THE EFFECTS OF TRADITIONAL, CONTRAST AND
PRE-EXHAUSTIVE TRAINING METHODS
ON PERFORMANCE VARIABLES

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In
Kinesiology

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Abstract

Purpose of the Study: Resistance training is one of the most effective modes of training utilized to increase athletic performance across a wide range of sports and activities of a physical nature. However, to cultivate desired changes in athletic performance, while also accounting for a reduced risk/severity of injury, resistance-training sessions must be tailored and specific to each sport or activity. Numerous training modalities have been developed to account for specificity during resistance-training sessions. The goals of these modalities are to increase specificity of resistance-training sessions with the expectation of optimizing athletic performance and/or injury prevention. Specificity is sometimes accomplished through manipulation of exercise order outside of prescribed traditional protocol norms. The purpose of this study was to investigate the acute effect of three resistance-training modalities, Traditional Training (TT), Contrast Training (CT) and Pre-Exhaustive Training (PT) on three performance measures critical to power performance sports.

Procedure: To ascertain if significant differences in performance were evident after acute treatment participants completed three resistance-training sessions of equal volume, varying in intensity and order of exercise completion. After treatment protocol participant's performance was evaluated following a 1-hr recovery period to ascertain if significant differences were evident on performance-tested variables due to treatments. Specifically, declines in vertical leap, agility and repeated-sprint performance may imply direct targeting of physiological systems responsible for performance and imply long-term benefits to such training.

Findings: Results indicated significant differences in time (ps; 0.001) to complete TT, CT and PT protocols. Also, significant differences were evident between Control vertical jump performance and TT (ps 0.009), CT (ps 0.001) and PT (ps 0.034) vertical jump performances respectively. Furthermore, results indicated significant differences in time to complete a T-test between TT and Control protocols (ps 0.042) plus CT and Control protocols (ps 0.007). Additionally, significant differences were evident between TT and CT protocols versus PT and Control sprint durations (ps 0.049).

Conclusions: Given that significant differences in performance existed between TT, CT, PT treatments and control protocols, modifications to exercise order outside those of traditional resistance-training protocols may be successful in increasing vertical jump height, agility capabilities and repeated sprint ability while significantly increasing the efficiency of workout sessions.

Chair:
Signature

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Date: Sep 18, 2014
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List of Abbreviations

1RM ................................................... one repetition maximum
CT ...................................................... contrast training
MCT-1 .............................................. monocarboxylate transporter one
NSCA ........................................... The National Strength and Conditioning Association
PE ................................................... pre-exhaustive training
RAST ........................................... Running-based Anaerobic Sprint Test
SLBLH ........................................ single-leg-bosu-lunge hop
TT ................................................... traditional training

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Chapter-1 Introduction

Resistance training is one of the key components to the development of an athlete's performance abilities; as such, it is a critical component linked to success. This is due in part to the beneficial effect resistance training has upon performance characteristics such as size, speed and strength while additionally decreasing the likelihood of injury or severity thereof. Furthermore, a host of potential psychological benefits accompany the physiological benefits of resistance training and may include increased confidence in one's abilities or activities and a sense of wellbeing, furthering the critical role resistance training plays in athletic success.

Because of the importance and wide application of resistance training, numerous resistance-training modalities have been adopted to accommodate specific requirements amongst sports and physical activities. The goals of these varying modalities have been to increase specificity of resistance-training sessions, through manipulation of training protocols outside of traditionally prescribed resistance-training and plyometric standards. Such manipulations are done with the expectation of optimizing athletic performance adaptations and/or injury prevention adaptations to resistance-training sessions. One such variable to manipulate resistance-training protocols outside of generally prescribed traditional training (TT) protocols is that of exercise order. Numerous studies have investigated the effects, or lack thereof, of manipulating exercise order during a resistance-training session with mixed results and conclusions (Alves, Rebelo, Abrantes, & Sampaio, 2010; Dodd & Alvar, 2007; Duthie, Young, & Aitken, 2002; Gonzalez-Rave, Delgado, Vaquero, Juarez, & Newton, 2011; Mihalik, Libby, Battaglini, & McMurray, 2008; Walker, Ahtiainen, & Hakkinen, 2010). Further research is warranted to evaluate the possible effects of exercise order manipulation, specifically, combining plyometric exercises with resistance-training exercise, during a performance-training
session. It may be manipulating exercise order results in a higher degree of sport-specific training adaptations and the optimal means by which to manipulate exercise order is still yet unknown, as seen by conflicting results in research to date. However, it may also be these conflicting results indicate manipulation of exercise order outside that of TT protocols fails to properly target sports-specific training adaptations in a portion of athletic populations. This may be due to distinct variations in how individuals respond to plyometric and resistance-training protocols, whether physiologically or psychologically, meaning certain individuals adapt or adjust better to varying exercise order during resistance-training sessions while some fail to adapt to such training deviations. The primary purpose of the current investigation was to evaluate the effects of manipulation of exercise order during a resistance-training session on specified performance parameters: Performance measures were vertical leap maximums, agility responses on a T-test and repeated sprint ability during a Running-based Anaerobic Sprint Test (RAST). It was hypothesized that varying exercise order would result in significant differences in performance responses following treatment.

While the effect of exercise order on performance variables was the primary focus of this investigation, if the tests utilized to assess the effects of exercise order on performance are sensitive enough to detect decrements in performance after acute resistance-training sessions, such recurring evaluation could be part of a normal strength and conditioning program to monitor adaptations or significant performance decrements. To date, the best indicator of overreaching and overtraining is a short and long-term decrement in performance requiring days to years to recover previous levels of performance (Armstrong & VanHeest, 2002; and noted by research reviewed in the textbook Essentials of Strength Training and Conditioning by Baechle and Earle, 2008). The performance-variable tests used in this study are a cost effective and practical means to diagnosis possible overreaching and overtraining by identifying
significant declines in performance. As such, having a variety of cost effective and easily executed diagnostic tests would be beneficial to professionals, coaches, strength and conditioning specialists and athletes for monitoring training adaptations or performance decrements during a resistance-training or plyometric program. It was hypothesized the performance tests utilized during the current investigation would be sensitive enough to detect significant declines in performance after acute resistance-training and plyometric protocols. Therefore, they could be used as a means to assess performance adaptations or significant declines in performance over the duration of a resistance-training or plyometric program, giving coaches, strength and conditioning specialists and athletes a simple, cost-effective means to analyze performance levels and avoid potential overtraining.
Chapter-2 Review of Literature

Introduction and Purpose

Every individual is born with a baseline level of specific physical abilities including, but not limited to, strength, sprinting speed, vertical leap and muscle size, which can be accentuated and amplified to varying degrees (Haekkinen, Komi, Alen & Kauhanen, 1987; Kraemer, Deschenes, & Fleck, 1988; Kraemer, 1997). One method of training to augment one’s innate abilities is the addition of resistance training to a performance-oriented training program. Resistance training has been shown in numerous studies to be beneficial to increasing muscular endurance, hypertrophy, power and strength, all of which can improve both athletic capabilities and enhance the quality of daily life (Hanson et al., 2013; Hurley, Hanson, & Sheaff, 2011; Kraemer et al., 1995; Machado, Koch, Willardson, Pereira, & Cardoso, 2011; Ramos Veliz, Requena, Suarez-Arrones, Newton, & Saez de Villarreal, 2014). As such, resistance training has been utilized by virtually all sports with the goal of increasing performance parameters and success.

The purpose of this review of literature is to outline the general guidelines currently prescribed by the National Strength and Conditioning Association (NSCA) for resistance-training, provide examples of past research on the effects of manipulated exercise order, describe the resistance-training modalities of the current investigation, introduce possible mechanisms for hypothesized changes in performance, describe the training continuum while detailing the range of signs and symptoms of overreaching plus overtraining and list the research questions of the current investigation.
NSCA Guidelines for Resistance-Training Protocols

A set of guidelines for developing and implementing a resistance-training program, with the goal of improving athletic markers of performance, has been developed by the NSCA. For increasing strength with core exercises the recommendation is a load greater than or equal to eighty-five percent of one repetition maximum (1RM) with an amount of repetitions less than or equal to six and a range of two to six sets. When developing strength with assistance exercises, the load should be limited to no less than eight repetitions maximum and a range of two to three sets. When training to increase maximal power, the NSCA recommends resistance exercises utilizing a load of eighty to ninety percent of 1RM for single-effort events with one to two repetitions and a range of three to five sets. For multiple-effort events the recommendations for resistance exercises are utilizing a load of seventy-five to eighty-five percent of 1RM with three to five repetitions and a range of three to five sets. When training for hypertrophy, the recommendations are a load of sixty-seven to eighty-five percent of 1RM with six to twelve repetitions and a range of three to six sets. Lastly, when training for muscular endurance, the resistance training recommendations are a load less than or equal to sixty-seven percent of 1RM with repetitions greater than or equal to twelve and a range of two to three sets.

Along with these recommendations, the NSCA has prescribed rest intervals for each of the training goals on the repetition continuum. The prescribed rest interval ranges are two to five minutes for strength and power, thirty seconds to one and a half minutes for hypertrophy and less than thirty seconds for muscular endurance per set. Also recommended by the NSCA is a periodization continuum which oscillates between training periods of low to moderate intensities with high volume and training periods of high intensity with low volume sport specific exercises. This training scheme is also accompanied by periods of active rest or unloading weeks.
which "Many strength and conditioning specialists believe that significantly reducing the volume and load assignments will make the athlete less susceptible to overtraining symptoms (Baechle & Earle, 2008, p. 513).

Campos, Luecke, Wendeln, Toma, and Hagerman (2002) investigated the effects of differing repetition ranges and loads on muscular endurance, hypertrophy and strength. Campos et al. (2002) found strength significantly improved for the lower repetition group, which performed three to five repetitions max, as compared to the intermediate group, which performed nine to eleven repetitions max, and the high repetition group, which performed twenty to twenty-eight repetitions max. Campos et al. (2002) also noted significant increases in maximal aerobic power and time till exhaustion for the high repetition group. Furthermore, repetitions till failure, at a load of sixty percent of 1RM, significantly improved for the high repetition group as compared to the low and intermediate repetition groups. Lastly, Campos et al. (2002) found significant hypertrophic effects in muscle fiber types I, IIA, and IIB for both the low and intermediate repetition groups.

The above findings by Campos et al. (2002) are in conjunction with NSCA recommendations as the study groups were separated along the outlined repetition-maximum continuum. Subjects in the low repetition groups, three to five repetitions max for four sets, achieved statistically significant increases in maximal power, subjects in the intermediate group, nine to eleven repetitions max for three sets, and the low repetition group displayed significantly larger increases in muscle hypertrophy, and subjects in the high repetition groups, twenty to twenty-eight repetitions max for two sets, displayed significant increases in maximal aerobic power and time to exhaustion.

A recent review by de Salles et al. (2009) evaluated thirty-five past training studies to investigate the effects of varied rest intervals during resistance-training sessions on short and
long-term physiological adaptations. The review found that when training for absolute muscular strength or muscular power the recommended rest interval between sets was three to five minutes. Longer rest intervals allowed for higher intensities of training along with an increase in volume. However, when training for muscular hypertrophy, rest intervals of thirty to sixty seconds are recommended by Salles et al. (2009) and advantageous due to greater levels of growth hormone release during shorter intervals. And, for muscular endurance, rest intervals of twenty seconds to one minute are advantageous to the development of increased velocities during repeated contractions at submaximal workloads. These conclusions are also in conjunction with NSCA guidelines for rest intervals between sets, which coupled with the conclusions of Campos et al. (2002) indicates manipulations of repetition ranges, sets per exercise, and rest intervals (within specified training continuum areas) between sets is limited given desired resistance-training outcomes. Therefore, variables which can be manipulated within training protocols and produce improvements for desired athletic markers is an area of great interest to athletes, coaches and strength and conditioning specialist.

**Traditional Training Protocols**

When implementing a resistance-training program, it is important to take into consideration desired training outcomes specific to one’s sport or activity and the training variables which can be manipulated to develop muscular endurance, power, size and strength. Variables that can be manipulated include, but are not limited to, selection and order of exercises, frequency, intensity, volume, muscle action or sport specific exercises, isolation or compound exercises, velocity of performed exercise and rest intervals. Small changes in these variables can elicit specified adaptations, both beneficial and detrimental, in regards to
muscular endurance, power, size and strength adaptations achieved through resistance training for one's sport or activity.

Recommendations by the NSCA and literature suggest that exercises such as the snatch or power clean should be ordered first during a resistance-training session. This is due to the highly technical nature of such power exercises, where form, which is critical to safety, could be compromised by prior fatigue. After power exercises, core exercises should be executed and then a resistance-training session can conclude with assistance exercises when applicable to the training session. This type of training is considered traditional training (TT) and is the general consensus to develop power and athletic performance accepted by many professionals and institutions. Furthermore, it is recommended that multi-joint exercises be completed prior to single-joint exercises. This is due to the highly technical nature of multi-joint power exercises and the consideration that fatigue may lead to improper form, possibly increasing the likelihood of injury, and limiting the training adaptations due to decreased levels of performance. Also to be considered is the recommendation that plyometric exercises be completed before resistance exercises. It is believed that plyometric exercises require maximal efforts and prior fatiguing of muscular systems may decrease abilities and effects of stretch reflex training. However, training modalities which manipulate the order of exercises outside of these training guidelines have also been shown to be conducive to the development of power and athletic abilities (Alves et al., 2010; Duthie et al., 2002; Gonzalez-Rave et al., 2011; Mihalik et al., 2008; Walker et al., 2008).

Exercise Order Manipulation

Research has found that manipulating exercise order can lead to a whole host of positive training adaptations (Alves et al., 2010; Duthie et al., 2002; Gonzalez-Rave et al., 2011;
Mihalik et al., 2008; Walker et al. 2008). The reasoning behind manipulation of exercise order is that resistance-training modalities, which manipulate the order of exercises during a resistance-training or sport-specific drills session, may better mimic the demands of sporting activities. As such, manipulating exercise order could increase specificity of resistance-training or sport-specific training sessions, leading to a greater degree of sport-specific adaptations to training protocols. While the efficacy of manipulating exercise order is still debated, researchers have revealed significant adaptations may be present with a variety of training modalities outside of the TI model. Duthie et al. (2002) investigated the effects of exercise order upon power performance during jump squats with complex, contrast and traditional-training methods. Analyses of data revealed no significant differences between the three training modalities; however, the authors reported a trend for CT protocols to elicit superior jump-squat performance. It is important to note that Duthie et al. (2002) investigated the acute effects of such protocol, where the non-significant trend of CT may have produced superior results, to that of TI, had the study examined the effects of four or more weeks of such training.

One study which investigated the effects of complex and compound training upon vertical jump height and lower body power production, post four weeks of training, was conducted by Mihalik et al. (2008). Results indicated no significant differences among training protocols and significant increase versus baseline in both vertical jump height and power production performance. Alves et al. (2010) also found complex-training methods significantly increased squat jump performance and decreased sprint durations for five and fifteen meter sprints after six weeks of training. Additionally, Walker et al. (2008) found contrast loading had significant training-induced benefits for squat-jump height after eleven weeks of training and Gonzalez-Rave et al. (2011) noted significant gains in squat-jump height, muscle mass and creatine kinase after sixteen weeks of contrast loading protocols. As such, it appears both acute
and long-term training-induced benefits are possible with resistance-training protocols where exercise order is manipulated, as compared to TT protocols.

While many studies have evaluated the effect of exercise order on a variety of performance variables, Mihalik et al. (2008) noted few studies have evaluated varied resistance-training modalities in combination; with workloads equated across all treatment protocols. Such an investigation would add to the literature on resistance-training modalities that manipulate exercise-order protocols as compared to TT protocols, comparing which are superior in increasing vertical leap performance, power production, sprinting ability and muscle mass development. While resistance-training modalities with modified-exercise order have been beneficial to increasing performance parameters in past research, whether TT methods or modalities with modified-exercise ordered are superior to one another or equal remains an unanswered question. This warrants further exploration into the long-term adaptations which may or may not be evident amongst the varied modalities and TT.

**Contrast Training Protocols**

One such modality which manipulates exercise order is contrast training (CT). CT combines resistance-training exercises at loads of seventy-five to eighty-five percent of 1RM with plyometric exercises during a single combined set. This is in contrast to TT recommendations because it places plyometric exercises after heavy lifting sets and incorporates light exercises during multi-joint exercises. Although the exercise order of CT doesn't follow recommended guidelines, recent studies on incorporation of CT into training sessions have shown significant effects on training outcomes. In a 2002 study by Duthie, Young and Aitken individuals with a greater level of strength showed significant improvements in performance when using CT methods as compared to TT methods. Also, in a 1996 study by
Gullich and Schimdtbeicher the authors advocated CT may be advantageous to speed/strength adaptations to resistance training. This is due to the fact increased neuromuscular activation may be present after maximum voluntary contractions, which could lead to increased recruitment of fast-twitch muscle fibers during subsequent muscle actions and significant adaptations over time. Furthermore, Duthie et al. (2002) found that comparison of the TT and CT methods, without division into high and low strength groups, failed to display statistically significant differences among groups. This means that CT could be a time efficient means of training as compared to TT methods if adaptations are equivalent throughout a training cycle. Unfortunately, this study only compared acute effects during a single session vs. looking at a longitudinal resistance-training program and differences in adaptations over time. It could be either the CT or TT method is superior in the development of performance parameters, CT and TT fail to display significant differences over time, or one of these methods is superior to the other in initial training sessions or one modality might be superior in the long run.

Pre-exhaustive Training Protocols

While CT protocols aim to increase strength and explosive power through the coupling of resistance exercises of moderate to heavy loads, seventy-five to eighty-five percent of 1RM, with explosive-power resistance or plyometric exercises at loads of zero to thirty percent of 1RM, another training modality, pre-exhaustive training (PE), aims to significantly boost muscle hypertrophy and increase muscular endurance, as compared to traditional-training protocols. Such variations of PE may be accomplished by coupling of agonist-agonist muscle contractions and rest interval manipulations, during and between sets, to induce or approach failure during subsequent sets. Salles et al. (2009) investigated the effects of varying rest intervals on performance outcomes during resistance training and chronic adaptations over time due to rest
interval manipulation. Salles et al. (2009) ascertained that shorter rest intervals, coupled with moderate loads of ten repetitions maximum, created the greatest increases in serum growth hormone levels. They further stated that rest intervals of thirty-seconds were significantly better at increasing serum growth hormone levels as compared to rest intervals of one minute or greater with ten repetition max loads. PE methods take advantage of shorter rest intervals between sets and as such may increase growth hormone levels post exercise and positively affect muscle hypertrophy, as compared to longer rest interval protocols. Salles et al. (2009) also ascertained that shorter rest intervals were conducive to increased muscular endurance, with a range of fifteen to twenty repetitions max, and utilizing loads of fifty to sixty percent of 1RM resulted in higher torque and velocity of contractions following muscular endurance training.

Moreover, Salles et al. (2009) indicated muscular endurance training significantly boosts one's ability for submaximal muscle contractions. Whether through increased mitochondria or capillary density, muscular endurance training allows for increased reliance on oxidative metabolism for submaximal muscle contractions. Lastly, in order to maintain repetition ranges during muscular endurance training, Salles et al. (2009) noted a decrement in load may be necessary from set one to two and so on until the terminating set at shorter rest intervals. Decrease in load may be necessary due to elevated levels of fatigue during muscular-endurance training protocols. PE methods take advantage of such principles as utilizing loads of fifty to sixty-five percent of 1RM and repetition ranges of fifteen to twenty-five repetitions max. Also, the coupling of exercises allows for different training loads to be applied, incorporating different ends of the training continuum into groups of exercises, such as CT. PE could not only be a time efficient means of training, but could also result in significantly enhanced sport-specific-training outcomes as compared to traditional muscular-endurance training protocols, although research is needed to validate this hypothesis. Furthermore, PE removes or significantly limits rest
intervals during coupled exercises during and between sets. This manipulation or removal of rest intervals may adversely affect volume, but, may advantageously affect muscle hypertrophy and endurance training. This is due largely to the effect of rest intervals on circulating hormones such as growth hormone and the availability of pyruvate for conversion to lactate.

A study by Keller, Hackney, Fairchild, Keslacy and Ploutz-Snyder (2010) found that reduced recovery resulted in greater anaerobic metabolism due to an increase of circulating lactate levels. Keller et al. (2010) used reciprocal supersets where alternating sets of agonist-antagonist muscle groups are exercised with no rest interval between pairs of exercises and a limited recovery time after pair completion. This modality of training resembles PE, with the exception that PE is agonist-agonist paired training and not agonist-antagonist paired training. In the above study, anaerobic metabolism was increased vs. traditional-resistance training.

Agonist-agonist paired training may be even more difficult than agonist-antagonist training, significantly increasing levels of blood lactate, hence an even greater reliance on anaerobic metabolism and possibly increased intensity when compared to traditional resistance training methods. A study by Messonnier, Freund, Feasson, Prieur, Castells, Denis, Linossier, Geyssant and Lacour (2001) determined lactate exchange and removal abilities can be improved upon by endurance training at similar work rates. It is hypothesized that PE training will be of a high enough intensity to induce such changes in lactate exchange and removal abilities. Furthermore, Baker, McCullagh and Bonen (1998) found that monocarboxylate transporter one (MCT-1) was responsible for increased lactate uptake ability for both heart and skeletal muscle, with lower training intensities required to facilitate increases in MCT-1 in heart muscle tissues as opposed to higher training intensities in skeletal muscle. MCT-1, which McCullagh, Poole, Halestrap, O’Brien, and Bonen (1996) positively correlated (r=.82) with lactate uptake in skeletal muscles and the activity of citrate synthase, which can be used as a marker of the oxidative output of
muscle tissues. As such, research has demonstrated high intensity training can increase lactate uptake and the oxidative capacity of skeletal muscle.

Although the previous studies used running protocols, similar results could occur with PE methods for resistance training due to the intensity of this modality. It could be such increases in MCT-1 capacity lead to a buffered oxidative system, which may offset a decrease in anaerobic glycolysis as fatigue becomes a factor, accounting for increased time till failure at moderate intensity activities. Furthermore, it is hypothesized by the current investigation that the exclusion of rest intervals between groups of exercises may be advantageous to increased growth hormone levels, similar to Salles et al. (2009), and cause changes in anaerobic potential, due to the anaerobic glycolytic pathway becoming overwhelmed, such as Keller et al. (2010); however, such assumptions require further investigation. Repeated bouts till or near failure may cause a long term buffering capacity of the anaerobic glycolytic pathway increasing its efficiency and energy output potentials. As such, PE may be more conducive to increasing numerous positive adaptations in athletic performance markers than TT methods. Either through CT or PE methods, it appears exercise order and/or rest intervals can be manipulated safely while still resulting in significant improvements in athletic markers of performance.

Possible Mechanisms Responsible for Performance Decrements

Energy systems. It is hypothesized by the current investigation that participant performance will be inhibited following resistance-training and plyometric protocols, resulting in statistically significant decrements in performance during the performance-variable testing sessions. One mechanism predicted to play a part in performance-variable decrements is that of fatigue or inhibition of the energy systems. The three energy systems that provide the muscles
of the body with energy include the adenosine triphosphate and phosphocreatine (ATP-PC) system, anaerobic glycolysis and aerobic glycolysis or oxidative metabolism. The ATP-PC system uses creatine phosphate (CP) to supply adenosine diphosphate (ADP) with an extra phosphate molecule to replenish adenosine triphosphate (ATP) from ADP and CP. The rate of this reaction is extremely fast, provides the majority of energy for initial stages of muscle contraction, and lasts from zero to fifteen seconds. However, maximal output of energy from the ATP-PC system occurs approximately one to two seconds into exercise and declines significantly over the next thirty seconds until it is almost negligible in providing energy thereafter. Complete replenishment of ATP takes approximately three to five minutes and for the ATP-PC system approximately eight minutes. The ATP-PC reaction occurs in the sarcoplasm (Gastin, 2001; Scott, 2011; and noted by research reviewed in the textbooks Essentials of Strength Training and Conditioning by Baechle and Earle, 2008; Exercise Physiology Human Bioenergetics and Its Applications 3rd Edition by Brooks, Fahey, White, & Baldwin, 2000).

Anaerobic glycolysis occurs when pyruvate is converted to lactate when intensity dictates the need for immediate energy and oxygen is unavailable for oxidative processes. Maximal contribution of this energy system occurs at five seconds and is relatively maintained thereafter. Anaerobic glycolysis is then responsible for providing the majority of energy for the next sixty to seventy seconds of intense activity. While the reaction converting pyruvate to lactate for energy is not as quick as the ATP-PC system, it can provide significantly larger amounts of total energy due to greater stores of glycogen and glucose found in the blood as compared to CP stores. Anaerobic glycolysis also occurs in the sarcoplasm (Gastin, 2001; Scott, 2011; and noted by research reviewed in the textbooks Essentials of Strength Training and Conditioning by Baechle and Earle, 2008; Exercise Physiology Human Bioenergetics and Its Applications 3rd Edition by Brooks et al., 2000).
Aerobic glycolysis or oxidative metabolism occurs when pyruvate or free fatty acids are shuttled into the mitochondria to be oxidized via the Krebs cycle. This energy system is primarily responsible for energy contribution after a duration of approximately seventy-five seconds, given a decreased level of intensity and/or fatigue and availability of oxygen. Replenishment of glycogen for use as a substrate during energy production can take twenty-four hours or more to recover to pre-exercise levels, assuming both sufficient intensity of exercise to reduce glycogen stores and adequate consumption of carbohydrates post cessation of demanding activities. Whether glycogen or free fatty acids are used is dependent upon the intensity of exercise and availability of substrates for oxidation, however, with a decrease in intensity or onset of fatigue free fatty acids become the primary substrate for oxidation. Aerobic glycolysis or oxidation of fats occurs in the mitochondria (Gastin, 2001; Scott, 2011; and noted by research reviewed in the textbooks Essentials of Strength Training and Conditioning by Baechle and Earle, 2008; Exercise Physiology Human Bioenergetics and Its Applications 3rd Edition by Brooks et al., 2000).

Although each of the three energy systems has a period where it is responsible for the majority of energy contributed to muscle tissue, each system plays a part during any time of energy production. At approximately seventy-five seconds into fatiguing exercise, equal contribution is seen from the anaerobic systems, both ATP-PC and anaerobic glycolysis, and the oxidative systems. Even during the initial stages of contraction the aerobic systems plays a small part in energy production (Gastin, 2001; Scott, 2011; and noted by research reviewed in the textbooks Essentials of Strength Training and Conditioning by Baechle and Earle, 2008; Exercise Physiology Human Bioenergetics and Its Applications 3rd Edition by Brooks et al., 2000).

Given the complexities of the energy systems, predicting which energy system or combination of systems may be responsible for energy production during each of the
performance variables tested is also complex. For the vertical leap performance test the main energy system of interest is the ATP-PC system since each attempt of the vertical leap will last approximately one to two seconds, at the height of energy production for the ATP-PC system, with a rest period of approximately two minutes between jump attempts. Due to the limited time from start to finish of each jump contributions from the other systems may be almost negligible. For the T-test performance, both the ATP-PC system and anaerobic glycolysis are the energy systems of interest. T-test trials are expected to range between nine and twelve and a half seconds, based upon previous research on T-test agility by Wallmann, Gillis, and Martinez (2008) and Essentials of Strength Training and Conditioning 3rd Edition Baechle and Earle descriptive statistics (p. 278). Performance events lasting such durations illicit the majority of energy for contractions from anaerobic glycolysis with a significant contribution originating from the ATP-PC system. This is because the T-test requires multiple change of direction events and the ATP-PC system may be relied upon heavily during the duration of the T-test as it has a maximal expected time of twelve and a half seconds, well within the thirty-second timeframe of energy production by the ATP-PC system before system fatigue initiates. Furthermore, while anaerobic glycolysis and the ATP-PC system may have provided the majority of energy for contraction during the T-test, a small contribution from aerobic processes may also be present.

The RAST performance-variable test will be the most complex of the performance variables tested. RAST protocols are intended to produce fatigue in participants and the duration of each RAST session will be between two and three minutes, as estimated by thirty-seven meter sprint times from Essentials of Strength Training and Conditioning 3rd Edition Baechle and Earle descriptive statistics (p. 278) and addition of twenty-second rest intervals between attempts of RAST sprints (This is only an estimate as no normative data is available on RAST protocols for athletes and RAST sprints are only thirty-meter for this investigation). Due to
the duration of the RAST protocols all three energy systems may be required to produce energy during sprints. The limited twenty-second recovery period between sprints will not be adequate recovery time. As such, each subsequent sprint may become increasingly reliant upon a greater degree of aerobic energy input, as the ATP-PC system struggles to meet energy demands with depleting glycogen stores inhibiting energy production by anaerobic glycolysis. Similar results were noted by Gaitanos, Williams, Boobis, & Brooks (1993), who investigated intermittent sprinting on a friction-loaded cycle ergometer. Gaitanos et al. (1993) used ten sprints of a six-second duration separated by thirty seconds of recovery. They found significantly elevated levels of lactate in the blood after sprint five, indicative of increased anaerobic glycolysis, which peaked at sprint nine and had a small non-significant decline at sprint ten. The authors suggested such declines in lactate production indicated a reduced reliance on anaerobic glycolysis and a switch to the ATP-PC system as the primary energy system responsible for ATP production. Energy input from the oxidative system was also indicated; however, since the rate of ATP production is reduced during oxidative processes and ATP-PC energy outputs are limited when compared to anaerobic glycolysis, declines in peak power output were associated with the decline in energy production by the anaerobic glycolysis system. It is likely such events will occur during RAST protocol and account for declines in performance during RAST performance sessions.

**Muscle damage.** While energy system limitations may play a critical role in declining performance, another factor that may help explain significant declines in performance is muscle damage following plyometric or resistance-training exercises. Plyometric training has been shown to cause significant damage to muscles and inhibit performance in a variety of sport-specific areas. Craig Twist and Roger Eston (2005) found that ten sets of maximal vertical jumps
caused a significant increase in plasma creatine kinase (CK) levels, a well-documented marker of muscle damage, significant decreases in peak power outputs during repeated cycle ergometer sprints and increased time to complete sprints during repeated sprint protocols. Similar procedures were followed by Marginson, Rowlands, Gleeson and Eston (2005) who also found countermovement jump, squat jump, and isometric strength performances were all significantly decreased by prior plyometric exercise. Furthermore, Macaluso, Isaacs and Myburgh (2012) found that plyometric exercise selectively damaged Type II muscle fibers significantly more than other fiber types. This damage to Type I muscle fibers is significant, because the majority of power derived from muscle contraction occurs over the first ten seconds of contraction, with the majority of force created by Type IIx fibers (The Biomechanical Basis of Sports Performance, Maughan and Gleeson p. 76). If these fibers are damaged significantly by plyometric exercise it may account for reductions in peak power output and performance following plyometric exercise sessions.

While plyometric exercise has been shown to elicit significant amounts of muscle damage, investigations into the effects of resistance training have revealed similar results when considering the effect(s) of resistance training upon muscle tissues. Heavens et al. (2014) found significantly elevated levels of CK, interleukin 6 and myoglobin, all signs of inflammation, immune response and muscle damage, after high-intensity resistance training. Furthermore, the effect of eccentric exercise and muscle damage in the form of sarcomere damage and disruption has also been documented. Armstrong et al. (1983) and Fride' n, J. (1983) all demonstrated that muscles engaged in eccentric exercise displayed damage to sarcomere units. Ingalls, Warren, Williams, Ward and Armstrong (1998) were also able to demonstrate reduced Ca2+ release and sensitivity post eccentric exercise, which they attributed to sarcomere disruptions. Inhibition of contractile units via sarcomere damage, whether directly through
inhibited tension or through reduced excitability due to Ca2+ disruptions, could account for decreased performance after resistance training of an eccentric nature. Lastly, a significant reduction in RFD was demonstrated by Miles, Ives, & Vincent (1997) after maximal eccentric exercises and Sargeant and Dolan (1987) demonstrated a significant increase in recovery time, two days compared to four days recovery to baseline, and a significant reductions in peak power following higher velocity eccentric exercise when comparing one hundred-ten revolutions per minute to eighty revolutions per minute. It appears plyometrics, resistance training and eccentric training all can produce significant damage to muscle tissue which has subsequently been linked to decreased performance in contraction capabilities of muscle tissue, RFD and peak velocity in past research. These factors of damage could account for the decreases in performance found during the current investigation. Such inhibiting factors in contractile muscle units may account for the hypothesized decrements in performance following treatment protocols for this investigation.

Overtraining Signs and Symptoms

While it is hypothesized the treatment protocols in this study will result in performance decrements, what this implies about training statuses and long-term training regimens, where exercise order is manipulated outside that of TT protocols, is also of interest. In a review by Armstrong and VanHeest (2002), the authors presented a continuum of training states which describes the effect of increasing frequency, intensity and volume of training on performance in competition and during training. First, an athlete is in a state of undertraining, associated with minimal physiological adaptations and no increase in performance. Then, with proper increases in frequency, intensity and volume an athlete enters a state of acute overload. During acute overload physiological adaptations and performance improvements become evident. From this
point, with increased frequency, intensity and volume of training, an athlete enters a state of overreaching, which is condoned by the NSCA as a short-term means of increasing performance. During overreaching protocols, athletes will experience peak performance plus maximal physiological adaptations and are at the pinnacle of their performance, if given proper recovery protocols.

If frequency, intensity and volume of training continue past this point, or, adequate recovery is not given, an athlete will then enter a state of overtraining, associated with decreases in performance and unfavorable physiological adaptations. Armstrong and VanHeest (2002) noted some of the major signs and symptoms of overtraining published in research which included decreased physical performance, general fatigue, loss of vigor, insomnia, change in appetite, irritability, restlessness, anxiety, loss of bodyweight, loss of motivation, lack of mental concentration and feelings of depression. While the exact mechanism(s) of overtraining is/are not known, Armstrong and VanHeest (2002) noted research has investigated many biological and physiological parameters in an attempt to isolate or identify the mechanism behind overtraining. These include, but are not limited to, decreased resting and maximal heart rate, increased heart rate and VO2 during submaximal exercise, decreased maximal aerobic power, decreased respiratory exchange ratio, increased sympathetic nerve responses, impaired anaerobic energy metabolism, increased frequency of upper respiratory tract infection, decreased hematocrit and hemoglobin, decreased leucocytes and immunophenotypes, decreased serum iron and ferritin, decreased electrolytes, increased ammonia, decreased serum testosterone and cortisol, decreased growth hormone, and increased creatine kinase. Not only will overtraining lead to numerous physiological and psychological complications resulting in possible decrements in performance and mental capacities/functions, overtraining can also lend itself to increased susceptibility or frequency of injury. Renstroem and Johnson (1985) stated
over-use injuries in sports are typically the result of repeated micro-traumas, resulting from a multitude of causes, one of which is improper overload, such as increased frequency, intensity and volume without proper recovery. These injuries include, but are not limited to, compartment syndrome and soreness in muscles, stress fractures in bones, and bursitis in overstressed joints. Lastly, Herring and Nilson (1987) noted that overuse accounts for nearly fifty percent of all sports injuries. While overreaching and overtraining do not always equate to injury, we can see a litany of complications caused by overuse and it seems evident overtraining can increase risk for injury.

It is important to note, that while one or many of these factors may be present in an individual who is training, the inclusion of one of the before mentioned does not necessarily indicate that one is over-trained or will experience decreased performance. The variability from person to person therein is the difficulty of isolating a mechanism(s) which can cause one to become over-trained as exhibit by decrements in performance. To date, no specific mechanism has been isolated as a cause of overtraining, and as such, the best means to determine if one is over-trained or approaching overtraining is to measure for decreases in performance. While this is the only absolute means of measurement of determining if one is over-trained, the before mentioned factors associated with over-training, such as insomnia, decreased appetite and loss of motivation are important factors to consider if one suspects an athlete is approaching a state of overtraining and aims to prevent decrements in performance or burnout. Kellmann (2010) stated,

When talking to coaches, it appears easier to frame the current topic as underrecovery rather than over-training. It is the coaches’ job to train athletes at the optimal level (which is often at the limit); however, they should also avoid overtraining. Coaches may be much more receptive to working with the concept
of underrecovery because it acknowledges that underrecovery can also be due
to factors, which are outside of their control. (p. 101)

Using this approach may seem less like an attack upon methods a coach or strength and
conditioning specialist has used in the past, which may have resulted in exceptional athletes
with high levels of performance. The approach of underrecovery admonishes that certain
factors are outside the control of a coach, such as variability among athletes, and demonstrates
that while certain training protocols may be beneficial to one or several athletes, individual
tailoring may be needed to see exhibited increases in performance and avoid overtraining in
other athletes.

If the performance-variable tests in this current study are sensitive enough to detect
decrements in performance during acute resistance-training sessions, they may be a valuable
tool to detect both short- and long-term decrements in performance or validate a coach’s or
athlete’s training protocols are producing favorable adaptations when it comes to the
performance parameters of vertical leap, agility and repeated-sprint ability. Furthermore, if used
during a resistance-training or plyometric program, given the performance tests are sensitive
enough to detect decrements in performance after acute resistance-training and plyometric
protocols, they may be a valuable tool to detect overreaching and possibly prevent an athlete
from entering a state of overtraining. Such performance testing tools may quantify significant
decrements in performance, leading to the implementation of adequate recovery periods,

hence, preventing overtraining prior to any significant detrimental effects. Lastly, with
manipulation of exercise order during a resistance-training session, specifically combining
plyometric and resistance-training exercise, it may be athletes enter a training state of
overreaching or overtraining more easily than TT. This may be due to the fact of efficiency when
combining plyometric and resistance-training exercises. Such efficiency means a coach or
athlete may be able to incorporate a higher amount of training sessions into a training regimen, due to the efficiency of such modalities; however, increased volume may inadvertently result in reaching a state of overreaching and overtraining much easier when comparing varying training modalities to TT protocols. Further research is needed to validate such hypotheses, as this current study will only investigate the acute effects of resistance-training sessions with manipulated exercise order, not long-term adaptations or performance changes.

**Conclusion**

It may be that between contrast training, pre-exhaustive training and traditional training protocols one or more could lead to superior performance adaptations or a greater possible incidence of overtraining and long-term decrement in performance. Furthermore, if decrements in performance are evident through the selected means of evaluation, such measures can be used to determine an athlete’s susceptibility to overtraining. The use of such testing protocols can be a time efficient and easy means to test an individual or a team for possible signs of overreaching or overtraining. An athlete, coach or strength and conditioning professional could readily use such techniques and have another means to decrease the likelihood of overtraining in their players, if findings reveal the given performance parameters tested are sensitive enough to detect significant declines in performance after acute resistance-training sessions.

**Research Questions**

1) Will the volume, as calculated by total weight lifted during treatments, be equivalent for Traditional, Contrast and Pre-exhaustive methods?

2) Will the time, measured in minutes, to complete treatment protocols be equivalent for Traditional, Contrast and Pre-exhaustive methods?
3) Will vertical leap performance be equivalent for the following after treatment:
   a) Traditional, Contrast and Pre-exhaustive methods compared to Control?
   b) Traditional compared to Contrast methods?
   c) Traditional compared to Pre-exhaustive methods?
   d) Contrast compared to Pre-exhaustive methods?

4) Will T-test performance be equivalent for the following after treatment:
   a) Traditional, Contrast and Pre-exhaustive methods compared to Control?
   b) Traditional compared to Contrast methods?
   c) Traditional compared to Pre-exhaustive methods?
   d) Contrast compared to Pre-exhaustive methods?

5) Will sprint performances be equivalent for the following after treatment:
   a) Traditional, Contrast and Pre-exhaustive methods compared to Control?
   b) Traditional compared to Contrast methods?
   c) Traditional compared to Pre-exhaustive methods?
   d) Contrast compared to Pre-exhaustive methods?
Chapter-3 Methods

Introduction

The purpose of this investigation was to examine the effect of three varying resistance-training sessions on the performance measures of agility, vertical leap and anaerobic endurance/sprint parameters after a one-hour recovery period post treatment. Chapter-3 includes a review of the research method and design appropriateness, a discussion of the population of interest, the sample, training and study protocols, performance measures, statistical analyses and results.

Study Design

The current study was of a quasi-experimental pretest-posttest randomized-treatment design, so as to determine the amount of change produced by the prescribed treatments. It was not of a true experimental design due to factors of inclusion for participants. The factors of inclusion were intended to limit variances amongst participants and subsequently control for large variances in performance. The study was designed to ascertain the effects of three different resistance training protocols, CT, TT, and PE methods, which will be discussed in detail bellow, on a subsequent performance-testing session including the following performance measures: 1) Vertical leap (Maximum power output), 2) T-test (measure of agility responses) and 3) Repeated sprint test (Anaerobic endurance).

The independent variables were the resistance-training protocols and the dependent variables were the performance measures. The executed study design was appropriate as it examined the effect of the three training protocols on subsequent performances, indicating the treatment was responsible for performance outcomes as compared to baseline testing levels.
control-day protocols and within training protocols. Lastly, given the small sample size, \( n = 10 \), multiple statistical procedures were utilized to test for normality amongst participants and collected performance variables, which will be detailed further in the statistical analyses section. The following sections will outline the study design for data collection of performance variables. A timeline for day one visit to the lab, to treatment day protocol and collection of performance variable data can be seen in Figure-1 below.

Figure-1. Represents the complete outline of the study design.
Sampling

The participants of this study were obtained as a convenience sample, as certain requirements were needed to execute training protocols. Inclusive factors included participation in resistance training over the past six months, a minimum of twice weekly, and the use of the squat exercise while engaged in resistance training. Also, participants were required to complete a 1RM squat, with proper form and depth, of at least their body weight, to have been injury free over the past six months and be between the age ranges of eighteen to twenty-nine years of age. The factors of inclusion were intended to limit possible variances in strength, muscular endurance and muscle-fiber type among other adaptations associated with regular resistance training and age, with the ultimate goal of limiting the effect of variance among performances.

Participants

A total of n=14 (male n=8 and female n=6) healthy young adults consented to participate in the current investigation. Of the initial fourteen participants only ten (male n=7 and female n=3) completed the study. The ten participants who completed the study had an average age 22.2 +/- 1.62yr, average height of 180.66 +/- 9.08cm, average weight of 75.85 +/- 8.2kg, an average body-fat percentage of 16.5 +/- 7.22% and an average estimated 1RM squat of 105.23 +/- 37.76kg. Of which, the participants included an activity range of moderate (3 to 4 days a week of exercise related activities) to highly (5+ days a week of exercise related activities) active lifestyles. All participants signed an informed consent form prior to participation in the study, which was authorized by the Committee on the Rights of Human Subjects at Sonoma State University which can be seen in Appendix-A. Furthermore, prior to signing of the informed consent all participants were knowledgeable of the training protocols, testing procedures, risks
associated with the study and were made cognizant of the fact they could drop from the investigation at any time without repercussion.

**Equipment**

The equipment used for data collection can be seen in Appendix-B. The Brower Timing system was utilized for collecting data on both the T-test and repeated-sprint performance variables. Vertical leap was measured using a Vertc by Sports Imports.

**Pre-meal Options**

To account for large variances in dietary intakes, participants were instructed to fast overnight before coming to the lab for baselines, control protocols or treatment protocols. A standardized breakfast was issued, of which the participants were allowed to choose from three options of equal caloric distribution, which can be seen in Appendix-C. However, all participants opted for the first meal option, cereal with milk, for the duration of the study. This measure of control limited the effects of varying dietary intake amongst the participants, such as differences in performance related to lack of sufficient energy to participate at one-hundred percent from having skipped breakfast, sluggishness after large meals or varying levels of carbohydrate and lipid ingestion by participants. Also, it was a limited amount of food, approximately 180Kcal, so energy for performance would most likely come from stored substrate utilization instead of available free substrates from a large breakfast. Furthermore, to limit the effect of hydration statuses, all participants received 250ml of water along with the pre-meal and were allowed to bring water bottles for hydration during baseline testing, performance testing and treatment protocols. In between sets participants were encouraged to drink fluids, during appropriate rest
intervals, and all participants received 250ml water after treatment protocols, with the exclusion of the control group who received no treatments.

**Refueling/Recovery between Sessions**

Another possible source of invalidity during performance testing could have been varying choices in dietary intake between sessions to recover after resistance-training treatments or control protocol. As such, a recovery protein bar, Organic Food Bar Protein type with 22g protein, 33g of carbohydrate, 9g of fat, 364mg potassium and a total of 330Kcal was given to participants on all lab visits during the first five to ten minutes of the one-hour recovery period post treatments or during control protocols. This eliminated the possible variance in refueling choices and aided in recovery of substrates used during resistance-training protocols.

**Pre-treatment Warm-up Protocols**

The Pre-treatment warm-up protocols can be seen in Appendix-D. All exercises were supervised and completed with verbal assistance if form for any warm-up exercise was improperly executed, i.e., knees not reaching above parallel on high-knees jog or knee positioned over toes for lunges.

**Testing for Anthropometrics, Squat 1RM$s$, Lunge Loads and Familiarizations**

Upon first arrival to the lab, all participants received the Par-Q and Exercise Risk Assessment questionnaires, which can be seen in Appendix-E. This was done to control for cardiovascular-risk factors amongst participants and reduced the likelihood of an exercise-induced cardiovascular episode. After the Par-Q and Exercise Risk Assessment questionnaires participants completed the study specific questionnaire, seen in Appendix-F, which filtered for
factors of inclusion and was intended to reduce the risk of injury during the study. Lastly, after checking for individual participant risks and factors of inclusion, participants were then allowed to sign the informed consent paperwork and were briefed on the benefits and risks associated with participation in the study. After signing of the informed consent paperwork, participants were instructed to ingest their choice of pre-meal. Participants were then evaluated for the following anthropometric measurements and areas of interest: Age, height, weight, waist to hip ratio, body-fat percentages and activity level. For accuracy on the body-fat percentage measurement participants were instructed to lay horizontally on their back for ten minutes prior to using the BodyStat. Participants were also kept warm during the ten minute period of BodyStat analysis to ensure optimal conduction through electrodes on warm skin. Keeping participants warm was accomplished with the use of either a blanket or sleeping bag covering the entire body, dependent on the temperature in the lab and participants comfort level.

After all anthropometrics were obtained, participants were familiarized with and completed the pre-treatment warm-up protocols. Upon completion of pre-treatment warm-up protocols, familiarization with and baseline testing for vertical leap maximum was completed (for a detailed description of vertical leap procedures see Vertical Leap. in Performance Measures). Next, participants completed testing for one repetition squat maximums following NSCA guidelines and using a three repetition approach to estimate 1RM squat values, which can be seen in Appendix-G. 1RMs were then approximated using Table 15.8 in Essentials of Strength Training and Conditioning 3rd Edition (p. 397) from the three repetition maximums. The 1RM approximations were then used to calculate training loads, from fifty-five to eighty-five percent of 1RMs depending upon which treatment. Following baseline testing for 1RM on the squat exercise, participants were given a three minute rest break before determination of load for the weighted-lunge exercise.
The lunge exercise is dynamic in nature and an assistance exercise foremost; however, lunges can also be used to develop strength. Using three repetition maximum testing protocol would be inappropriate for weighted-lunges and as such an eight repetition maximum testing procedures was utilized following NSCA guidelines. Initial loads for testing started at fifty pounds (25lb dumbbell in each hand) if lunges were not a familiar exercise, otherwise, if participants were familiar with weighted-lunges and had a regular load assigned during resistance training it was utilized, with a decrement of ten pounds (5lb for each dumbbell). Participants were then instructed to complete 8RM of the lunge exercise, four repetitions per leg, or till failure. Failure was deemed as an inability to continuously lunge without a pause, inability to properly control the dumbbells, such as excessive swinging or dropping of a dumbbell, improper leg position, such as non-adequate depth or internal/external rotation, or participant determination of inability to complete further repetitions. If the set was completed without failure, the next set had the load increased by ten pounds (5lb per dumbbell) after a three-minute rest interval. This pattern was continued until determination of an eight repetition maximum for the lunge exercise, then a 1RM approximation was determined using Table 15.8 in Essentials of Strength Training and Conditioning 3rd Edition (p. 397) and appropriate loads were determined for each participant for the lunge exercise. Upon completion of the lunge eight repetition maximum testing, familiarization with and baseline testing for the agility measure was completed using the T-test (for a detailed description of T-test procedures see Agility Measure, in Performance Measures). Lastly, familiarization with and baseline testing for repeated-sprint testing was completed using the RAST performance measure (For a detailed description of RAST test procedures see Repeated-Sprint Testing, in Performance Measures). RAST procedures were the last measures the participants completed on day one of baseline testing and
familiarizations. Participants were then instructed to return to the lab on their prescribed treatment day, for a random treatment no less than seventy-two hours post baseline testing.

**Treatment Protocols**

The following section will detail the treatment protocols and explain a brief rationale for their inclusion in this investigation. Training protocols can be seen in detail in Appendix-H.

**Treatment-1 with TT protocols.** On arrival to the lab, participants ingested their pre-meal of choice prior to completing the “Pre-treatment Warm-up”. Participants then began the resistance training protocols for TT. As stated above, NSCA guidelines dictate completion of plyometric exercise prior to any resistance-training exercises and loaded strength exercises should be completed prior to any assistance exercises. As such, participants completed all plyometric exercises prior to the squat exercise with identical loads, sets, repetitions and rest intervals as CT, without coupling of exercises. The plyometric exercise were four sets of body-weighted box jumps onto a plyo-box, with the sets having a repetition range of ten jumps for set one and two, nine jumps for set three and eight jumps for set four. Then, participants completed four sets of single-leg-bosu-lunge hop (SLBLH)s, at a maximum of four repetitions per leg, since a SLBLH is a single joint exercise, and a repetition range of four repetitions for sets one, two and three, and, three repetitions per leg for set four. After all plyometrics were finished, participants next completed the squat exercise and then the weighted lunges. Participants were instructed to jump onto the plyo-box with a two foot take-off and landing, both on top and while jumping off of the plyo-box, with the use of a countermovement arm swing to assist jumping force. Participants were also instructed to land in a sports-specific position, a quarter squat, both landing on top of the plyo-box and when descending to the floor.
Repetitions of box jumps were completed as quickly as possible, with rest intervals between sets of plyometric exercises set at two minutes and three minutes between weighted exercises, as dictated by NSCA guidelines.

**Treatment-2 with CT protocols.** On arrival to the lab, participants ingested their pre-meal of choice prior to completing the pre-treatment warm-up protocol. Participants then began the resistance training protocols for CT. Protocols for CT were completed exactly as those for TT, except for the order of exercise completion. The four sets for CT were set at a load of 85% of 1RM. Loads were calculated from 1RM values determined during baseline testing for participants for the squat exercise as per NSCA guidelines for developing strength and Campos et al. (2002). Each of the four sets set at 85% of 1RM were coupled with four sets of body-weighted box jumps onto a plyo-box, with the sets having a repetition range of ten jumps for set one and two, nine jumps for set three and eight jumps for set four. Immediately following the racking of the weight for the last repetition of the squats at 85% of 1RM the participants were instructed to proceed to the plyometric box as fast as possible, less than five seconds per all participants, to complete the prescribe body-weight box jumps. Box jumps were completed with the same repetition ranges and technique as in TT.

This procedure was repeated for three additional sets, with sets one and two comprising of six repetitions and sets three and four of the squat exercise comprising of only five repetitions to compensate for possible fatigue, with three minutes of rest between coupled sets. Salles et al. (2009) determined three to five minutes of rest was optimal for producing greater muscular strength adaptations as it allows for both greater intensities and volumes. This study allotted to use rest intervals of three minutes instead of longer rest intervals of up to five minutes for two
reasons. First, shorter rest intervals would most likely result in greater fatigue responses as compared to longer rest intervals, and secondly, rest intervals of longer duration significantly increase the duration of a training session. Three minute rest intervals were both time efficient, a variable of interest to many professionals responsible for implementation of resistance-training programs, and, shorter rest intervals were intended to possibly increase levels of fatigue as compared to longer duration rest intervals. Duthie et al. (2002) used similar training protocol; however, they used three sets of five repetition maximum which had been shown to be sufficient to increase strength. Duthie et al. (2002) based their protocol on a 1986 study by Fleck and Kontor Complex Training. Since that 1997 study, numerous studies have been conducted on the optimal number of sets and repetitions to develop strength. Fleck and Kraemer (2003) later restated their position and deduced two to five sets were optimal for developing strength. As stated above, the NSCA also prescribes a repetition range of three to six sets for the development of strength. With this in mind, the current investigation used four sets, on the lower end of the range prescribed for developing strength, as results could be extrapolated to higher number of sets if found to be significant at only four sets. Furthermore, it was hypothesized that to understand the effects of resistance training on a subsequent session of training, a higher number of sets would equate to an increased volume; hence, a greater degree of possible changes in performance due to fatigue, so utilization of three sets was ruled out while five to six sets were not time efficient. Lastly, participants completed a coupled set of weighted lunges at twelve repetitions maximum for the first two sets, then ten repetitions maximum for sets three and four, coupled with four sets of SLBLHs, at a maximum of four repetitions per leg, since a SLBLH is a single joint exercise, and a repetition range of four repetitions for sets one, two and three, and, 3 repetitions per leg for set four of CT.
**Treatment-3 PT with protocols.** On arrival to the lab, participants ingested their pre-meal of choice prior to completing the pre-treatment Warm-up protocol. Participants then began the resistance-training protocol for PE. PE mimics CT protocol, but differs in the desired performance outcomes. While CT utilizes loads of eighty-five percent of one repetition maximums, PE use loads of fifty to sixty-five percent of 1RM for resistance exercises. These load assignments follow NSCA guidelines and research, such as Salles et al. (2009) and Campos et al. (2002), for the development of both enhanced muscular hypertrophy and muscular endurance. While loads larger than sixty-five percent of 1RM may also be conducive to increased muscle hypertrophy, such as the lower repetition group in the study by Campus et al. (2002), maintaining such loads and repetition ranges with decreased rest intervals would be increasingly difficult or impossible through the completion of a set. The lower repetition group in the previous study utilized rest intervals of a three minute duration, which allowed for sufficient recovery and increased volume; however, the investigators determined this style of protocol was not as conducive to the development of muscular endurance as a repetition range of twenty to twenty-eight repetitions maximum with a one minute rest interval between sets. As such, using coupling methods to combine both the hypertrophic and muscular endurance portions of the training continuum may be advantageous to the development of sport-specific performance attributes in athletes, specifically muscle hypertrophy and muscular endurance.

**Performance Measures**

The following sections will outline the study design for data collection of performance variables. A timeline for collection of performance variable data can be seen in Figure-2.
Figure 2. Represents the time protocol utilized for collecting performance variable data after the 1-hr recovery period.

After completion of treatment or control sessions participants were given a protein bar, within the first ten minutes of the one-hour recovery period. Participants were then instructed to remain in the Exercise Physiology Lab at Sonoma State University for the duration of the one-hour recovery period. During the entire one-hour recovery period participants were supervised to ensure no other food items or drinks besides water were ingested, and, so that participants remained in a relaxed state, no moderate or rigorous activities, for the duration of the hour. Participants were allowed to walk to the restrooms located thirty feet from the lab as needed, were encouraged to drink water as needed after the 250ml requirement was administered per protocol and could engage in activities such as reading, homework, watching movies/shows, listening to music or engaging in conversation about what they liked or disliked about the previous training protocols. At fifty-five minutes into the recovery hour, participants were taken
back to the Sonoma State University Weight-Training Facility and warm-up protocols commenced upon the sixtieth minute mark.

Participants were given twenty-five minutes for the warm-up protocol and if completed prior to the twenty-five minutes were instructed to continue to walk around and stay warm until the full twenty-five minutes was concluded. This was done to ensure all participants had consistent warm-up times and testing for performance variables initiated at the same time for all participants. Upon completion of warm-up protocols participants began vertical leap protocol with a duration of fifteen minutes, then T-Test protocol with a duration of twenty minutes and lastly RAST protocol for a duration fifteen minutes. Each performance protocol had a set time for completion to keep data collection times for performance variables on a consistent schedule. Within the designated durations for each performance test, approximately three minutes was given as a buffer to reset testing equipment as needed and in case of equipment malfunction. If participants completed testing prior to the end of the designated time they were instructed to continue walking around, for the buffer period of approximately zero to three minutes, to stay warm and testing for the next performance variable started at its' designated time per schedule. Performance variables were tested primarily on the Sonoma State Gymnasium basketball court, however, due to time conflicts amongst departments and athletic teams, some performance variable testing sessions were recorded on the Sonoma State University Track, the Recreation Center basketball court at Sonoma State University or the Field House basketball court in the Kinesiology department at Sonoma State.

**Vertical leap.** The first performance marker tested was vertical leap, as it is both a cost and time efficient, simple parameter to measure, and, vertical leap is a significant contributing
factor to performance in a variety of sports settings. Vertical leap was also the first marker of performance tested as it was the least physiologically demanding, and, it served as further warm-up for the subsequent markers to be analyzed. Participants were instructed to stand with feet shoulder width apart and, using a countermovement arm swing, jump to touch the highest vein possible on the Vert. While taking off and landing on two feet. Three attempts were specified as a warm-up, at submaximal efforts, separated by a two-minute rest period for recovery. After recovery, participants were instructed to give maximal effort in their attempts to jump, with feet shoulder width apart and a countermovement arm swing while reaching for the highest vein possible with a two foot take-off and landing for three addition attempts. Each maximal effort attempt was separated by a two minute recovery period and encouragement was given to participants throughout the repetitions. Three such attempts were given and the highest jump, measured in inches, was recorded as either the baseline, control or after treatment marker for vertical leap performance dependent upon visit to the lab. Similar procedures were followed for both Mihalik et al. (2008) and Luebbers et al. (2003).

**Agility measure.** A standard T-test was used as a measure of agility performance as it requires sprinting, side shuffling, changes of direction and back peddling in one all-inclusive drill. Furthermore, numerous studies have used the T-test as a means to assess agility, such as Asadi (2012), Köklü, Alemdaroğlu, Koçak and Erol (2011), Patterson, Udermann, Doberstein and Reineke (2008), and Semenick (1990). The basic outline for the T-test can be seen in Figure-3.
Figure 3. Represents the basic outline for the T-test with distances as presented.

The T-test was the second, if treatment day, or third, if baseline day, performance variable measured as it was the second most metabolically demanding performance test. Four standard eight inch cones were placed in a T-formation as seen above in Figure-3. Participants were instructed to assume a comfortable staggered-standing stance in front and to the left of the starting cone-A. Participants were allowed to place either foot in the forward staggered start position. At the tester's signal, a “go”, the participant was instructed to step on the touch pad for the TS-175 to start the timing unit and sprint to cone-B, 10m away, and touch the tip of the cone with their right hand. Immediately after touching cone-B, participants were instructed to shuffle laterally to the left 5m to cone-C and touch the tip of cone-C with their left hand. Immediately after touching cone-C, participants were instructed to laterally shuffle to cone-D, 10m to the right and touch cone-D with their right hand. Immediately after touching cone-D, participants were instructed to laterally shuffle back to cone-B and touch cone-B with their left hand.
Immediately following touching cone-B, participants were instructed to back-peddle to the starting point of cone-A, on the right side of the cone, and through the timing gates to stop the Brower Timing system. Passing cone-A concluded the attempt of the T-Test. Participants were given two warm-up trails and instructed to give only fifty percent effort on attempt one and eighty-five percent effort on attempt two during the warm-up. Verbal encouragement was given during the duration of the T-Test and precluding attempts three, four and five at maximum effort of each data collecting session. A two minute rest period was given between attempts of the T-Test. The best time of the three trails was utilized for data collection. Furthermore, an attempt was disqualified if participants failed to touch any cone, touched a cone with the wrong hand, crossed their feet on the side shuffle or failed to face forward for the duration of the test. Similar procedures were used by Asadi (2012), Köklü et al. (2011), Patterson et al. (2008) and Semenick (1990).

Repeated sprint testing. To evaluate repeated sprinting performance, RAST protocols were modified and used to test for anaerobic endurance/power. Furthermore, RAST testing was the last performance variable tested as it was the most metabolically demanding test. The modifications to the RAST protocols included an additional round of RAST testing, after a three minute recovery period for each individual, and, a modification on sprinting direction and distance of each sprint. It was hypothesized that only one RAST testing session may not produce enough stimuli to display sufficient fatigue and/or significant variances between treatment protocols or RAST baseline performances. Furthermore, athletes are often expected to sprint throughout the duration of a practice session, hence, two RAST testing sessions better simulated a practice session with multiple skills or drills requiring sprint efforts.
A normal RAST consists of sprints between two cones, with coaches using stopwatches for timing. The current investigation wanted to use timing gates to increase accuracy on sprint times, however, the timing gates available for use in this study were limited to timing a sprint in only one direction. So, to account for the use of the timing gates, after each sprint participants received twenty seconds to return to the starting position after passing the timing gates at thirty meters. The normal thirty-five meter distance was also modified so the RAST could be performed indoors on the Sonoma State basketball Gymnasium. With these modifications in mind, the RAST procedures were executed as follows: Two sprints were given as warm-up, one at sixty-five percent and eighty-five percent effort, with twenty seconds between warm-up attempts after which a one-minute recovery period was given to each participant.

After the one minute recovery, participants were then instructed to stand a half step from the TS-175 touch pad and on the signal "go", step on the touch pad as they sprinted for the thirty meter timing gates. As soon as participants crossed the timing threshold for the IRE and IRD-T175 and the CMLS MEM recorded a time for the sprint, a twenty second timer, either on a cellphone or stop watch, was started to time for the twenty second return time to the starting line. At ten seconds the participant was given a verbal warning of ten seconds remaining and asked how hard they felt they were working on a scale from one to ten, which was recorded with one being the easiest and ten being the hardest they have ever worked. At five seconds on the timer a countdown was started and on one the participant was instructed once again to step onto the timing pad to initiate the timer and sprint with full effort towards the timing gate. Once again the participant had twenty seconds to return to the starting line, was given a ten second verbal warning and asked how they felt on a scale of one to ten. Then a five second count down was again given and on one the participant was instructed to sprint to the thirty meter timing gates. This process was repeated for a total of six sprints and then the participant received a
three-minute recovery period. After the three-minute recovery period, each participant was
given a warm-up sprint at eighty-five percent and an additional minute recovery period. Then
the same protocol, minus the initial warm-ups, was completed again for a total of six sprints. If
the timing pad was missed participants were instructed to run as fast as possible back to the
starting line and restart the sprint. Encouragement was given during the six sprinting trials, to
increase the potential for all-out effort and keep the participants motivated. During the study,
three sets of data for the sprints had to be excluded due to a groin injury, a cramping quadriceps
muscle and an injured hamstring while completing the RAST procedures.

Statistical Procedures

Given the limited sample size, factors of inclusion and the factor of one static group who
completed all treatments (served as a control for variances), to compare treatments and their
effect upon the performance variables an array of statistical procedures were utilized which
included the following: Matched paired T-test, Nonparametric Friedman’s Test and Univariate
Analysis of Variance with blocking techniques with a p-value set at 0.05 for all statistical tests.
Chapter 4 Results

Volume

Volume, which was calculated as the aggregate weight lifted during each treatment in kg, averaged 8051.95kg ± 1815.85kg, 8051.95kg ± 1815.85kg and 8060.91kg ± 1785.516kg for TT, CT and PE respectively (See Figure-4). With no significant differences in volume, differences in performance were most likely due to treatment.

![Graph showing volume per treatment](image)

*Figure-4.* Represents the average volume of weight lifted for each treatment. No significant differences were found between any of the treatments. Means ± SD are present.

Time

Time, which was measured in minutes, averaged 63.4min ± 6.42min, 49.7min ± 5.68 and 32.9min ± 4.82min for TT, CT and PE respectively (See Figure-5). Although the total volume
during the training modalities was equated, total times for each training modality were found to be significantly different via a Nonparametric Friedman's Test and a blocked ANOVA with Tukey Post Hoc ($p \leq 0.001$) for all treatments.

**Figure-5.** Represents the average time to complete each treatment. Means ± SD are present. *, significant differences between the trials.

**Vertical Leap Results**

Vertical leap, which was measured in centimeters, averaged 56.52cm ± 11.90cm, 55.38cm ± 12.88cm, 57.02cm ± 11.95cm and 59.56 ± 11.71cm for TT, CT, PE and Con respectively (See **Figure-6**). A Nonparametric Friedman's Test revealed significant differences in the mean treatment jump heights ($p \leq 0.002$). A blocked ANOVA with Tukey Post Hoc analysis revealed significant differences between TT and Control ($p \leq 0.009$), CT and Control ($p \leq 0.001$) and PE and Control ($p \leq 0.034$) and can be seen in **Figure-6**.
Figure-6. Represents the average vertical leap for each treatment. Means ± SD are present. *, significant differences between the trials.

T-test Results

T-test time, which was measured in seconds, averaged 11.49s ± 1.13s, 11.41s ± 0.95s, 11.06s ± 0.88s and 11.27s ± 0.77s for TT, CT, PE and Con respectively (See Figure-7). A blocked ANOVA with Tukey Post Hoc testing revealed significant differences between TT T-test times and Con T-test times (p≤ 0.045). Further analysis via matched pairs t-test revealed significant differences between TT T-test times and Con T-test times (p≤ 0.042), and, CT T-test times and Con T-test times (p≤ 0.007) which can be seen in Figure-7.
Sprint Times Results

Sprint time, which was measured in seconds, averaged 4.88s ± 0.49s, 4.77s ± 0.54s, 4.64s ± 0.49s and 4.60s ± 0.52s for sprint 1 of set one sprints for TT, CT, PE and Con respectively (See Figure-8), 5.47s ± 0.66s, 5.43s ± 0.58s, 5.13s ± 0.50s and 5.13s ± 0.55s for sprint 6 of set one sprints for TT, CT, PE and Con respectively (See Figure-9), 4.88 ± 0.54s, 4.56s ± 0.32, 4.66s ± 0.43s and 4.66s ± 0.44s for sprint 7 of set two sprints for TT, CT, PE and Con respectively (See Figure-10), and, 5.53s ± 0.65s, 5.37s ± 0.52s, 5.24s ± 0.45s and 5.22s ± 0.53s for sprint 12 of set two sprints for TT, CT, PE and Con respectively (See Figure-11). A Matched Pairs T-Test on sprint time data revealed significant differences between TT sprint one and control sprint one (TT1 - Con1 (p≤0.048), TT sprint six and PE sprint six (TT6 - PE6 (p≤ 0.027), TT sprint six and control sprint six (TT6 - Con6 (p≤ 0.033)), CT sprint one and PE sprint one (CT1 - PE1 (p≤ 0.046)), CT sprint one and control sprint one (CT1 - Con1 (p≤ 0.009)), CT sprint six and PE sprint six (CT6 - PE6 (p≤ 0.004)) and CT sprint one and control sprint six (CT6 - Con6 (p≤ 0.012)) displayed in Figures- 8, 9, 10 and 11. Figure-12 displays each of the significant differences amongst all sprints for comparisons amongst treatments.
Figure-8. Represents the average time for sprint completion for sprint one of set one sprints. Means ± SD are present. *, significant differences between TT and Con, CT and PE, and CT and Con.

Figure-9. Represents the average time for sprint completion for sprint six of set one sprints. Means ± SD are present. *, significant differences between TT and PE, TT and Con, CT and PE, and CT and Con.
Figure-10. Represents the average time for sprint completion for sprint seven of set two sprints. Means ± SD are present. No significant differences between treatments.

Figure-11. Represents the average time for sprint completion for sprint twelve of set two sprints. Means ± SD are present. No significant differences between treatments.
Figure 12. Represents the average time for sprint completion for all sprints which were significantly different. Means ± SD are present. *, significant differences between TT1 and Con1, CT1 and PE1, CT1 and Con1, TT6 and PE6, TT6 and Con6, CT6 and PE6, and, CT6 and Con6.
Delimitation/Limitations

Delimitations include the following for this investigation: limited sample by strength consideration. Only individuals who could perform a 1RM squat of approximately their body weight or above were included in the study. Age restrictions were placed upon the sample, so ages eighteen and below plus twenty-nine and above are not represented in the sample.

Limitations include the following for this investigation: since a convenience sample was used, results cannot be extrapolated to the general population. All conclusions can be associated with males and females between the ages of eighteen to twenty-nine, who are moderately to highly active, with a relative level of strength greater than or equal to 1RM of their body weight for the squat exercise. Also of interest, testing surface was changed for a scheduling conflict with one of the SSU athletic teams on three occasions. Furthermore, familiarity with the nature of the training (plyometric exercises vs. number of repetitions) and testing such as T-test and repeated sprint ability may have significantly varied amongst participants. Lastly, subjective fatigue and motivation were factors outside of the control of the investigators, along with participant sleeping patterns and recovery techniques following the days of treatments.
Chapter-5 Discussion

Introduction

The purpose of this investigation was to examine the effect of three varying resistance-training modalities on the performance measures of agility, vertical leap and anaerobic endurance/sprint parameters after a one-hour recovery period post-treatment. Each of the three treatments was equated for total volume lifted, seen in Figure-4, and participants executed the same resistance exercises during each of the treatment sessions. The manipulated variables of interest were exercise order, modified as plyometrics prior to resistance exercise or a coupling of resistance exercises and plyometrics, and intensity, calculated as percentage of 1RM utilized during each treatment. Chapter-5 examines proposed mechanisms for the results obtained after treatments for the current investigation.

Time

When designing and implementing a resistance-training program one of the single most important factors to consider is that of time to complete training sessions. Balancing time between resistance training and skills/drills practice for athletes or incorporating resistance training into a daily exercise routine can be a difficult and frustrating task when time constraints are abundant. Resistance-training modalities that focus on efficiency of resistance-training sessions, while maintaining training efficacy as evident through an equal or greater extent of sport or activity-specific training adaptations, are an important area of research and applicable to a variety of settings in regards to resistance-training efficiency.
Robbins, Young, Behm and Payne (2010) investigated the effect of complex agonist-antagonist training vs. traditional training with the bench throw and pull exercises. Results indicated no significant differences between the two training modalities with respects to bench throw height, peak velocity, peak power, bench pull volume and electromyographic activity, however, a significant difference in efficiency was indicated. The researchers found complex agonist-antagonist training procedures to be twice as efficient as traditional-training procedures. Given that no differences were evident in performance outputs between the two investigated resistance-training modalities and time efficiency was doubled with complex-training procedures, it may be complex resistance-training procedures are a superior method of resistance training, that allow for maintenance or gains in performance abilities while maximizing efficiency. However, it is important to note that Robbins et al. (2010) only investigated the acute effect of complex-training procedures. Further investigation is needed to ascertain if complex vs. traditional training methods are equivalent over a longer training duration. Another study that investigated the effect of reciprocal supersets vs. TT, by Kelleher et al. (2010), found significant differences when comparing exercise efficiency. Supersets had a significantly higher energy expenditure, KJ/min, 34.70 +/- 2.97 KJ/min vs 26.28 +/- 2.43 kJ/min, when compared with TT methods. The authors noted superset training may benefit exercises attempting to increase energy expenditure with a fixed volume and time constraints.

Similar to Kelleher et al. (2010) and Robbins et al (2010), this current investigation found significant differences in time efficiency amongst the three treatment protocols TT, CT and PE (p<0.001), with similarities amongst the effects of training protocols on performance variables. Kelleher et al. (2010) manipulated rest intervals between sets of exercises similar to PE protocol for the current investigation and Robbins et al. (2010) manipulated exercise order when combining plyometrics with
resistance training in a single resistance-training session, which is similar to CT and PE protocols for this investigation. Results indicated no significant differences amongst the CT and TT protocols in regard to performance declines such as Robbins et al. (2010), which may indicate that CT protocols for the current study are a time efficient means to produce and/or maintain performance factors with a focus on strength. Furthermore, PE protocols for the current investigation were similar to the Kelleher et al. (2010) investigational supersets, which coupled exercise with minimal rest between exercises and sets. As such, PE may be advantageous to increased exercise efficiency and energy expenditure, while also resulting in various beneficial training adaptations; however, more research is needed to validate such claims.

**Decreased Vertical Leap**

Significant decreases in vertical leap performance were evident with all treatment protocols versus Control ($\alpha < 0.05$) and displayed non-significant trends amongst treatments. Decrease in performance can most likely be attributed to muscle damage rather than energy system fatigue. This is due to the fact vertical leap performance is primarily dependent upon the ATP-PC system for energy. Given sufficient recovery time, a one-hour recovery period after resistance-training sessions, ATP-PC stores had ample time to recover to normal levels as CP levels take approximately eight minutes to fully recovery. As such, the most likely factor responsible for decreased performance was muscle damage. Whether through sarcomere damage, reduced peak force, reduced rate of force development, decreases in muscular strength, damage to type II specific fibers or any combination of these factors or an unknown factor(s) associated with muscle damage after plyometric or eccentric resistance training,
vertical leap ability was significantly reduced following treatment. Similar results were indicated by Avela, Kyrolainen, Komi and Rama (1999), Byrne and Eston (2002), and Byrne, Twist, and Eston (2004).

Of specific interest though were the non-significant trends amongst the three treatment protocols, with CT, TT and PE protocols resulting in mean jump heights of 55.38 cm ± 12.88 cm, 56.52 cm ± 11.90 cm and 57.02 cm ± 11.95 cm respectively. As such, the CT protocol appeared to have the greatest detrimental effect upon vertical leap performance, although CT results were not significantly different from TT or PE results. Whether this is due to exercise order, a source of error, post-activation potential or some unknown mechanism(s) cannot be clarified by this investigation. It may be these protocols result in the development of vertical leap ability, as evident through the significant acute effect upon performance versus control during this investigation, throughout a six to twelve week resistance-training program. Furthermore, given the non-significant differences amongst CT, TT and PE protocols, research investigating possible differences in longitudinal-training adaptations may reveal significant differences between CT, TT and PE protocols. It may be one or more of these protocols are preferential in the development of vertical leap performance. This is only speculation, as further research is needed to ascertain if any significant differences in longitudinal-training adaptations in vertical leap performance exist between CT, TT and PE protocols of this nature.

**Increased T-Test Times**

Significant increases in time to complete a T-test were evident between the CT and TT protocols versus Control (p ≤ 0.042) and (p ≤ 0.007) respectively) and displayed a non-significant trend between PE and Control sessions. Similar to vertical leap performance decrements, decreases in performance for the
T-test agility measure can most likely be attributed to muscle damage, with a possible portion of decreased performance related to energy system fatigue. This is due to the fact that while T-test performance is significantly dependent upon the ATP-PC system for energy, similar to vertical leap performance, there may also be a large reliance on anaerobic glycolysis for energy production during the T-test. This assumption stems from the fact that energy production from anaerobic glycolysis peaks on average at five seconds and is relatively maintained thereafter until roughly sixty to seventy-five seconds, dependent upon the training status of an individual. It may be that after resistance-training protocols participants' glycogen levels were depressed, leading to a fatiguing effect for anaerobic glycolysis and subsequent under-performance. Participants would need on average twenty-four hours to completely regenerate glycogen stores for anaerobic performance after intense resistance training.

A fatigued glycolytic system would inhibit rapid anaerobic glycolysis energy production and shift the majority of energy production to the ATP-PC system, which can generate energy the fastest in comparison to the other energy systems; however, with much lower energy production totals. Similar results were noted by Gaitanos et al. (1993), who found a lack of significant lactate production as intermittent sprint protocol continued past a certain duration. The researchers determined a lack of lactate production signaled a fatiguing of anaerobic glycolysis for energy productions, hence, a reduction in performance. Given the results of Gaitanos et al. (1993) and the current investigation, it may be a fatigued glycolytic system was partly responsible for the decreased ability to perform on the T-test drill.

While anaerobic fatigue may have played a role in the decreased performance on the T-test, the most likely factor responsible for decreased performance on the T-test was muscle damage. Whether through sarcomere damage/disturbance, reduced peak force, reduced rate of force development, decreases in muscular strength, damage to type II specific fibers or any combination of these factors, or,
an unknown factor(s) associated with muscle damage after plyometric and/or eccentric-resistance training, T-test ability was significantly reduced following treatment. To the best knowledge of the current study's authors, no research exists on the relationship between acute resistance-training sessions and performance on a subsequent T-test. However, since the T-test is a measure of explosive power and an ability to decelerate, change directions and accelerate rapidly in multiple planes it would stand to reason any factor inhibiting explosive, powerful movements would also inhibit performance on a T-test similar to vertical leap or any movement requiring peak rates of force development and power.

As stated above, muscle damage is associated with a decrease in peak power, rate of force development, damage to type II fibers and sarcomere impairment. Since the T-test is dependent upon many of these factors, an inability to respond optimally in any of these areas or a combination thereof would lend itself to a decline in performance. It may have been muscle damage caused by the resistance-training and plyometric protocol in this investigation and/or a reduction in glycolytic capacity following treatment protocols may have accounted for the significantly reduced ability to perform on the T-test. Furthermore, since both TT and CT protocols were significantly different from Control and not significantly different from one another, either approach should lead to increased performance capabilities over time on T-test performance and overall athletic performance. This is speculation, as further research is needed to ascertain if significant differences exist between TT and CT resistance-training protocol in terms of long-term adaptations to training.

Lastly, although not significant, there was on average a decrease in time to completion on the T-test for PE versus Control. Due to the nature of the PE protocol, which focused on muscular endurance versus strength training in TT and CT, there may have been a buffering effect on the anaerobic glycolytic system due to the intensity of training and rest interval manipulation with PE. However, it could also be
that the load assignments during PE were not significant enough to cause the same degree of muscle damage as that of the TT and CT protocols. Research in the future could focus on analyzing metabolites in the blood, PH shifts and lactate thresholds during and post PE sessions to see if some buffering is evident. Also, further research into PE protocols on T-test performance could illuminate other unknown mechanism(s) responsible for the non-significant trend to improve on T-test performance during this investigation.

**Increased Repeated Sprint Times**

Significant increases in time to complete a thirty-meter repeated sprint were evident between the TT and CT protocols versus Control for sprint one of the first set of sprints (p ≤ 0.05), CT and PE protocols for sprint one of the first set of sprints (p ≤ 0.05) and TT and CT protocols versus PE and Control for sprint six of the first set of sprints (p ≤ 0.05). No significant differences were found amongst any of the treatments or Control for sprints seven through twelve of the second set of sprints. Just as with the decrements in performance for vertical leap and T-test, decreases in performance for the RAST protocols can most likely be attributed to muscle damage, with a larger component of decreased performance related to energy system fatigue, unlike T-test decrements. This is due to the duration of the RAST protocols, which ranged from on average one hundred forty-five to one hundred eighty-five seconds. The greater duration of the RAST protocols may have implied a heavier reliance upon the ATP-PC, anaerobic glycolysis system and oxidative metabolism for energy production as compared to the other performance variables. The decrements in performance for the RAST protocol are most likely attributed to anaerobic glycolysis fatigue, similar to Gaitanos et al. (1993), who investigated the effects of maximal cycle-ergometer sprints on metabolic disturbances.
As previously stated above, Gaitanos et al. (1993) found significant increases in lactate production at sprint five and a peak in lactate production at sprint nine, followed by a drop in lactate production, although not a significant drop, on sprint ten. The authors stated the drop in lactate production was indicative of a fatigue or cessation of anaerobic glycolysis energy production or possible inhibition of the anaerobic glycolytic system by a limiting factor. Similar mechanisms may have accounted for the decrements in performance during this investigation, as protocols were similar to Gaitanos et al. (1993), with the exception of a few key elements. Gaitanos et al. (1993) used cycle sprints, with rest intervals of thirty seconds between sprints and participants were seated on a stationary bike, without any activity, during the recovery period between cycle sprints. RAST protocol may have been significantly more difficult as sprints were all-out maximal efforts running as compared to cycling, with only twenty-second recovery periods between sprints and an active-recovery jog back to the thirty-meter starting position. As such, the degree of recovery may have been further limited during RAST protocol, as compared to Gaitanos et al. (1993), and all-out maximal sprints should have recruited a greater amount of contractile units, due to arm swing and core balance factors, than the cycling sprints. An increase in contractile unit recruitment could lead to greater reductions in glycogen stores for anaerobic glycolysis or increases in anaerobic glycolysis rate limiters; however further research is needed to validate such ideas.

Reduced glycogen stores due to both greater intensity and shorter recovery periods may have accounted for the significantly earlier reduction in performance during RAST protocols, as compared to Gaitanos et al. (1993), as the anaerobic glycolytic system may have been fatigued or inhibited more during RAST protocol. Furthermore, a fatiguing or inhibition of the anaerobic glycolytic system may also account for the steady decline in sprint performance for sprints seven through twelve, which weren’t
found to be significantly different from their counterparts in sprints one through six. A steady decline in performance may have indicated a limited supply of rapid energy in the initial stages of sprinting. During the initial stages of sprinting the anaerobic glycolytic system is responsible for a significant amount of energy to support sprints lasting from two to roughly sixty to seventy-five seconds, dependent once again on training status. The limited supply of energy from the anaerobic system would indicate a heavier reliance on ATP-PC and oxidative systems for energy, both of which can’t meet energy requirements as extensively and expediently as the anaerobic glycolysis system respectively; hence, a possible reason for increased initial sprint times followed by a slight incline in time through subsequent sprints.

While the energy systems may have played a significant role in the performance declines, another significant factor inhibiting performance on RAST protocols may have been muscle damage following plyometrics and resistance-training sessions. As previously stated, whether through sarcomere damage/disturbance, reduced peak force, reduced rate of force development, decreases in muscular strength, damage to type II specific fibers or any combination of these factors or an unknown factor(s) associated with muscle damage after plyometric or eccentric resistance training, repeated sprint ability was significantly reduced following treatments. Inhibition of peak power and rate of force development through muscle damaging protocols could limit acceleration and account for the decrease in performance on RAST protocols. Such limits to optimal peak force and rate of force development may be generated by selective damage to Type IIx muscle fibers.

Macaluso et al. (2012) found that plyometric exercise selectively damaged type II muscle fibers significantly more than other fiber types. Since type IIx fibers are the primary contributors to contractile forces in the initial moments of contraction significant damage to these units may have occurred during
TT and CT protocol, leading to reductions in peak power output and rate of force development during sprinting. Furthermore, sarcomere damage and reduced Ca2+ release and sensitivity were demonstrated by Armstrong et al. (1999), Frider’s (1983) and Ingalls et al. (1998). Damage to sarcomere units may also account for the decreases in performance during RAST protocols. Whether inhibition of contractile units via sarcomere damage due to length discrepancies, inhibited tension capability, Ca2+ disruptions or a combination of these factors, sarcomeres that cannot function properly may greatly impact recruitment of or quality of motor unit recruitment. If contractile units fail to be recruited or are recruited at an inhibited rate, it could account for problems in RFD following muscle damage. A reduced RFD means a significant reduction in peak force and decreased performance, especially during the initial stages of contraction.

All the above factors associated with muscle damage may have been present in the current study’s participants after treatment protocols and subsequently responsible for significant decreases in performance. Furthermore, since no significant differences were seen with both the TT and CT protocols after acute treatment, it may be that either approach to training may be beneficial to the development of adaptations specific to repeated-sprint abilities; however, further research is needed to investigate the effects of these two training protocols on repeated-sprint ability over a longitudinal duration. It could be that either TT or CT is better suited to the development of traits associated with repeated-sprint ability, or, each could have distinct outcomes due to the manipulation of exercise order. Lastly, while PE protocol failed to elicit significant difference from Control, it should not be ruled out form further research into the effects of PE on traits associated with repeated sprint ability. It could be PE protocols exhibit unknown benefits in regards to repeated-sprint abilities over a longer period of training and its inclusion could be beneficial during a resistance-training program.
Conclusion

Research to date has yet to demonstrate which modifications to exercise order are the most desirable when it comes to plyometric and resistance-training adaptations; however, it has been demonstrated that modifications to exercise order can be beneficial to efficiency during a plyometric or resistance-training session (Kelleher et al., 2010; Robbins et al., 2010). This investigation also demonstrated modifications to exercise order can increase efficiency of plyometric and/or resistance-training sessions, so, coaches plus strength and conditioning specialties interested in increasing efficiency when developing a plyometric or resistance-training program may include such modifications to exercise order. Lastly, since the performance tests for the current investigation were able to detect decrements in performance after acute resistance-training sessions, they could be utilized as part of a normal strength and conditioning program to monitor adaptations or significant performance decrements. As such, having a variety of cost effective and easily-executed diagnostic tests would be beneficial to professionals, coaches, strength and conditioning specialists and athletes for monitoring training adaptations or performance decrements during a resistance-training or plyometric program.
Appendix-A IRB Approval

Sonoma State University
Institutional Review Board

October 9, 2013

Dear Mr. Dowdle:

Subject: IRB Application # 2429, THE EFFECTS OF TRADITIONAL, CONTRAST AND PRE-EXHAUSTIVE TRAINING METHODS ON PERFORMANCE VARIABLES

I am pleased to inform you that your application to the Sonoma State Institutional Review Board has been reviewed and approved as Expedited B-7. Please contact Carol Hall or me immediately should you encounter any unforeseen difficulties, or make any significant changes to your planned procedures.

This approval is effective from 10/09/13 through 10/08/14. Please notify Carol Hall when your project has been completed. A progress report and renewal application is required by 09/08/14 if your project will continue past the end date listed above.

Thank you for your cooperation with our processes. We wish you the best of fortune as you complete your research project.

Sincerely,

Matthew Benney
SSU Human Subjects Administrator
Appendix-B Equipment

a) Free-standing Vertec by Sports Imports

b) Four standard 8in cones for T-test formation

c) Brower Timing Systems info: Handheld timing unit called Coaches Monitor model# CML5MEM,
   Speed traps with infrared beams unit model numbers IRE and IRD-T175 and TS-175 with touch
   pad on setting 3 for hit mode (3-beeps)

d) J/fit Plyo-Boxes: Height (24in) and Height (18in)

e) Elliptical trainer by PrecorUSA model# EFX556i

f) Free-weight squat rack by Tuff Stuff, with Cap Barbell bumper plates and a standard 45lb barbell

g) Standard issued dumbbells for lunge exercises and Bosu Ball© Sport Balance Trainer

h) Bodystat 1500 MDD with Electrodes by Ambu, WhiteSensor 0415M ECG electrodes
### Appendix-C Pre-meal Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Food</th>
<th>Calories</th>
<th>Carbs (g)</th>
<th>Fat (g)</th>
<th>Protein (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>1 cup Corn Chex</td>
<td>126</td>
<td>26</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.5 cup 1% milk</td>
<td>53</td>
<td>6.1</td>
<td>1.2</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>(or) 0.5 cup soy milk (vanilla)</td>
<td>50</td>
<td>5</td>
<td>1.8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>179/176</strong></td>
<td><strong>32.1/31</strong></td>
<td><strong>1.7/2.3</strong></td>
<td><strong>6.3/7.3</strong></td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>1 Yogurt Cup (6oz low fat, fruit variety)</td>
<td>174</td>
<td>32.4</td>
<td>1.8</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>174</strong></td>
<td><strong>32.4</strong></td>
<td><strong>1.8</strong></td>
<td><strong>7.4</strong></td>
</tr>
<tr>
<td><strong>Option 3</strong></td>
<td>Half Bagel (avg. plain 3.5&quot; diameter)</td>
<td>144</td>
<td>28</td>
<td>0.8</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Cream Cheese (1TBS, low fate)</td>
<td>23</td>
<td>0.7</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>167</strong></td>
<td><strong>28.7</strong></td>
<td><strong>2.6</strong></td>
<td><strong>6.6</strong></td>
</tr>
</tbody>
</table>

ALL MACROS CALCULATED USING CALORIEKING.COM averages provided in database.
### Appendix-D Warm-up Protocols

<table>
<thead>
<tr>
<th>Activity/Exercise</th>
<th>Time/Repetitions</th>
<th>Rest</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliptical</td>
<td>10 minutes</td>
<td>10-20 seconds</td>
<td>Max HR of 130bpm</td>
</tr>
<tr>
<td>Butt Kickers moving forward</td>
<td>20 repetitions</td>
<td>10-20 seconds</td>
<td>10 repetitions/leg</td>
</tr>
<tr>
<td>Butt Kickers moving backward</td>
<td>20 repetitions</td>
<td>10-20 seconds</td>
<td>10 repetitions/leg</td>
</tr>
<tr>
<td>High Knees moving forward</td>
<td>14 repetitions</td>
<td>10-20 seconds</td>
<td>7 repetitions/leg</td>
</tr>
<tr>
<td>High Knees moving backward</td>
<td>14 repetitions</td>
<td>10-20 seconds</td>
<td>7 repetitions/leg</td>
</tr>
<tr>
<td>Lateral Over-Unders</td>
<td>12 repetitions</td>
<td>10-20 seconds</td>
<td>Start 6 left, then 6 right</td>
</tr>
<tr>
<td>Forward Lunges</td>
<td>6 repetitions</td>
<td>10-20 seconds</td>
<td>Start with right foot</td>
</tr>
<tr>
<td>Backward Lunges</td>
<td>6 repetitions</td>
<td>10-20 seconds</td>
<td>Start with left foot</td>
</tr>
<tr>
<td>Forward Inch Worm</td>
<td>4 repetitions</td>
<td>10-20 seconds</td>
<td>Keep knees straight</td>
</tr>
<tr>
<td>Backward Inch Worm</td>
<td>4 repetitions</td>
<td>10-20 seconds</td>
<td>Keep knees straight</td>
</tr>
<tr>
<td>Sprints</td>
<td>2 repetitions</td>
<td>10-20 seconds</td>
<td>1st@65%, 2nd@85%</td>
</tr>
</tbody>
</table>

First sprint completed at sixty-five percent effort and second sprint completed at eighty-five percent effort. Warm-up was completed following the two repetitions of sprints.
Appendix-E Par-Q and You

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES  NO
1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want - as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to be as active as possible. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:
- If you are not feeling well because of a temporary illness such as a cold or a fever - wait until you feel better.
- If you are or may be pregnant - talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME_________________________   DATE ______________________   WITNESS_________________________

SIGNATURE _______________________

SIGNATURE OF PARENT (or guardian for participants under the age of majority).

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
Appendix-E cont’d

PAR-Q & YOU

Physical Activity Readiness Questionnaire—PAR-Q
(revised 2002)

Choose a variety of activities from these three groups:

Endurance

J-2 days a week Continuous activity for your heart, lungs and circulatory system.

Strength

3 to 4 days a week Strength training activities that involve pushing, pulling and lifting.

Flexibility

3 to 4 days a week Stretching and flexibility exercises.

Starting slowly is very safe for most people. (You can consult your health professional. For a copy of the Guide Handout and some information, call 1-888-254-8799 or go to www.parq.com)

Eating well is also important. Follow Canada’s Food Guide to ensure eating is balanced and meets basic needs.

Fitness and Health Professional

Weight control: Healthy

• Unplug from the office environment

• Do not aim for long

• Observe a physical activity plan

• Exercise at least three times a week

• Take one day off from work

• Don’t have to work

• Plan one day off

• Do not have to work

To order multiple printed copies of the PAR-Q, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gendall (2002).

Disponible en français sous le titre «Questionnaire sur l’amplitude à l’activité physique—Q-AFP (revé 2002)).

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FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors’ use by contacting the Canadian Society for Exercise Physiology (address below):

The Physical Activity Readiness Medical Examination (PARmed-X) — to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy) — to be used by doctors with pregnant patients who wish to become more active.

References:


Appendix-E cont’d

Exercise Risk Assessment

Name ___________________________ Gender _______ Age _______
Email address ___________________________________________________
Phone ____________________________

Please provide the following information as accurately and completely as possible so that it can be used to assess your cardiovascular exercise risk.

**Known Cardiovascular, Pulmonary or Metabolic Disease**

Have you been diagnosed with any of the following diseases/disorders/conditions or had any of the following procedures?

- Yes □ No Myocardial infarction ("heart attack")
- Yes □ No Stroke or ischemic attack ("mini-stroke")
- Yes □ No Heart bypass surgery or other heart surgery
- Yes □ No Coronary catheterization and/or angioplasty
- Yes □ No Abnormal ECG (tachycardia, heart block, etc.)
- Yes □ No Other cardiovascular disease/disorder (aneurysm, etc.)
- Yes □ No Chronic obstructive lung disease (asthma, COPD, etc.)
- Yes □ No Diabetes (insulin dependent, non-insulin dependent)
- Yes □ No Hyperlipidemia (high LDL, low HDL, etc.)

Comment: ______________________________________________________

**Signs or Symptoms Suggestive of Cardiovascular and Pulmonary Disease**

Have you experienced any of the following?

- Yes □ No Pain/discomfort in your chest, jaw or arms
- Yes □ No Shortness of breath at rest or mild exertion
- Yes □ No Dizziness or fainting spells
- Yes □ No Difficulty breathing while lying down
- Yes □ No Swelling of your ankles
- Yes □ No Skipped heart beats or a racing heart beat
- Yes □ No Occasional leg pain, especially while walking
- Yes □ No Heart murmur
- Yes □ No Fatigue or shortness of breath with usual activities

Comment: ______________________________________________________
Appendix-E cont’d

Risk Factors of Cardiovascular Disease
Do you have a personal history of any of the following?
☐ Yes ☐ No Cigarette smoking: packs/day ______, years smoked __________
☐ Yes ☐ No Obese or highly overweight: body weight _________________
☐ Yes ☐ No Physical inactivity: ________________________________
☐ Yes ☐ No High blood pressure (SBP>140, DBP>90), BP __________ mmHg
☐ Yes ☐ No High cholesterol (total>200, LDL>130): total __________, LDL ______ mg/dl
☐ Yes ☐ No Diabetes or high blood glucose (>110): blood glucose __________ mg/dl
☐ Yes ☐ No Family history of heart attack/stroke at young age: _________________
Comment: ____________________________________________________________

Drugs/Medications
Please list any prescription or over the counter drugs/medications you are currently taking.
Drug / medication Purpose / reason for taking
__________________________________________________________

Classification of Exercise Risk (ACSM Guidelines)
☐ Low Risk: Free of cardiovascular, pulmonary and metabolic disease; and free of any signs or symptoms of cardiovascular disease; and possess no more than 1 major risk factor of cardiovascular disease; and male ≤ 45 y, female ≤ 55 y
☐ Moderate Risk (age): Free of cardiovascular, pulmonary and metabolic disease; and free of any signs or symptoms of cardiovascular disease; and possess no more than 1 major risk factor of cardiovascular disease; and male > 45 y, female > 55 y
☐ Moderate Risk (risk factors): Free of cardiovascular, pulmonary and metabolic disease; free of any signs or symptoms of cardiovascular disease; regardless of age; possess 2 or more major risk factors of cardiovascular disease
☐ High Risk: Regardless of age; diagnosed with cardiovascular, pulmonary or metabolic disease; or possess any signs or symptoms of cardiovascular disease

Participants in the low risk category can participate in maximal intensity exercise with little risk of cardiovascular problems (e.g., arrhythmia, etc.). It is not necessary that they get medical clearance prior to participating in exercise or any lab test.

Participants in the moderate risk category have a somewhat higher risk of experiencing cardiovascular problems with vigorous (>60% VO₂ max) to maximal exercise intensity. ACSM recommends anyone in the moderate risk category get medical clearance prior to vigorous exercise. Lower intensity exercise (<60% VO₂ max) poses less cardiovascular risk and can be done without prior medical clearance.

ACSM recommends that participants in the high risk category get medical clearance prior to participating in any type of exercise test or exercise program.


In Case of Emergency
Name ___________________________ Phone ___________________________
Appendix-F Inclusion Questionnaire

1) Have you participated in resistance training, a minimum of twice weekly, over the past six months? (Pre-determined recovery weeks are acceptable)

2) Do you use the squat exercise on a frequent basis while participating in resistance training with at least your body weight loaded on a free-weight barbell?

3) Are you familiar with your 1RM squat weight? If not, what is your normal weight load and repetition range when you do the squat exercise?

4) Are you familiar with the lunge exercise? If so, what is your normal weight load and repetition range when you do the lunge exercise?

5) Have you suffered any injuries in the past six months while engaged in resistance training or any other activity?
Appendix-G 3RM Testing Protocol

(Adapted/modified from NSCA Guidelines, Essentials of Strength and Conditioning 3rd Edition)

1) Start with a weight equal to 50% of individual’s body weight.
2) Instruct individual to complete 5 repetitions.
3) Have individual rest approximately 1 minute.

4) Increase load to 75% of body weight if previous set was completed with ease.
5) Instruct individual to complete 5 repetitions.
6) Have individual rest for approximately 2 to 3 minutes.

7) If successful, estimate a weight near a 4 to 6 repetition maximum.
8) Instruct individual to complete 4 to 6 repetitions.
9) Have individual rest for 3 minutes.

10) If successful add 10 to 20lb.
11) Instruct individual to complete 3 repetitions.
12) Have individual rest for 3 minutes.

13) If successful add 10 to 20lb.
14) Attempt 3 repetitions.
15) Rest 3 minutes.

16) If successful add 10 to 20lb.
17) Attempt 3 repetitions.
18) Rest 3 minutes.

19) If weight lifted successfully for 3 repetitions, with good form, then mark down as 3RM. If not then continue process, either up or down, until 3RM is determined.

20) Continue steps 16 through 18 until you reach a weight which you can complete only 3RM, with good form, and mark down as your 3RM maximum. This can then be used to determine an individual’s 1RM and loads for resistance training.
### Appendix-H Treatment Protocols

#### Legend
1) Rep = repetitions  
2) WL = workload  
3) BW = body weight only  
4) SLBLH = Single Leg Bosu-Lunge Hop  
5) DB = dumbbell  
6) * = repetitions split between each leg (i.e. 8* = 4 left 4 right)  
7) 1RM = % of 1 repetition maximum

#### Traditional Training Methods (Tx1)

<table>
<thead>
<tr>
<th>Exercise 1-Box Jump</th>
<th>Exercise 2-SLBLH</th>
<th>Exercise 3-Squat</th>
<th>Exercise 4-DB Lunge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep = 10</td>
<td>Rep = 8*</td>
<td>Rep = 6</td>
<td>Rep = 12*</td>
</tr>
<tr>
<td>WL = BW</td>
<td>WL = BW</td>
<td>WL = 85%</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1RM</td>
<td></td>
</tr>
<tr>
<td><strong>Rest Interval</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td><strong>Set 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep = 10</td>
<td>Rep = 8*</td>
<td>Rep = 6</td>
<td>Rep = 12*</td>
</tr>
<tr>
<td>WL = BW</td>
<td>WL = BW</td>
<td>WL = 85%</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1RM</td>
<td></td>
</tr>
<tr>
<td><strong>Rest Interval</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td><strong>Set 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep = 9</td>
<td>Rep = 8*</td>
<td>Rep = 5</td>
<td>Rep = 10*</td>
</tr>
<tr>
<td>WL = BW</td>
<td>WL = BW</td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rest Interval</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td><strong>Set 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep = 8</td>
<td>Rep = 6*</td>
<td>Rep = 5</td>
<td>Rep = 10*</td>
</tr>
<tr>
<td>WL = BW</td>
<td>WL = BW</td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3 minutes</strong></td>
<td><strong>3 minutes</strong></td>
<td><strong>3 minutes</strong></td>
<td><strong>Workout complete</strong></td>
</tr>
<tr>
<td>Before next exercise</td>
<td>before next exercise</td>
<td>before next exercise</td>
<td></td>
</tr>
</tbody>
</table>
Appendix-I cont’d

**Contrast Training Methods (Tx2)**

<table>
<thead>
<tr>
<th>Set 1</th>
<th>Exercise Combination 1-</th>
<th>Exercise Combination 2-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Squat + Box Jump</td>
<td>Lunges + SLBLH</td>
</tr>
<tr>
<td>Rep</td>
<td>Rep = 6</td>
<td>Rep = 12*</td>
</tr>
<tr>
<td></td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td>Rest Interval</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Set 2</td>
<td>Rep = 6</td>
<td>Rep = 12*</td>
</tr>
<tr>
<td></td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td>Rest Interval</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Set 3</td>
<td>Rep = 5</td>
<td>Rep = 10*</td>
</tr>
<tr>
<td></td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td>Rest Interval</td>
<td>3 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Set 4</td>
<td>Rep = 5</td>
<td>Rep = 10*</td>
</tr>
<tr>
<td></td>
<td>WL = 85% 1RM</td>
<td>WL = 85% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td></td>
<td>(No rest between combined exercises)</td>
<td>(No rest between combined exercises)</td>
</tr>
<tr>
<td></td>
<td>3 minutes before next Exercise</td>
<td>Workout complete</td>
</tr>
</tbody>
</table>

**Pre-Exhaust Training Methods (Tx3)**

<table>
<thead>
<tr>
<th>Set 1</th>
<th>Exercise Combination 1-</th>
<th>Exercise Combination 2-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Squat + Box Jump</td>
<td>Lunges + SLBLH</td>
</tr>
<tr>
<td>Rep</td>
<td>Rep = 15</td>
<td>Rep = 24*</td>
</tr>
<tr>
<td></td>
<td>WL = 65% 1RM</td>
<td>WL = 65% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td>Rest Interval</td>
<td>30 seconds</td>
<td>30 seconds</td>
</tr>
<tr>
<td>Set 2</td>
<td>Rep = 12</td>
<td>Rep = 22*</td>
</tr>
<tr>
<td></td>
<td>WL = 60% 1RM</td>
<td>WL = 60% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td>Rest Interval</td>
<td>30 seconds</td>
<td>30 seconds</td>
</tr>
<tr>
<td>Set 3</td>
<td>Rep = 12</td>
<td>Rep = 20*</td>
</tr>
<tr>
<td></td>
<td>WL = 55% 1RM</td>
<td>WL = 55% 1RM</td>
</tr>
<tr>
<td></td>
<td>WL = BW</td>
<td>WL = BW</td>
</tr>
<tr>
<td></td>
<td>(No rest between combined exercises)</td>
<td>(No rest between combined exercises)</td>
</tr>
<tr>
<td></td>
<td>3 minutes before next Exercise</td>
<td>Workout complete</td>
</tr>
</tbody>
</table>
References


