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this project is to determine if altering the speed of lifting and load of the resistance training results in a different hormonal response immediately after the training session. It is hypothesized that a traditional velocity resistance exercise protocol will have a significantly different hormonal response than the slow velocity resistance exercise protocol.

ELIGIBILITY

In order to participate in this study you must be male, between the ages of 18 and 35, healthy and free of musculoskeletal injuries specific to the ankle, knee, hip or shoulder joints. You will be screened for participation using a health history questionnaire. In order to participate in this study you must be physically fit and have prior experience performing resistance training. The total time commitment, if you choose to participate, will be approximately 2.5 hours. For the first testing session, you will spend approximately 0.5 hrs testing maximum strength for the bench press and squat exercises. Later, you will perform one of the resistance training protocols during 1 hour sessions for visits 2 and 3, spread over 2 – 3 weeks.

PROCEDURES

1. Each subject will be involved in 4 total visits

1) Consent visit (approximate time 10-30 minutes)

2) Maximum strength testing visit (approximate time 30 min to 1 hour)

3) Exercise Protocol 1or 2 (approximate time 1 hour)

4) Exercise Protocol 2 or 1 (approximate time 1 hour)

Each subject will fill out a health history questionnaire to establish that they qualify for the study, and will sign an informed consent statement. If agreeing to participate, all subjects will undergo a testing session to determine maximal strength for both the barbell bench press and the barbell back squat exercises. These results will ensure that each subject is capable of performing the exercises required in this study. All subjects will participate in both resistance exercise protocols.

2. Once the subjects' lifting loads are determined, the subjects will participate in two lifting sessions over a 2 week period. These sessions will include performing the free weight squat exercise followed by the free weight bench press exercise. One session will involve lifting the weights for 3 sets of 10 repetitions at maximal speeds using 70% of maximum loads, while the other session will involve lifting 1 set of 10 repetitions very slowly (10 sec raising and 10 sec lowering) while using 28% of maximum loads. During the slow lifting session, subjects will hear an audio signal telling them the correct velocity to lift the weights. The order of which lifting protocol will

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be performed first (fast or slow) will be randomly assigned for each subject. Rest intervals between sets will be 1 minute, and between exercises will be 2 minutes.

3. Each subject will give two blood samples each collection day (visits 2 and 3). Samples will be approximately 20 mL (which is equivalent to 2 tablespoons of blood) and will be taken 5 minutes pre-exercise and 5 minutes postexercise. Blood samples will be taken from a vein on the inside of the elbow using sterile procedures.

RISKS

There is inherent danger in all physical exercise. You may experience muscle soreness during the 48-72 hours following your testing sessions. There is also the possibility of injury to your shoulder, or your knees, hips or back when performing the activities in this study. You may also experience some bruising or discomfort at the site of the blood sampling. You will be given a 24 hour contact number for study personnel to convey any type of unusual discomfort or injury.

BENEFITS

You will get a chance to learn about your hormonal response to resistance exercise, as well as the effects of performing resistance exercise at very different velocities.

PAYMENT TO PARTICIPANTS

There will be no compensation for participation in this study.

PARTICIPANT CONFIDENTIALITY

Your name will not be associated in any publication or presentation with the information collected about you or with the research findings from this study. Instead, the researcher(s) will use a study number or a pseudonym rather than your name. Your identifiable information will not be shared unless (a) it is required by law or university policy, or (b) you give written permission. Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future. All data and videos from this study will be destroyed after it has been presented at a scientific conference and/or after it has been published in a scientific journal, and after a 7 year period.

INSTITUTIONAL DISCLAIMER STATEMENT

"In the event of injury, the Kansas Tort Claims Act provides for compensation if it can be demonstrated that the injury was caused by the negligent or wrongful act or omission of a state employee acting within the scope of his/her employment."

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose further information collected about you, in writing, at any time, by sending your written request to: Dr. Andrew Fry, 1301 Sunnyside Ave., Room 101C. If you cancel permission to use your information, the researchers will stop collecting additional information about

you. However, the research team may use and disclose information that was gathered before they received your cancellation, unless notified otherwise.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s) listed at the end of this consent form.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or (785) 864-7385, write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ ____________________________________ ____________

Print Subject's Name Signature of subject Date

_______________________________ ____________________________________ ____________

Print Name of Person Signature of Person Obtaining Consent Date

Obtaining Consent

_______________________________ ____________________________________ ____________

Print Name of Witness Signature of Witness Date

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Appendix C

Pre-Exercise Testing Health & Exercise Status Questionnaire

PRE-EXERCISE TESTING
HEALTH & EXERCISE STATUS
QUESTIONNAIRE

THE UNIVERSITY OF KANSAS

Name ____ Date_____________

Home Address ____

Phone Number ______________________ Email ______________________

Birthday (mm/dd/yy)____/_____/_____

Person to contact in case of emergency_______________________________________

Emergency Contact Phone _____________________

Gender________ Age ______(yrs) Height ______(ft)______(in) Weight______(lbs)

A. JOINT-MUSCLE STATUS (✓Check areas where you currently have problems)

Joint Areas
( ) Wrists
( ) Elbows
( ) Shoulders
( ) Upper Spine & Neck
( ) Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( ) Feet
( ) Other____________________

Muscle Areas
( ) Arms
( ) Shoulders
( ) Chest
( ) Upper Back & Neck
( ) Abdominal Regions
( ) Lower Back
( ) Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet
( ) Other__________________

B. HEALTH STATUS (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Acute Infection
( ) Diabetes or Blood Sugar Level Abnormality
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction

( ) Edema	( ) Pancreas Dysfunction
( ) Epilepsy	( ) Liver Dysfunction
( ) Multiply Sclerosis	( ) Kidney Dysfunction
( ) High Blood Cholesterol or Triglyceride Levels	( ) Phenylketonuria (PKU)
( ) Allergic reactions to rubbing alcohol	( ) Loss of Consciousness

* *NOTE: If any of these conditions are checked, then a physician's health clearance will required.*

C. PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical examination______________________________

Physical problems noted at that time____

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES __________NO

If YES, what limitations were recommended?___________________________________

____

D. CURRENT MEDICATION USAGE (List the drug name, the condition being managed, and the length of time used)

MEDICATION	CONDITION	LENGTH OF USAGE
____________________	____________________	____________________
____________________	____________________	____________________

E. PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

PA	SED		PA	SED	
( )	( )	Chest Pain	( )	( )	Nausea
( )	( )	Heart Palpitations	( )	( )	Light Headedness
( )	( )	Unusually Rapid Breathing	( )	( )	Loss of Consciousness
( )	( )	Overheating	( )	( )	Loss of Balance
( )	( )	Muscle Cramping	( )	( )	Loss of Coordination
( )	( )	Muscle Pain	( )	( )	Extreme Weakness
( )	( )	Joint Pain	( )	( )	Numbness
( )	( )	Other______________________	( )	( )	Mental Confusion

F. FAMILY HISTORY (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes

( ) Sudden Death (other than accidental)

G. EXERCISE STATUS

Do you regularly lift weights? **YES** **NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

What is your back squat 1 repetition maximum (RM)? _____________

What is your bench press 1 RM? ____________

What are your other 1 RMs that are not listed? ____

Appendix D

Rate of Perceived Exertion Scale

RPE Scale

While exercising we want you to rate your perception of exertion, i.e., how heavy and strenuous the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in you muscles and on your feeling of breathlessness or aches in the chest.

Look at this rating scale; we want you to use this scale from 1 to 10, where 1 means "no exertion at all" and 10 means "maximal or very, very strong exertion."

For most people this is the most strenuous resistance exercise they have ever experienced.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Don't underestimate it, but don't overestimate it either. It's your own feeling of effort and exertion that's important, not how it compares to other people's. What other people think is not important either. In addition, this scale has no anchor. That is, if after giving a "10" on a previous rating, you decide that the current exercise is more strenuous, you may give a higher number (i.e. "11"0. Look at the scale and the expressions and then give a number.

Any questions?

Borg CR-10 Scale of Perceived Exertion

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"
11		
•	Absolute Maximum	Highest possible

Appendix E

Model Release Form

Model Release Form

Agreement by the subject to confer rights to use photographs(s) or video(s) by the KU School of Education

I hereby give my consent for my photograph or videograph taken this day to be used by the KU School of Education, or any of its departments, in any way related to the publicity programs of this organization.

Date

Name (please print)

Signature

Grade Level

Academic Major

Hometown

If the subject is a minor (younger than 18 years old), please

complete the following:

Name of parent or guardian (please print)

Signature of Parent or Guardian

SOE photo job #

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