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Comparison of linear and daily undulating periodization in resistance training using simple measures of overreaching

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COMPARISON OF LINEAR AND DAILY UNDULATING PERIODIZATION IN RESISTANCE TRAINING USING SIMPLE MEASURES OF OVERREACHING

By

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Abstract

This study was conducted in an effort to determine if a linear or nonlinear periodized resistance training program had a greater tendency to contribute to a state of overreaching over 8 weeks. Simple outcome measures were used in an effort to determine the onset of overreaching. These measures included average sleeping heart rate, standing broad jump, 10-yard dash, seated medicine ball throw, ratings of perceived exertion (RPE), one repetition maximum (1RM) back squat, and 1RM bench press. The participants were 25 (18 female and 7 male) college students in the Kinesiology major at Western Washington University. Subjects were separated into one of three groups: a control, linear periodized (LP), or nonlinear periodized (DUP) training group. After 8 weeks both training groups significantly increased their 1RM back squat and bench press ($p<0.05$). The DUP group increased their mean 1RM bench press and back squat from 46.30 ±18.47 kg to 50.83 ±19.26 kg and 67.15 ±20.54 kg to 79.34 ± 23.80 kg, respectively. The LP group increased their mean 1RM bench press and back squat from 46.82 ± 25.96 kg to 51.14 ± 25.87 kg and 74.77 ± 33.22 kg to 84.09 ± 30.10 kg, respectively. All groups significantly improved ($p<0.05$) their standing long jump performance over the course of the study. The control group improved from a mean of 1.86 ± 0.13 m to 2.04 ± 0.17 m, LP from 1.89 ± 0.40 m to 2.03 ± 0.41 m, and DUP from 1.87 ± 0.42 m to 1.99 ± 0.40 m. Only the DUP group significantly improved their seated medicine ball throw performance ($p<0.05$) from a mean of 4.09 ± 0.78 m to 4.46 ± 0.69 m. The LP and DUP groups significantly decreased ($p<0.05$) their 10-yard dash times from a mean of 1.85 sec ± 0.15 to 1.75 sec ± 0.18 and 1.84 sec ± 0.14 to 1.77 sec ±0.14, respectively. Average sleeping heart rate and RPE did not change significantly in any group. The lack of a significant decrease in performance measures or increase in average sleeping heart rate or RPE in either training group caused the null hypothesis to be accepted.

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Chapter I

The Problem and Its Scope

Resistance training programs are generally designed using the principles of specificity, overload, and progression. Resistance training should be performed with a specific purpose or goal using intensities that the body is not accustomed to and these intensities should increase as the individual becomes adapted to them (Baechle & Earle, 2000). While utilizing these principles alone will result in improved performance, there is a tendency for these improvements to attenuate or cease after an extended period of time (Baechle & Earle, 2000). In order to prevent this from happening, many individuals follow a program design strategy called periodization. This refers to planned variations of variables such as specificity, intensity, and volume over phases or “periods” of training. This application is done to increase the effectiveness of a training program and to avoid plateaus in positive adaptations after a period of time (Baechle & Earle, 2000; Fleck, 1999; Hoffman, 2002; Kraemer, 2007).

Many studies have demonstrated that periodized training programs are more effective than non-periodized training programs (Baker, 1994; Kraemer, 1997; Rhea, Ball, Phillips, & Burkett, 2002a; Stone, et al., 2000). Studies have examined the differences between linear and non-linear (undulating) periodization models of resistance training regarding subjects’ improvements in various performance measures such as strength, endurance and power, and job-specific tasks. The results of these studies have been mixed, with some showing undulating periodization to be superior (Baker, 1994; Kraemer, 1997; Rhea, et al., 2002a) and some showing no significant difference between the two (Buford, 2007; Hoffman, 2009; Peterson, 2008; Rhea, 2003). In general it appears that nonlinear periodization is just as effective as, if not more effective, than, traditional linear periodization models.

One possible factor that could contribute to nonlinear periodization being more effective than traditional linear periodization is a decreased chance of an athlete reaching a state of overreaching (Peterson, 2008). Overreaching is typically characterized as either the lack of an increase in performance or a short term decrease in performance caused by increased training volume and or intensity (Armstrong, 2002; Baechle & Earle, 2000; Borselen, 1992; Bushie, 2007). When overreaching persists for some time and is not treated with a decrease in training volume and intensity, the subject can then enter into a state of chronic fatigue, known as overtraining syndrome (Hoffman, 2002). Once an individual has become overtrained it may take weeks or months of rest to return to their pre-overtrained state (Armstrong, 2002; Borselen, 1992; Bushie, 2007; Fry, 1997; Lemyre, 2007; Stone, 1991; Urhausen, 2002). Overtraining is characterized by increases in resting heart rate, decreases in sports performance, decreases in maximal power output, decreased muscular strength, muscle soreness, weight loss, decreased appetite, sleep disturbances, frequent illness, and other related symptoms (Armstrong, 2002; Borselen, 1992; Fry, 1997; Stone, 1991; Urhausen, 2002). While a lot of research has been dedicated to the study of overtraining, very little has been done using a training program that would typically be used in an athletic or recreational setting (Fahlman & Engels, 2005). Instead, extreme overtraining protocols were developed in an effort to most effectively elicit measureable signs of overreaching (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992).

The phenomenon of overtraining has been studied extensively in regard to aerobic training, but to a lesser extent in anaerobic training (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992). With athletes in almost every sport now utilizing some form of resistance training to improve performance, it is important to create a method to easily and repeatedly test individuals for signs of overtraining in an effort to prevent it from occurring. The difficulty with preventing the onset of overtraining, or its early stage often referred to as overreaching, is that easily measurable markers have not been identified (Armstrong, 2002). Indicators of overtraining that have most often been utilized typically involve blood sampling to measure various biochemical markers (Costa, Jones, Lamb, Coleman, & Williams, 2005; Fry, 1997; Fry, 1994a; Meeusen, 2004; Moore, 2007; Snyder, Jeukendrup, Hesselink, Kuipers, & Foster, 1993; Warren, 1992). While this method may prove to be more accessible and effective in the future, as of now it is not an easily available, affordable method for most individuals.

The topic of which resistance training program is best for various individuals and training goals is an on-going debate between strength coaches, personal trainers, and other individuals in charge of program design. In an effort to use the overreaching measures utilized in this study in a relevant scenario, the training models of linear periodization as well as daily undulating periodization will be utilized with equated volume and intensity. It has been suggested that undulating periodization may diminish the risk of overtraining due to its frequently changing training stimulus (Peterson, 2008). This study will be conducted in an effort to determine if one periodization model has a greater tendency to contribute to a state of overreaching.

Purpose of the Study

The purpose of this study was to develop a set of easily used outcome measures of overreaching in individuals performing a resistance training program. These measures included average sleeping heart rate, standing broad jump, 10-yard dash, seated medicine ball throw, rating of perceived exertion, 1RM back squat, and 1RM bench press. These measures were monitored in current Western Washington University Kinesiology students performing either a traditional linear periodization model of resistance training or a nonlinear daily undulating program to observe any differences between stresses of the different training methods. Volume and intensity of the two models were equated.

Statement of the Null Hypothesis

No difference in indicators of overreaching will be seen between the two periodization models. These indicators include average sleeping heart rate, standing broad jump, 10-yard dash, seated medicine ball throw, ratings of perceived exertion 1RM back squat, and 1RM bench press.

Significance of the Study

This study is important to the athletic and resistance training populations, because it may reveal an easily administered set of tests that can gauge if an individual's body is responding positively to training stimuli. This will allow more effective use of training time and the possible prevention of overreaching, which could eventually lead to the overtraining syndrome (OTS). OTS can take weeks to months to recover from and preventing its onset is extremely important for optimal training (Fry, 1997). This study would also allow programs to be more personalized to individuals' current physiological state, as it would be possible to increase or decrease their training intensity or volume as indicated by their overreaching outcome measures.

Limitations of the Study

1. The participants in this study are students in the Kinesiology major from Western Washington University. The results of this study will not hold the same validity in other populations.
2. Lack of adherence to the program could potentially impact the results. Subjects need to complete all of the training set forth in the program provided by the researcher. The lead researcher stressed the importance of not missing any training sessions. The subjects were informed that if more than 3 training sessions were missed they would be dropped from the study.
3. Some subjects may have been more motivated than others to train intensely and/or to perform during the testing sessions, which could influence the measurements of strength and power.
4. Subjects who were more experienced with strength training may have affected the strength and power measurements, as they may have had greater familiarity with the tests and better technique in performing them.
5. Some subjects may have been taking an ergogenic aid to enhance their physical capabilities without notifying the experimenter.
6. Strength training was restricted in the training groups to only the program provided for this experiment, although other physical activities including cardiovascular ones were not restricted. This may impact the results if some subjects were performing a greater amount of physical activity than others.

Definition of Terms

Basic Strength Training Phase: Strength training periodization period consisting of high loads and low volume. This phase is done with the purpose of increasing strength (Baechle & Earle, 2000).

Central Fatigue: The fatigue hypothesis stating that muscles are believed to be capable of greater output, but the central nervous system blocks continued extraordinary effort. This may be done to prevent injury (Taylor, Allen, Butler, & Gandevia, 2000).

Daily Undulating (Nonlinear) Periodization: The strategy of training periodization that involves large daily fluctuations in the load and volume assignment of exercises from one training session to the next (Baechle & Earle, 2000).

Hypertrophy/Endurance Training Phase: A strength training periodization period consisting of very low loads and very high volume. The goals of this phase include increasing lean body mass, increasing muscular and metabolic endurance, and developing a training base for more intense training in later training phase (Baechle & Earle, 2000).

Ergometer: Instrument for measuring work (Powers & Howley, 2001).

Hypertrophy: An increase in the size of cells or organs, especially muscle fibers (Kraemer, 2007)

Linear Periodization: The strategy of purposely varying specificity, intensity, and volume of a training program in a linear fashion with intensity increasing over time (Baechle & Earle, 2000).

Macrocycle: Training period that typically constitutes an entire training year or complete training program (Baechle & Earle, 2000).

Microcycle: Training period that typically lasts between one and four weeks, depending on the program (Baechle & Earle, 2000).

Mesocycle: Training period that typically lasts several weeks to several months (Baechle & Earle, 2000).

Peripheral Fatigue: When a muscle's homeostasis has been disturbed, through tissue damage, decreased pH, or some other factor, to the point that the muscle is incapable of responding effectively as it does when rested (MacIntosh & Rassier, 2002).

Strength/Power Training Phase: Strength training periodization period consisting of high loads and low volume utilizing power/explosive exercises. This phase is utilized in an effort to increase power (Baechle & Earle, 2000).

Seated Medicine Ball Throw: Test used to measure upper body power. This test is performed by an individual sitting on the floor with legs comfortably spread apart and a 5-15lb medicine ball in their hands. The individual then uses a chest-pass movement to throw the ball as far as possible in a straight line from the body. The distance where the ball first hits the ground is marked and recorded.

Standing Broad Jump: Test used to measure lower body power. This test is performed by an individual standing just behind a starting line. The participant then bends at the knees and hips before swinging their arms forward in an attempt to jump as far forward as possible. The back of the heel closest to the starting line is marked and recorded. This is compared to future values to evaluate changes in lower body power (Kraemer, 2007).

T Test: A test of agility that requires the athlete to sprint in a straight line from a standing start to a cone 9 meters away. The athlete then side-shuffles to the left, without crossing their feet, to another cone that is 4.5 meters away. They then touch that cone with their hand before side-shuffle to the right to another cone that is 9 meters away. The final steps are to side-shuffle back to the middle cone and backpedal to where the participant started. This test is done as quickly as possible in an attempt to get the fastest time (Hoffman, 2000).

Weekly Undulating (Nonlinear) Periodization: The strategy of training periodization that involves large variations in the load and volume assignment of exercises from one week to the next.

Chapter II

Review of Literature

Two of the most common forms of periodization used today are linear periodization and non-linear or undulating periodization (Hoffman, 2002). Numerous studies have examined the difference between linear and undulating periodization models on subjects' improvements in various performance measures such as strength, endurance and power, and job-specific tasks (Baker, 1994; Buford, 2007; Hoffman, et al., 2009; Peterson, 2008; Rhea, 2003; Rhea, et al., 2002a; Stone, et al., 2000). The design and outcome of these studies are discussed in detail in the following sections.

The section "Linear vs. undulating (nonlinear) periodization models" reviews research and literature examining the improvements and outcomes of using these two different modes of periodization (Baker, 1994; Buford, 2007; Hoffman, Wendell, Cooper, & Kang, 2003; Peterson, 2008; Rhea, 2003; Rhea, et al., 2002a). Linear periodization is considered the more "traditional" modality in many of these studies, with undulating periodization being compared in an attempt to see if it is as effective in eliciting various improvements.

The section "Overreaching/Overtraining Measures" examines various markers that have been utilized in previous research to identify a subject or athlete as being in an overreaching or overtrained state. These include performance measures (Alcaraz, 2008; Fry, 1994a; Fry, 1994b; Fry, 2000; Hoffman, 2000; Warren, 1992) as well as sleeping and resting heart rate (Dressendorfer, 1985; Jeukendrup, 1998; Jeukendrup, 1992), and perceived exertion (Foster, 1998; Hoffman, 2000; Snyder, et al., 1993).

The section “Overtraining Protocols” examines various studies that have been performed with the intent to induce overreaching or overtraining in subjects or athletes. In an attempt to relate this research to the current investigation, studies were included that utilized overreaching/overtraining measures mentioned previously. The majority of these studies utilized higher than normal volume and/or loads (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992). These are referred to as overtraining protocols.

Linear vs. Undulating (Nonlinear) periodization models.

Two of the most common forms of periodization used today in weight training are linear periodization and non-linear or undulating periodization (Hoffman, 2002). Linear periodization is the more traditional periodization model, derived from the former Soviet Union and used extensively by athletes and recreationally training individuals alike. This model is characterized by various blocks or cycles of training known as “mesocycles.” Each mesocycle focuses on a specific training goal and can last anywhere from a couple weeks to months at a time. By manipulating the volume, intensity, rest periods, and exercises of a mesocycle, it is possible to bring about specific performance improvements in the human body. These mesocycles typically include a hypertrophy/endurance phase, strength phase, power phase, and peaking phase (Baechle & Earle, 2000; Kraemer, 2007). A typical way in which the traditional linear periodization model is implemented is to perform the hypertrophy/endurance phase for a number of weeks, followed by the strength phase, then the power phase, and so on. The thinking behind this was that the athlete aimed to increase muscle mass (hyptertrophy), increase strength, convert the expression of that strength into powerful movements, then to achieve peak condition for competition. A commonly cited downside for this type of periodization is that it is not practical for people who either compete often, are in a competitive season, or would like to simultaneously work on their strength, power, endurance, and hypertrophy (Baechle & Earle, 2000; Kraemer, 2007; Peterson, 2008).

A study by Buford et al. (2007) compared the effects of 9 weeks of resistance training using either a linear periodization model (LP), weekly undulating periodization model (WUP), or daily undulating periodization (DUP) model. The subjects consisted of 20 men and 10 women from college weight training classes with previous weight training experience, but not within the past 2 months. All three groups trained 3 times a week using a full body free-weight routine consisting of exercises that included bench press, leg press, seated row, lat pulls, upright rows, lunges, leg extension, leg curls, standing calf raises, preacher curls, triceps extension, incline sit ups, back extension, and knee raises. Volume and intensity were equated over the 9 week period between the two conditions. Subjects were tested pre- mid- and post-training by way of skinfold body fat measurements, thigh and chest circumference, and 1RM testing on both the bench press and leg press exercise. RPE was also recorded using the Borg CR-10 scale to monitor subjects' perceived difficulty of each exercise set and exercise session.

The LP, DUP, and WUP groups all experienced significant increases over the 9 weeks of 24.2%, 17.5%, and 24.5% in the bench press and 85.3%, 79%, and 99.7%, in the leg press, respectively. Additionally, thigh and chest circumferences also showed a significant time effect in the LP, DUP, and WUP groups. Chest circumferences increased from 91.94 ± 7.28 cm to 93.78 ± 7.61 cm in the LP group, 96.75 ± 9.91 cm to 96.95 ± 9.74 cm in the DUP group, and 94.89 ± 9.49 to 95.72 ± 8.19 cm in the WUP group. Thigh circumferences increased from 49.44 ± 4.65 cm to 52.72 ± 5.40 cm in the LP group, 51.90 ± 4.45 cm to 53.80 ± 5.37 cm in the DUP group, and 50.22 ± 5.31 cm to 53.89 ± 3.79 cm in the WUP group. The average RPE rating of an exercise session decreased in the linear periodization and weekly periodization groups over the 9 weeks by 5.4% and 6.1%, but increased by 3.5% in the daily undulating periodization group. This finding indicates that undulating periodization may increase individuals' session RPE, although this was not found in another study comparing the same three periodization models (Rossi, 2007). This study demonstrated that significant strength and size increases can be observed over the course of 9 weeks in both male and female college students using linear, daily undulating, and weekly undulating periodization programs.

Rhea et al. (2002) compared linear and daily undulating periodization programs' effect on strength gains using 20 male subjects recruited from college weight training classes. All subjects had a minimum of 2 years of weight training experience. Subjects were required to resistance train three times a week for 12 weeks using the leg press and bench press. Abdominal crunches, bicep curls, and lat pull-downs were also performed, but any other resistance training was prohibited. The daily undulating periodization group cycled from set schemes of 3 sets of 8 repetitions to 3 sets of 6 repetitions to 3 sets of 4 repetitions on each consecutive workout. The linear periodization model used these same set and repetition schemes, but stayed consistent with one scheme for 4 weeks at a time. This allowed the two training groups to have equated intensity and volume over the 12 week study.

Testing of the two groups was performed pre-training, 6 weeks into the intervention, and at week 12. Testing consisted of 1-repetition max on the bench press and a Cybex incline leg press machine, body composition assessment by way of air plythesmyography (Bod Pod), and chest and thigh circumference measurements. Both the LP and DUP groups increased their strength significantly in the bench press by 14.4% and 28.8%, respectively; as well as by 25.7% and 55.8% in the leg press, respectively. The DUP group experienced significantly greater strength gains in terms of percentage than the LP group from weeks 1 to 6 and weeks 6 to 12. No significant differences were observed with body composition. The subjects in the DUP group did begin to report extended muscle soreness and fatigue in weeks 10-12. This may have been an indication of overreaching, even though strength tests did not appear to be considerably affected. This study showed that a 12 week DUP program was more effective at increasing strength than a LP program using a college-aged male population. However, the DUP program may have begun to show signs of overtraining late in the study.

Hoffman et al. (2009) compared the effectiveness of two different periodization models as well as a nonperiodized model of resistance training on 51 NCAA Division III football players. The training groups consisted of a nonperiodized program (NP), periodized linear program (PL), and a planned nonlinear periodized (PNL) program. All three groups performed resistance training for 12 weeks, 4 days a week, with days 1 and 3 focusing on the chest, shoulders, and triceps, and days 2 and 4 focusing on the legs, back, and biceps. The NP group used the same training "intensity" throughout the study, meaning the same set and rep schemes, as well as rest periods between sets, were used. The PL group performed a 4-week hypertrophy phase, 6-week strength phase, and a 4-week power phase. The PNL group changes its volume and intensity from workout to workout, alternating between a power workout and a hypertrophy workout. This is referred to in some other literature as daily undulating periodization (Baker, 1994; Rhea, 2003; Rhea, et al., 2002a).

Testing was performed pre- mid- and post testing. The testing consisted of 1RM bench press and back squat, vertical jump using a countermovement and a seated medicine ball throw. All three groups experienced significant improvements in 1RM in both the back squat and bench press from pre- to post-testing. The NP, PL, and PNL groups increased their 1RM bench from 125.9 ± 12.2 kg to 136.8 ± 9.5 kg, 118.5 ± 18.3 kg to 127.7 ± 20.7 kg, and 124.0 ± 25.0 kg to 134.3 ± 27.1 kg, respectively. The same groups increased their 1RM squat from 161.8 ± 16.6 kg to 194.8 ± 24.5 kg, 149.5 ± 25.0 kg to 180.5 ± 17.6 kg, and 164.2 ± 23.2 kg to 182.5 ± 25.6 kg, respectively. The majority of these improvements occurred between pre- and mid-testing. Vertical jump height also increased significantly in all three groups, but only from pre to mid testing. From pre- to mid-testing, values in the NP, PL, and PNL groups from 61.0 ± 8.0 cm to 63.5 ± 7.4 cm, 63.6 ± 7.1 cm to 65.1 ± 7.8 cm, and 59.1 ± 11.2 cm to 61.0 ± 10.8 cm, respectively. From mid-testing to post-testing, the vertical jump heights for the three groups either stayed the same or decreased non-significantly. The medicine ball toss increased significantly from pre to post for the PL group from 537 ± 49 cm to 570 ± 45 cm. For the NP and PNL groups, the medicine ball toss increased non-significantly from 566 ± 53 cm to 577 ± 45 cm and 556 ± 73 cm to 576 ± 53 cm, respectively. All three groups appeared to show similar strength improvements after 12 weeks of training. The results of this study demonstrated that all three periodization models were effective at increasing strength and jumping ability from week 1 to 6. After week six, there appeared to be very little improvement, possibly due to the high training level of these athletes. A population with as much training experience as these athletes may show initial improvements due to off-season detraining and then require a longer amount of time to improve their already significant strength and power levels.

Daily undulating periodization (UP) training was compared with linear periodization (LP) training in a study performed by Peterson et al. (2008) using 14 firefighter academy students. The training study was 9 weeks long, with 3 training sessions per week utilizing upper and lower body exercises. For the LP group, the 9 weeks were divided into three mesocycles, or training types, consisting of endurance/hypertrophy, strength, and power/speed. These mesocycles used set, rep, and rest period schemes in accordance with NSCA guidelines (Baechle & Earle, 2000). The UP group used these same mesocycles, but fluctuated from one to the other in each successive workout. Strength and performance improvements made via training were measured using 1RM squat and bench, vertical jump with countermovement, horizontal standing broad jump and 40 yard dash. Power was measured using a calibrated position trandsducer (TENDO FiTROdyne Powerlizer) as subjects squatted 30% and 60% of their 1RM as quickly as possible during the concentric part of the movement. To measure the transfer of resistance training improvements to improvements in actual firefighter skills, the subjects also completed a timed test termed “The Grinder,” which consisted of ten separate job performance tasks that are specific to firefighting. These included activities such as a hose pull, stair climb, and equipment hoist. Circumferences of subjects’ upper arm, chest, and upper thigh were also measured.

At the conclusion of the 9 weeks of training, both groups showed significant increases in 1RM bench and squat, power output and decreased time to complete the Grinder. The UP group experienced significantly greater improvements in the Grinder (297 ± 51.70 sec to 211 ± 21.54 sec vs. 304.43 ± 47.79 sec to 239.43 ± 26.25 sec) and greater improvements than the

LP group in 1RM for squat (135.76 ± 31.19 kg to 163.62 ± 31.52 kg vs. 119.07 ± 15.56 kg to 139.1 ± 11.71 kg) and bench (102.38 ± 27.85 kg to 119.55 ± 24.52 kg vs. 99.46 ± 23.44 kg to 108.11 ± 23.20 kg), peak power at 30% 1RM, average and PP at 60% 1RM, and vertical jumping ability (60.6 ± 6.25 kg to 66.22 ± 6.33 kg vs. 59.16 ± 7.79 kg to 62.05 ± 8.37 kg). Changes in body anthropometry were not significant. This study showed that a daily undulating periodization program elicited greater task-specific improvements for the firefighters as well as strength and power increases than a traditional linear periodization model.

Overreaching/Overtraining Measures.

Overreaching and overtraining are common causes of decreased performance among athletes and recreationally training individuals. Overreaching is typically characterized by a short term decrease in performance caused by increased training volume and or intensity (Armstrong, 2002; Baechle & Earle, 2000; Borselen, 1992; Bushie, 2007). When overreaching persists for some time and is not treated with a decrease in training volume and intensity, the subject can then go into a state of chronic fatigue, known as being overtrained (Hoffman, 2002). This is often referred to in the literature as the overtraining syndrome (OTS) (Armstrong, 2002; Borselen, 1992; Stone, 1991; Urhausen, 2002). OTS is characterized by increases in resting and sleeping heart rate, decreases in maximal performance, maximal power output, muscular strength, more muscle soreness, weight loss, decreased appetite, sleep disturbances and other related symptoms.

Heart Rate. Heart rate has often been used to monitor if an athlete is in an overtrained state in a number of ways. This includes monitoring if an athlete’s resting heart rate upon waking has increased above normal, or monitoring if an athlete's average sleeping heart rate has increased. The latter method has been suggested as a more sensitive measure of overtraining (Dressendorfer, 1985; Jeukendrup, 1998; Jeukendrup, 1992). The reasoning behind monitoring heart rate is that it is believed that when the body is becoming overtrained, the sympathetic nervous system becomes overactive and causes the aforementioned effect (Achten, 2003; Borselen, 1992; Mischler, 2003). Typically this has been used with aerobically trained athletes such as cyclists (Achten, 2003; Jeukendrup, 1998; Jeukendrup, 1992). With this population it has been suggested that heart rate should be checked every four to five days during times of increased training stress (Achten, 2003). Using heart rate to monitor overtraining in resistance trained populations has been discussed in theory, but no recent research has been conducted actually testing this premise.

A study performed by Mischler et al. (2003) examined the effect of prolonged exercise on sleeping heart rate (SHR) in 11 young recreationally trained men (mean age 25 ± 0.6 years). The subjects had their SHR monitored at night following a day of no exercise, then for four nights following five hours of intermittent bicycle ergometer and treadmill exercise. The subjects performed six 50-minute exercise bouts throughout the day at the moderate intensities of 57.0 ± 1.3% VO_{2max} and 64.7 ± 1.6% VO_{2max} for cycling and running, respectively. The subjects' mean SHR was 52 ± 1 bpm following the day of no exercise, 59 ± 1 bpm after exercise day 1, 61 ± 1 bpm after exercise day 2, 59 ± 1 bpm after exercise day 3, and 58 ± 1 bpm after exercise day 4. This study demonstrated that after increased training load, subjects' sleeping heart rates increased significantly from their pre-training value. While it is not known if these individuals were overreaching, the authors did attribute the increased SHR to an increase in sympathetic nervous system activity. As discussed earlier, this physiological response is believed to be present in overreaching and overtrained individuals.

Jeukendrup et al. (1992) also examined the effect of aerobic overtraining on sleeping heart rate. Eight male competitive cyclists underwent an intensified training program in an attempt to achieve a state of overreaching, although one dropped out due to an inability to maintain the increased training volume and intensity. This increase in training stress consisted of mostly high intensity interval training (ITT). After two weeks of the ITT, all eight cyclists were deemed overtrained due to a decrement in their time-trial performances and cycle ergometer tests. Coinciding with this were rate values that increased significantly from 49.5 ± 3.8 bpm to 54.2 ± 3.2 bpm. This study demonstrates that sleeping heart rate does increase in overreached endurance individuals.

Perceived Exertion. The Borg Rating of Perceived Exertion (RPE) scales are tools typically used to monitor or prescribe the intensity of an exercise (Baechle & Earle, 2000; Borg, 1998; Hoffman, 2002). The two scales most commonly used are the 0-10 scale referred to as the “Borg CR-10 scale” and the 6-20 scale, simply referred to as the “Borg RPE” scale (Borg, 1998). These indicate the perceived intensity of an exercise, ranging from “no exertion at all” at a rating of 0 on the CR-10 scale or 6 on the RPE scale to “extremely hard” at a rating of 10 or 20, respectively (Hoffman, 2002). The 6-20 scale is most often used when prescribing cardiovascular exercise, as the scale is believed to be correlated with heart rate and central fatigue (Taylor, et al., 2000). The 0-10 scale is typically used in reference to activities that cause peripheral fatigue, such as resistance training (Day, 2004; MacIntosh & Rassier, 2002). Many resistance training studies have used subjects’ self-reported RPE in an attempt to quantify the intensity of an exercise set (Gearhart, 2002; Lagally, 2004) or an entire exercise session (Day, 2004; Lagally, 2007; Sweet, 2004).

Day et al. (2004) investigated the reliability of the 0-10 Borg RPE scale when used to quantify the intensity of resistance training sets and the entire resistance training session. Twenty subjects (10 male and 10 female) in their early 20's who had at least six months of weight training experience participated in the study. The subjects participated in six weight training sessions over the course of seven days that included two days of high-, moderate-, and low-intensity training. These intensities were classified due to their 4, 10, and 15 repetition maximum (RM) guidelines, respectively. Subjects reported their RPE following the completion of each set as well as an entire exercise session RPE 30 minutes following the workout. It was found that RPE effectively represented the intensity of the exercise session and that average RPE of each individual set was not significantly different than the session RPE. These results suggest that the 0-10 Borg RPE scale is a reliable measure of a resistance training session's intensity. This study also reveals that monitoring the RPE of an overall resistance training session may be just as effective as reporting the RPE of each individual set.

The 15 point 6-20 RPE scale was similarly tested in another resistance training study (Gearhart, 2002). This study involved 10 men and 10 women in their 20's who had been participating in weight-training exercise at least twice a week for three weeks. A counterbalanced experimental design was used in which all subjects completed both a high-intensity (HI) and a low-intensity (LI) weight training protocol. RPE was reported after every repetition in the HI protocol and after every third repetition in the LI protocol. Seven exercises were completed in both scenarios and it was shown that the RPE of the HI protocol was reported as significantly higher than the LI protocol in all seven exercises. This study suggests that the 6-20 RPE scale is also effective at measuring the perceived exertion of a resistance training session.

Perceived exertion has also been examined as a possible monitoring tool for observing when an individual may be becoming overreached (Foster, 1998; Hoffman, 2000; Snyder, et al., 1993; Urhausen, 2002). Snyder et al. (1993) attempted to do this in a study involving well-trained cyclists. This study examined the changes in seven male cyclists after undergoing two weeks of high intensity interval training (ITT) in an attempt to elicit a state of short-term overtraining. The study involved three different periods of training each lasting two weeks. These included a moderate training, ITT, and recovery period, respectively. The cyclists underwent five maximal cycle ergometer tests (MT) throughout the study during which their blood lactate levels and RPE were measured. These tests were conducted prior to the experimental period, after one week of moderate training, after one week of ITT, after the second week of ITT, after one week of recovery, and at the end of the recovery phase. Using the same workload, it was shown that the cyclists' blood lactate to RPE ratio was higher after completing the ITT. Before completing the ITT, the subject's all had a blood lactate to RPE ratio of greater than 100 for the more intense workloads completed. After the subjects completed the ITT, a number of the subjects had a blood lactate to RPE ratio of less than 100, suggesting overreaching. Five of the seven cyclists were considered overreached after week one of ITT, while all seven were considered overreached at the completion of the second week of ITT. A state of overreaching was defined as having a decrease in performance on the maximal ergometer test, a lower general sense of well-being, and a blood lactate to RPE ratio of less than 100.

Performance Testing. The primary indication that an individual is overtrained is a decrease in their performance (Halson, 2004; Hoffman, 2000). This makes simple performance measures a very practical tool for measuring when an individual may be at risk for overreaching or overtraining. Studies have used sprints of 10 and 40 yards, agility tests, 1-repetition maximums of the bench press and back squat exercises, vertical jumps, medicine ball throws, lower body reaction time, isokinetic strength tests, and bench presses to volitional fatigue to assess overtraining status (Alcaraz, 2008; Fry, 1994a; Fry, 1994b; Fry, 2000; Hoffman, 2000; Warren, 1992). The validity of these tests may depend on their specificity to the subjects' training or sport. If the performance tests mirror the athlete's sport or the individual's typical resistance training movements, they should prove to be better indicators of actual decreases in their performance.

A study conducted by Hoffman et al. (2000) used various performance tests in an attempt to monitor overreaching in elite youth basketball players. Twelve players from the Israeli Youth Basketball Team (mean age, 16 ± 0 years) were monitored over a 6 month period leading up to a major basketball competition. The authors in this study used strength testing, speed and agility measures and anaerobic performance in an attempt to gauge when an athlete was becoming fatigued and possibly overtrained. Testing was performed once every four weeks in an attempt to assess any changes in players' outcome measures. For strength, the athletes performed one-repetition maximum testing for the bench press and back squat exercises. For acceleration and agility testing, athletes conducted a 27-m sprint and T test. These two tests were chosen because they were thought to be practical tests of basketball movements. Finally, anaerobic performance was tested using a sprint drill commonly referred to as the "suicide." This drill involves sprinting from the baseline on a basketball court to the near free-throw line, back to the baseline, to the half-court line, back to the baseline, to the far free-throw line, back to the baseline, and the far baseline before returning to the starting baseline.

The authors noted that the 27-m sprint appeared to be the most sensitive indicator for revealing players who were "fatigued" and subsequently possibly progressing towards overreaching. Specifically, when an athlete's sprint time increased 0.15 seconds or more from their best time, it was shown that their training log revealed an increase in training load and volume for the 2 weeks prior to testing. When this occurred, the athletes were excused from several practices. When the athlete was tested again a month later, their sprint times returned to within an acceptable range of their best time. The 0.15 second cutoff was arbitrarily chosen by the authors due to the use of a handheld stop watch.

Fry et al. (2000) attempted to monitor the onset of overreaching in six men (mean age 27.5 ± 5.4 years) who were participating in three weeks of high intensity resistance training. To accomplish this, the authors conducted performance tests prior to the high intensity program, and at the end of each week of training. The tests conducted included lower body reaction time, vertical jump, sprints of 10 and 40 yards, lateral agility tests and 1RM on the back squat. The back squat was selected for 1RM testing, because it was the primary exercise utilized in this training program. Lower body reaction time increased significantly by the third week of training from 6.3 ± 0.5 to 7.3 ± 1.0 seconds, but decreased to the non-significant increase of 6.5 ± 1.0 seconds by week 4. Vertical jump utilizing a counter-movement stayed consistent from pre-test to post test, showing no improvement, while a non-counter-movement vertical jump did show a significant increase from 51.3 ± 6.4 to 53.8 ± 7.1 seconds. Sprint times for 9.6 meters increased significantly from 1.75 ± 0.11 to 1.86 ±

0.13 seconds by week 4, while sprint times for 36.6 meters increased insignificantly from 5.27 ± 0.33 to 5.47 ± 0.50 seconds. Mean 1RM values on the squat exercise increased significantly from pre-testing to testing after week one of training from 139.5 ± 29.9 to 154.6 ± 27.7 kg, but did not increase at any other time during the 3 week intervention.

This study elicited a plateau in 1RM squat strength and counter-movement vertical jump performance as well as an increase in sprint times. While this may not show a clear indication of overtraining as defined by a decrement in performance, it has been suggested that a plateau in performance can be defined as indicative of overreaching (Lehmann, 1993; Stone, 1991).

Overtraining Protocols

Many studies have attempted to induce overtraining in resistance training individuals by subjecting them to relatively high intensities or relatively high volumes (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992). A study performed by Fry et al. (1994) was done to determine if three weeks of high intensity squats using a guided squat resistance exercise machine could elicit overtraining. The authors defined high intensity as squats performed with loads of 90-95% of subjects' 1RM. Six men with 2-12 years of resistance training experience who could parallel back squat a minimum of 1.2 times their own bodyweight volunteered for this study. Subjects were randomly divided into a training or control group. The training group performed 8 sets of 1 repetition at 95% of their 1RM with 2 min rest intervals between each repetition. This was performed 5 days a week, Monday through Friday, in an attempt to induce overtraining. The subjects in the control group performed a low intensity protocol, completing 3 sets of 5 repetitions at 70% of their bodyweight Monday, Wednesday and Friday.

In order to assess whether any performance decrements were occurring due to overtraining, performance testing was performed by all subjects pre-training and at the end of every training week. These tests included sprints of 10 and 40 yards, lateral running agility tests, vertical jumps using both a counter-movement and no counter-movement, high (61cm) and low (30.5cm) depth jumps, 1RM on the squat machine, and isometric and isokinetic peak leg extension torque at various angular velocities on a Cybex II dynamometer. Additionally, body composition was estimated anthropometrically to determine any body composition changes. Significant improvements were seen in the 1RM squat for the training group by the end of week 1 (109.8 ± 9.8 kg to 115.2 ± 10.9 kg), and for the control group by the end of week 3 (124.2 ± 4.3 kg to 131.6 ± 6.6 kg). The only decreases in performance that were apparent by the end of this study were significant decreases in leg extension torque by the training group at 1.05 $rad \cdot s^{-1}$ by week 3 as well as increases in 10 and 40 yard sprint times by week 2 (1.72 ± 0.06 sec to 1.82 ± 0.07 sec and 5.40 ± 0.20 sec to 5.59 ± 0.24 sec). No other changes were significant for either group. This study did not elicit easily identifiable cases of overreaching, which may be due to the short length of the training protocol. Even though a very high percentage of 1RM was used in these studies, a greater training volume over a longer period of time may be necessary to look at the occurrence of overreaching.

Another study by Fry et al. (2000) used a similar training protocol to the previous study, but utilized free-weight barbell back squats and lying leg curl exercises in an attempt to induce overtraining. This study also lasted three weeks and had the subjects run through a battery of tests each week to look for any performance decrements. During the 3 week high intensity protocol, there was a significant increase in 10 yard sprint times by week 4 from 1.75 ± 0.11 to 1.86 ± 0.13 seconds. It should also be noted that sprint times in both the 10 yard and 40 yard dash increased every week, although not significantly. Subjects' 1RM back squat also stayed relatively consistent, failing to significantly increase. Although the authors of this study could not define the subjects as overtrained, there were some performance decrements and a lack of significant increases in strength. Perhaps a protocol lasting longer than 3 weeks could better elicit the desired effects.

Summary

Undulating periodization has been shown to be just as effective as, if not more effective than, the more common linear periodization model at producing positive strength and performance improvements (Baker, 1994; Buford, 2007; Hoffman, et al., 2009; Rhea, et al., 2002a; Stone, et al., 2000). One explanation for this may lie in the fact that undulating periodization may decrease the chance of an individual reaching a state of "staleness" or overreaching (Peterson, 2008). This phenomenon of overreaching can cause an athlete or individual to experience decreases in performance, which is detrimental to their goals (Armstrong, 2002; Baechle & Earle, 2000; Borselen, 1992; Bushie, 2007; Urhausen, 2002). This problem is compounded by the fact that there is not an easily accessible set of tools that can be used to detect and attempt to prevent non-functional overreaching from occurring (Costa et al., 2005; Fry, & Kraemer, 1997; Fry et al., 1994; Meeusen, 2004; Moore, 2007; Snyder et al., 1993; Warren, 1992).

Measures that have shown promise in identifying overreached or soon to be considered overreached individuals have included average sleeping heart rate (Achten, 2003; Dressendorfer, 1985; Jeukendrup, 1998; Jeukendrup, 1992), training session rating of perceived exertion (Foster, 1998; Hoffman, 2000; Snyder, et al., 1993; Urhausen, 2002), Secretory Immunoglobuluin A percentage (Costa, et al., 2005; Fahlman & Engels, 2005;

Krzywkowski, et al., 2001; Mackinnon, 1994), and simple performance tests (Alcaraz, 2008; Fry, 1994a; Fry, 1994b; Fry, 2000; Hoffman, 2000; Warren, 1992).

While many of these measures have been used in an attempt to identify either aerobic or resistance training athletes who may be overreaching, they have not been combined in an attempt to find one accurate set of indicators. The current study adds all of these measures in an effort to create accessible, cheap, and effective measurement tools for athletes and recreationally training individuals.

Chapter III

Methods and Procedures

The purpose of this study was to determine if simple outcome measures could be used to determine the onset of overreaching in a college-aged resistance training population performing two different modes of periodized resistance training. This was achieved by having subjects monitor their average sleeping heart rate using a wireless polar heart rate monitor, record the RPE of each of their training sessions, and conducting performance tests at various points throughout the study. These performance tests consisted of a standing broad jump, 10 yard dash, and a seated medicine ball throw. In addition to the performance tests, subjects' 1RM bench press and back squat exercise were also conducted pre- and post-training in an effort to measure any strength changes.

Description of Study Population

The sample consisted of 18 female and 11 male students from the Kinesiology major at Western Washington University who volunteered to participate in the study with the understanding that extra credit would be awarded for completion. All subjects were between the ages of 18 and 25 and had at least one year of weight training experience and were familiar with the bench press and back squat exercises. Subjects had no previous history of orthopedic injuries that would be exercise limited. Participants were instructed to not perform any other resistance training in addition to this program and also to abstain from excessive cardiovascular activity prior to weight training sessions and testing sessions.

Design of Study

Testing. A multiple participant repeated measure design was conducted for the 1-repetition maximum tests using the bench press and back squat exercises, standing broad jump, 10-yard dash, and seated medicine ball throw. Two 1-repetition maximum tests were completed in all, one before training began and one after the completion of training (8-weeks). The performance tests of standing broad jump, 10-yard dash, and seated medicine ball throw were performed three times at pre- mid- and post-training. Average sleeping heart rate was measured in every subject twice weekly in order to allow rotation of the 12 available heart rate monitors to the 36 total subjects. The subjects also reported the RPE of all 24 of their exercise sessions (3 sessions a week for 8 weeks).

Table 1. Variables tested at each testing session.

	Strength Tests	**Power Measurements**	**Other Measures**
Pre-Training	1-RM Squat 1-RM Bench	Standing long Jump 10-yard dash Seated Medicine Ball Throw	N/A
Mid-Training	N/A	Standing long Jump 10-yard dash Seated Medicine Ball Throw	N/A N/A
Post-Training	1-RM Squat 1-RM Bench	Standing long Jump 10-yard dash Seated Medicine Ball Throw	N/A
Twice a week	N/A	N/A	Average Heart Rate
Every Training Session	N/A	N/A	RPE

Data Collection Procedures

Instrumentation. Maximum strength was measured using 1-repetition maximum lifts for the bench press and back squat in the Wade King Recreation Center on the available benches and inside squat racks. The standing broad jump, 10 yard dash, and seated medicine ball throw were conducted in a gymnasium. These tests required the use of a tape measure, stop watch, chair, and a small number of medicine balls to fit the subjects' strength levels appropriately. Average sleeping heart rate was collected by all subjects twice a week using a Polar wireless heart rate monitor (Polar Electro; Kempele, Finland). The monitor chest strap was put on by the subjects prior to bedtime and they slept with the monitor on. The watch receiver was placed within 5 feet of the individual to allow proper recording throughout the night. Upon waking the next morning, the average heart rate was recorded from the watch display.

Measurement techniques and procedures. The researcher initially explained the study and its time involvement to the subjects. Before any testing or training was conducted, the participants were informed of the testing procedures and provided with an informed consent document approved by the Western Washington University Internal Review Board. The participants were informed that they would be participating in a 3 day-a-week training study for 8-weeks. It was explained to the subjects that the first 1-2 training sessions would be monitored and assisted by the researcher. This was done to ensure that the correct technique was used according to NSCA guidelines, and that the participants were following the correct acute training variables (volume, intensity, rest periods) (Baechle & Earle, 2000). If participants wanted help or assistance with additional workouts, the researcher made himself available to do so. After the completion of each workout, the participants filled in the session rating of perceived exertion (RPE) on a provided table. The correct use of this scale was explained at the initial workout session (Borg, 1998). It was also explained that missing more than three training sessions over the 8-weeks of training would result in the subject being dropped from the study.

One-repetition max lifts using the back squat and bench press were performed by each participant at the beginning of the study and after training was completed (8-weeks). This was performed in the Wade King Recreation Center under the supervision of the lead researcher. The protocol for accomplishing this involved a light dynamic warm up followed by a light 10 repetition set on the exercise that was being tested. The load was then increased according to the NSCA guidelines for 1RM testing until a 1RM was attained (Baechle & Earle, 2000). Subjects then proceeded to a gym in Wade King to perform the standing broad jump, 10-yard dash, and seated medicine ball throw. The standing broad jump was conducted by having the subject start with their toes behind a line of tape. When ready they would then use a countermovement before jumping as far forward as possible without falling over. The distance from the starting line to their closest heal was then measured as the jump distance. The 10-yard dash was performed from a standing, split stance position. The start of each dash was self-selected and timing was done with a manual stopwatch. The seated medicine ball throw test was performed with the subject sitting with their backs against a wall. A weighted medicine ball was then tossed from chest level using a two-handed chest pass technique for distance. The first spot where the ball hit the ground was measured for distance from the wall.

Each of the aforementioned tests was performed 3 times with no limit on rest between trials. The best of the three trials was recorded for each subject. These performance tests were conducted a total of three times in the study. This included at the beginning of the study, the mid-way point (week 4), and at the conclusion of the study. Subjects also recorded their average sleeping heart rate twice a week throughout the 8-weeks. This was done using a wireless heart rate monitor that was worn overnight. Upon waking the subject would then record their average sleeping heart rate from the heart rate monitor watch. This resulted in a total of 18 heart rate data points for average sleeping heart rate.

Training Program Description. After initial testing, subjects were randomly assigned to one of three groups. These consisted of a control group and two training groups performing an 8-week resistance training program. The control group was advised to not change their current resistance training throughout the duration of the study. The training groups consisted of a traditional linear periodization (LP) and a non-linear daily undulating periodization (DUP) training group. Subjects trained 3 days per week with a minimum of 48 hours between sessions. Monday, Wednesday, Friday, or Tuesday, Thursday, Saturday are examples of acceptable training schedules. The exercises performed each week are listed in Table 2. These were identical for both groups with the exception of one upper body pull, upper body push, and biceps or triceps exercise. These were left open for the participant to choose an exercise from the list in Table 3. This was done to allow some individualization and to decrease monotony over the 8 weeks.

Table 2. Exercises performed in both training groups.

Day 1 (Ex. Monday)	Day 2 (Ex. Wednesday)	Day 3 (Ex. Friday)
Squat	Leg Press	Squat
Bench Press	Incline DB Bench Press	Bench Press
Leg Curl	Upright Row	Leg Extension
Upper Body Pull [a]	Upper Body Push [b]	Upper Body Pull [a]
Upper Body Push [b]	Upper Body Pull [a]	Upper Body Push [b]
Biceps [c]	Back Extension	Triceps [d]
Plank		Plank

***a,b, and c refer to lists of possible exercises in Table 3 below.**

Table 3. List of exercises from which subjects could choose to train upper body pull, upper body push, biceps, and triceps.

Upper Body Pull	**Upper Body Push**	**Biceps**	**Triceps**
Pull-ups	Incline press (barbell or dumbbell)	Bicep Curl (dumbbell or barbell)	Triceps extension (seated, standing, or lying down with dumbbell or barbell)
Rows (seated, bent-over, one-arm, etc…)	Shoulder press (seated or standing with dumbbells or barbell)	Preacher Curl (dumbbell or barbell)	Tricep cable pushdown
Pulldowns (lat pulldown, close-grip pulldown, etc…)	Dips (lean forward to emphasize chest)	Hammer Curl	

The numbers of repetitions, % of 1RM, sets, and rest period between sets for the three mesocycles or training types are shown in Table 4. The LP group performed 8 training sessions using each mesocycle in a sequential manner. This started with the muscular endurance mesocycle, followed by hypertrophy for 8 sessions, then the strength focus for the last eight sessions. The DUP group used the same three workout types for the same number of workout sessions in each group, but the workouts were varied from one training session to the next. This is summarized in Table 5. This scheduling ensured that both groups had equated volume and intensity over the entire training program.

Table 4. Training goal characteristics.

Training Type	Muscular Endurance	Hypertrophy	Strength
Rep Range	12-15 RM	8-12 RM	4-6 RM
% 1RM	≤ 67%	75-85%	85-95%
Sets	3	3	3
Rest Period between sets	30 seconds	≥ 1.5 min	2 min

Table 5. LP and DUP workout schedule for the study.

Linear Periodization Group (LP)		
Training Sessions 1-8	Training Sessions 9-16	Training Sessions 17-24
Muscular Endurance	Hypertrophy	Strength
Daily Undulating Periodization (DUP)		
Monday	Wednesday	Friday
Strength	Hypertrophy	Muscular Endurance

Subjects were instructed to fill out a workout log for each training session to ensure that they were aware of the previous weights they used for every set on each exercise. An example was given to each participant and it was explained how to use the log effectively. This ensured that the subjects knew exactly what weights they used in previous sessions.

They were instructed to increase the amount of weight used in each exercise by about 5% if the maximum number of repetitions in a rep range were completed. For example, if subject A completed 15 repetitions on the bench press using 180 lbs during an endurance workout, he would then increase his weight by about 5% in his next workout. In this case 5% is 9 lbs, so 10 lbs would be recommended. The exceptions to this rule are the strength specific workouts or mesocycle. During these training days, weight was increased after every set that the maximum number of repetitions was performed. This was done in an effort to most effectively elicit continued progress.

Subjects were given a training table to fill in their rating of perceived exertion (RPE) following every training session using the Borg CR-10 scale. This was done in an attempt to monitor any changes in perceived effort while using the same intensity. Heart rate tables were also given out so that average sleeping heart rates could be recorded twice a week.

Data (Statistical) Analysis

The pre-training data were compared with mid-training data and post-training data to see if one training program caused a greater change in the indicators of overreaching than the other. The specific variables compared were seated medicine ball throw, standing long jump, 10-yard dash, average sleeping heart rate, and RPE. The average sleeping heart rate and RPE values were averaged for weeks 1-3, 4-5, and 6-8 to allow pre- mid- and post-comparison. Subjects' 1RM strength on the bench press and back squat were also measured to monitor any strength changes. All of the statistics were calculated by using Microsoft Excel 2007 and PASW statistics 18 (formerly SPSS). Means and standard deviations were calculated and a two-way repeated measures ANOVA was used for the independent variables of type of periodization and time. A two-way mixed repeated measures ANOVA was used for the dependent variables of average sleeping heart rate, standing broad jump, 10-yard dash, seated medicine ball throw, RPE, 1RM back squat, and 1RM bench press. The probability was set at $p \leq 0.05$.

CHAPTER IV

RESULTS and DISCUSSION

Introduction

Simple outcome measures were monitored over the course of 8 weeks to determine if one mode of periodization was more likely to induce overreaching in a college-aged resistance training population. The experimental design used was a three way repeated measures ANOVA for the performance measures of standing broad jump, seated medicine ball throw, 10-yard dash and average sleeping heart rate. The distance jumped, throwing distance, dash time, and average sleeping heart rate acted as the dependent variables for the tests, respectively. The RPE of each training session was also used as an outcome measure for the two resistance training groups. This measure was examined using a two way repeated measures ANOVA design. In addition to the performance tests, subjects' 1RM bench press and back squat exercise were also assessed pre- and post-training using a two way repeated measures ANOVA to measure any strength changes. Results pertaining to the analysis are presented and discussed following the description of the subject characteristics.

Subject Characteristics

The initial study population consisted of 11 males and 26 female students from the Kinesiology major at Western Washington University. All subjects were between the ages of 18 and 25 years old, had at least one year of weight training experience and were familiar with the bench press and back squat exercises. Subjects had no previous history of orthopedic injuries that would limit exercise. Participants were instructed to not perform any other resistance training in addition to this program and also to abstain from excessive cardiovascular activity prior to weight training sessions and testing sessions. During the duration of the study a total of 8 females and 4 males dropped out of the study. Two female and 2 male subjects dropped out due to non-research related injuries, 2 females and 2 males dropped out because of missing too many workouts due to illness, and 4 female subjects dropped out due to lack of time. This resulted in a final subject pool of 25 (18 females, 11 males). A greater number of control subjects dropped out of the study than the two training groups, leaving an uneven distribution between the three groups. The final distribution was 10 subjects in the linear periodization group, 11 subjects in the nonlinear periodization group, and 4 subjects in the control group.

Subject Characteristics Table

Table 6. Subject characteristics by group and sex

Group	Sex	# of subjects		Age (years)	Height (cm)	Weight (kg)
CG	**Males**	2	**Mean (±SD)**	21.50 (±0.71)	180.34 (±7.18)	88.86 (±26.03)
	Females	2		22.00 (±0)	163.83 (±1.80)	55.68 (±1.61)
LP	**Males**	2	**Mean (±SD)**	21.00 (±0)	176.53 (±5.39)	72.73 (±6.43)
	Females	8		21.63 (±0.52)	170.82 (±5.72)	63.47 (±7.27)
DUP	**Males**	3	**Mean (±SD)**	21.33 (±0.58)	179.49 (±2.93)	72.27 (±1.64)
	Females	8		21.75 (±0.89)	165.42 (±7.85)	64.77 (±15.03)

CG = Control Group; LP = Linear Periodization Group; DUP = Nonlinear Periodization Group

Results

A repeated measures design was used in this study to determine statistical significance of the dependent variables. For the results of the various testing measures, the dependent variables are referred to as 0, 4, and 8, where 0 is the pre-test data, 4 is the testing collected after 4 weeks (if applicable), and 8 is the post-test data collected at the conclusion of the 8 weeks.

Comparison of the pretest and posttest bench press data by way of a two-way repeated measures ANOVA revealed that there was not a main interaction effect ($F_{2,22}$ = 1.706, p=0.205, η_p^2 = 0.134) between groups, but there was a significant main effect of time from pretest to posttest ($F_{1,22}$=34.09, p=0.000, η_p^2 =0.608) Examining the control group's values from pretest to posttest did not demonstrate a significant difference ($F_{1,22}$=2.455, p=0.215, η_p^2 =0.450) in 1RM bench press weight, as seen in Table 7. Both the linear ($F_{1,2}$ =17.19, p=0.002, η_p^2 =0.656) and nonlinear ($F_{1,22}$=44.0, p=0.000, η_p^2 =0.589) training groups showed a significant improvement in 1RM bench press weight from pre- to post-test. Table 7 shows that the mean weight lifted in the linear group increased 9.2%, while Table 9 displays the change in 1RM weight lifted in the nonlinear group was a 9.8% increase. These improvements in upper body strength may be attributed to the respective training programs performed over the 8-weeks of the study. No significant increase in bench press was seen in the control group, with a 2.8% increase from pre to post.

Table 7. Control, linear, and nonlinear 1RM bench press values.

Group		**MEAN (kg)**	**SD (kg)**	**N**
Control[a]	**Benchweight 0**	61.93	39.30	4
	Benchweight 8	63.64	39.93	4
LP[b]	**Benchweight 0**	46.82	25.92	10
	Benchweight 8	51.14	25.87	10
DUP[b]	**Benchweight 0**	46.28	18.47	11
	Benchweight 8	50.83	19.26	11

Benchweight 0 = Pre-test 1RM bench press value; Benchweight 8 = Post-test 1RM bench press value.
a = no significant difference from pre to post
b = significant difference from pre to post

Comparison of the pretest and posttest 1RM squat data by way of a two-way repeated measures ANOVA revealed that there was a main interaction effect ($F_{2,22}$=3.456, p=0.046, η_p^2 =0.244) and a significant main effect ($F_{1,22}$=31.497, p=0.000, η_p^2 =0.589). This relationship can be seen in Figure 1. The control group did not have a significant difference ($F_{1,22}$=6.00, p=0.092, η_p^2 =0.667) in 1RM back squat weight when comparing pretest values to posttest values (Table 8). Even though not statistically significant, the control group did have an overall increase in 1RM squat strength from pretest to posttest of 2.4%, suggesting that some testing effect did occur (Table 8). The linear periodization group did significantly ($F_{1,22}$=14.703, p=0.004, η_p^2 =0.620) increase their 1RM back squat values 12.5% from pretest to posttest, as shown in Table 8. The nonlinear periodization group similarly had a significant increase in the 1RM back squat ($F_{1,22}$=46.167, p=0.000, η_p^2 =0.822), increasing 18.2%.

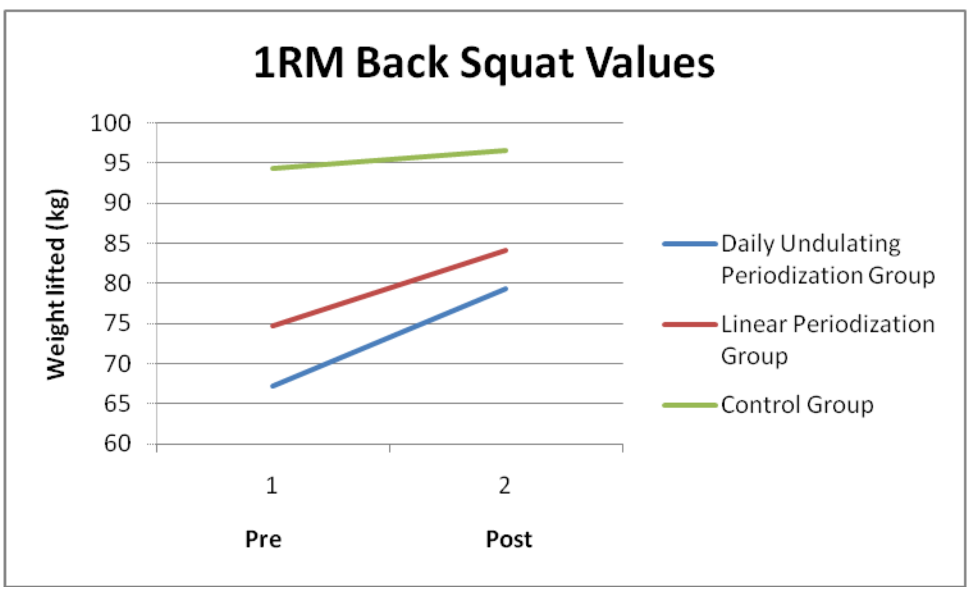

Figure 1. Mean weight in lbs of the 1RM back squat for all three groups. Test 1 = pretest; Test 2 = posttest.

Table 8. Control, linear, and nonlinear 1RM back squat values.

Group		MEAN (kg)	SD (kg)	N
Control[a]	**Squatweight 0**	94.32	48.30	4
	Squatweight 8	96.59	49.95	4
LP[b]	**Squatweight 0**	74.77	33.22	10
	Squatweight 8	84.09	30.10	10
DUP[b]	**Squatweight 0**	67.15	20.54	11
	Squatweight 8	79.34	23.80	11

Squatweight 0 = Pre-test 1RM back squat value; Squatweight 8 = Post-test 1RM back squat value.
a = no significant difference from pre to post
b = significant difference from pre to post

The standing long jump test was performed by all three groups at pre-test (0 weeks), mid-test (4 weeks), and post-test (8weeks) sessions. Comparison of all three groups by way of a two-way repeated measures ANOVA revealed that there was not a main interaction effect ($F_{4,44}$=0.431, p=0.785, η_p^2 =0.038) between groups. Despite this finding all three groups did have a significant main effect of test, improving their jump distances from the pretest to the posttest sessions ($F_{2,44}$=30.183, p=0.000, η_p^2 =0.578). The control group improved significantly ($F_{2,6}$=9.369, p=0.032, η_p^2 =0.757) 9.5% from pretest to pos-test, with the greatest increases in distance occurring during the first four weeks (Table 9). These increases may be attributed to the practice effect of getting better at the movement with repeated trials over time. The linear periodization ($F_{2,18}$=19.633, p=0.000, η_p^2 =0.686) and nonlinear ($F_{2,20}$=11.249, p=0.002, η_p^2 =0.529) periodization training groups also had significant improvements in jump distance of 7.1% and 6.2%, respectively. All three group had significantly increased jump distances from pretesting to midtesting ($F_{1,22}$=21.113, p=0.000, η_p^2 =0.490) and midtesting to posttesting ($F_{1,22}$=11.804, p=0.002, η_p^2 =0.349) sessions. The lack of a decrease in jump performance fails to show a possible decrease in lower body power due to overreaching (Fry, 2000). This is most likely due to the moderate amount of volume utilized for both training groups.

Table 9. Control, linear, and nonlinear standing long jump distance values.

Group		**MEAN (in)**	**SD (in)**	**N**
Control[b]	**Jumpdistance 0**	73.38	5.31	4
	Jumpdistance 4	79.25	5.56	4
	Jumpdistance 8	80.38	6.57	4
LP[b]	**Jumpdistance 0**	74.46	15.87	10
	Jumpdistance 4	77.75	14.87	10
	Jumpdistance 8	79.75	16.14	10
DUP[b]	**Jumpdistance 0**	73.77	16.37	11
	Jumpdistance 4	75.82	16.45	11
	Jumpdistance 8	78.36	15.58	11

Jumpdistance 0 = Pre-test standing long jump value; Jumpdistance 4 = Mid-test standing long jump value; Jumpdistance 8 = Post-test standing long jump value
a = no significant difference across the 3 test periods
b = significant difference across the 3 test periods

The seated medicine ball throw was another power test performed by all three groups at the time intervals of pretesting (0 weeks), midtesting (4 weeks), and posttesting (8 weeks). Comparison of all three groups by way of a two-way repeated measures ANOVA revealed that there was not an interaction effect ($F_{4,44}$=2.320, p=0.072, η_p^2 =0.174) between groups. There was a significant main effect difference across the test sessions ($F_{2,44}$=3.768, p=0.031, η_p^2 =0.305) . A significant (p = 0.335) difference was not found across the three testing sessions for the control group. As seen in Table 10, the control group's mean medicine ball throw increased 1.2% over the 8 weeks. The linear periodization group also failed to show a significant ($F_{2,18}$=1.838, p = 0.188, η_p^2 =0.170) change in medicine ball throw distance over time. In fact, the linear periodization group's mean throw distance decreased 1.2% from pretest to midtest, before increasing from midtest to posttest 3.2%. This trend can be seen in Table 10 and Figure 2. This temporary decrease in medicine ball throw performance may have been an indicator of overreaching during that period of time (Fry, 2000).

The nonlinear periodization group did significantly ($F_{2,20}$=6.379, p = 0.007, η_p^2 =0.389) increase their mean throw distance from pretest to posttest. As displayed in Table 10, the mean values increased 9% from pretest to posttest.

Table 10. Control, linear, and nonlinear seated medicine ball throw values.

Group		**MEAN (in)**	**SD (in)**	**N**
Control[b]	**MedBall 0**	164.13	22.42	4
	MedBall 4	165.00	22.11	4
	MedBall 8	166.13	24.37	4
LP[b]	**MedBall 0**	167.25	30.10	10
	MedBall 4	165.30	23.37	10
	MedBall 8	170.60	28.41	10
DUP[b]	**MedBall 0**	160.96	30.73	11
	MedBall 4	170.91	23.13	11
	MedBall 8	175.45	27.08	11

Medball 0 = Pre-test seated medicine ball throw value; Medball 4 = Mid-test seated medicine ball throw value; Medball 8 = Post-test seated medicine ball throw value
a = no significant difference across the 3 test periods
b = significant difference across the 3 test periods

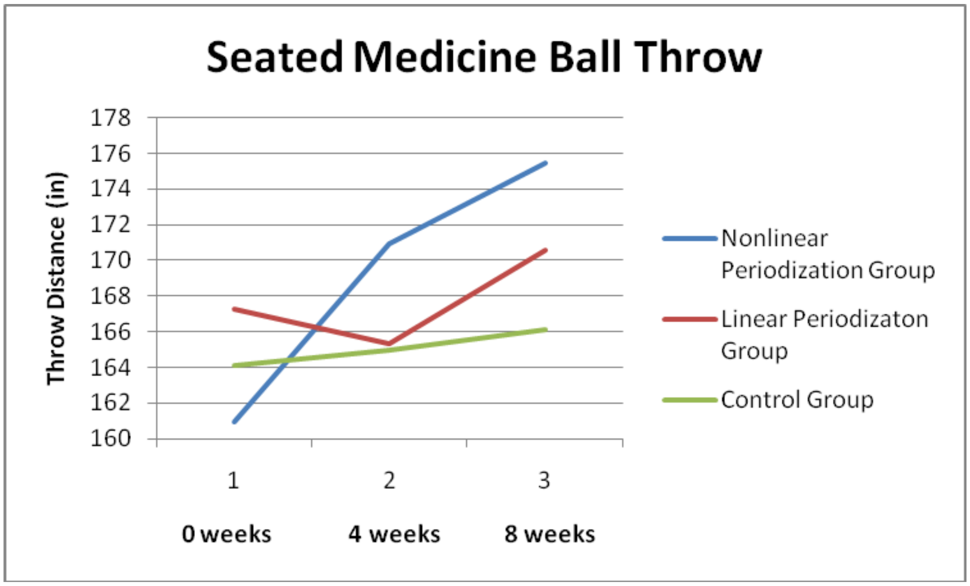

Figure 2. Mean distances in inches of the seated medicine ball throw for all three groups.

Ten yard dash performance was measured in all subjects in all groups at the same time intervals as standing long jump and seated medicine ball throw (pretest, midtest, and posttest) and are shown graphically in Figure 3. Comparison of all three groups by way of a two-way repeated measures ANOVA revealed that there was not an interaction effect ($F_{4,44}$=0.963, p=0.437, η_p^2 =0.081) and there was a significant main effect difference across the three test perioids ($F_{2,44}$=3.647, p=0.034, η_p^2 =0.142). The control group failed to show any significant ($F_{2,16}$=0.110, p = 0.797, η_p^2 =0.035) change over the 8 weeks (Table 20). The linear periodization group decreased their mean sprint time from pretest to midtest and midtest to posttest. These decreases were large enough to be deemed significant ($F_{2,16}$=4.223, p=0.053, η_p^2 =0.345) as shown in Table 11. The nonlinear group also decreased their mean 10-yard dash time during both time intervals, showing a significant ($F_{2,20}$=3.523, p=0.049,

η_p^2 =0.261) decrease over time (Table 11). The control group had 0% change in sprint time from pre to post, while the LP and DUP groups decreased their sprint times 5.4% and 3.8%, respectively. The lack of a decrease in sprint performance (increase in time) failed to support the idea that subjects may have overreached. This performance measure is thought by some researchers to be the most effective performance measure for monitoring overreaching and overtraining (Fry, 1994b; Hoffman, 2000).

Table 11. Ten yard dash values for control, linear periodized, and nonlinear periodized groups.

Group		MEAN (sec)	SD (sec)	N
Control[a]	**Dash 0**	1.79	0.14	4
	Dash 4	1.77	0.08	4
	Dash 8	1.79	0.09	4
LP[b]	**Dash 0**	1.85	0.15	10
	Dash 4	1.82	0.16	10
	Dash 8	1.75	0.18	10
DUP[b]	**Dash 0**	1.84	0.14	11
	Dash 4	1.83	0.18	11
	Dash 8	1.77	0.14	11

Dash 0 = Pre-test 10-yard dash time; Dash 4 = Mid-test 10-yard dash time; Dash 8 = Post-test 10-yard dash time.
a = no significant difference across the 3 test periods
b = significant difference across the 3 test periods

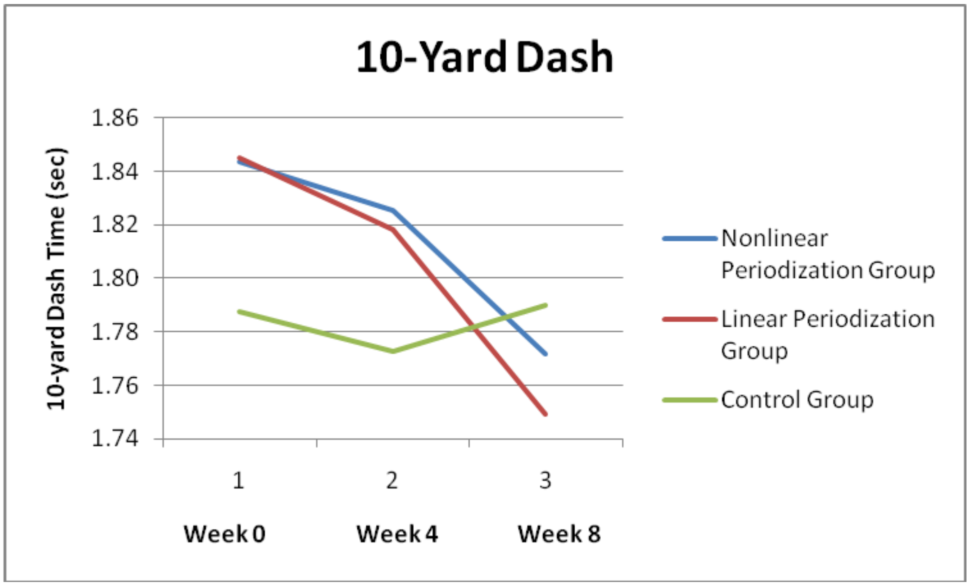

Figure 3. Mean times in seconds of the 10-yard dash for all three groups.

Average sleeping heart rate data was monitored in all subjects over the course of the 8 week study. Each subject recorded their sleeping heart rate twice weekly for a total of 16 measurements (Figure 4). For statistical analysis, these data points were averaged over weeks 1-3, weeks 4-5, and weeks 6-8 (Figure 5). Two subjects in the DUP group were not included due to lack of heart rate data. Comparison of all three groups by way of a two-way repeated measures ANOVA revealed that there was not a main interaction effect ($F_{4,40}$=1.763, p=0.155, η_p^2 =0.150) of group or test. None of the groups had a statistically significant change in average sleeping heart rate over the 8 weeks ($F_{2,40}$=0.536, p=0.589, η_p^2 =0.020.

Table 12. Average sleeping heart rate values for the control, linear, and nonlinear groups.

Group		MEAN (bpm)	SD (bpm)	N
Control[a]	**HR (bpm) Weeks 1-3**	65.53	7.41	4
	HR (bpm) Weeks 4-5	66.95	6.42	
	HR (bpm) Weeks 6-8	65.95	6.76	
LP[a]	**HR (bpm) Weeks 1-3**	64.16	5.60	10
	HR (bpm) Weeks 4-5	63.00	4.62	
	HR (bpm) Weeks 6-8	63.32	5.58	
DUP[a]	**HR (bpm) Weeks 1-3**	60.93	12.10	9
	HR (bpm) Weeks 4-5	62.51	12.29	
	HR (bpm) Weeks 6-8	62.98	13.36	

a = no significant difference over the tests

The difficulties that subjects felt each resistance training workout presented in terms of exertion were recorded using ratings of perceived exertion (RPE). The RPE values recorded over the course of the 8 weeks for all 24 workouts (3 per week) are displayed in Figures 4 and 5 below. Only 10 of the 11 DUP subjects are represented in this analysis due to missing data that was never submitted for one subject. Comparison of all three groups by way of a two-way repeated measures ANOVA showed that there was no significant interaction effect ($F_{2,36}$=0.047, p=0.954, η_p^2 =0.003) between groups or main effect ($F_{2,36}$=0.900, p=0.416, η_p^2 =0.048) of time or group. The linear periodization group's mean RPE did decrease from 7.0 to 6.8 from the beginning to the end of the training period, but this change was not statistically ($F_{2,18}$=0.310, p=0.737, η_p^2 =0.033) significant (Table 13). The nonlinear periodization group exhibited the opposite trend, displaying an overall increase in RPE values from 7.1 to 7.4, although not statistically ($F_{2,18}$=0.612, p=0.533, η_p^2 =0.069) significant as shown in Table 24. When the average RPE values of both training programs were compared over the training period there was not a significant change over time. This is displayed in Table 24. The observed power for this statistical test was 0.431, suggesting that a trend may have become apparent with a larger sample size.

Table 13. Average RPE values over the course of 8 weeks of training for the linear periodization group.

Group		MEAN	STANDARD DEVIATION	N
LP[a]	**Avg RPE Weeks 1-3**	7.0	0.82	10
	Avg RPE Weeks 4-5	6.9	0.88	10
	Avg RPE Weeks 6-8	6.8	0.92	10
DUP[a]	**Avg RPE Weeks 1-3**	7.1	1.85	10
	Avg RPE Weeks 4-5	7.2	1.87	10
	Avg RPE Weeks 6-8	7.4	1.35	10

a = no significant difference over the tests

Summary

The comparison of 8-weeks of resistance training using linear or nonlinear periodization did not result in overreaching as measured with simple measures. Both programs resulted in significant increases in upper and lower body strength over the 8 weeks.

The lack of a decrease in maximum strength in either group failed to show that there was a case of overreaching or overtraining that could be measured by way of a decreased performance using maximum strength measures (Fry, 1994b; Hoffman, 2000). The linear periodization group did exhibit a mean decrease in seated medicine ball throw distance from pretest to midtest, which could be interpreted as a sign of possible overreaching (Fry, 2000). However, the lack of a decrease in other performance measures (10-yard dash, standing long jump, 10-yard dash) at that same testing time fails to further support this conclusion. This may have been a sign of upper body muscular fatigue rather than an indicator of a state of overreaching in the entire body.

Chapter V

Summary and Conclusions

Many studies have demonstrated that periodized resistance training programs are more effective than non-periodized training programs (Baker, 1994; Kraemer, 1997; Rhea, et al., 2002a; Stone, et al., 2000). Studies have examined the differences between linear and non-linear, or undulating, periodization models of resistance training regarding subjects' improvements in various performance measures such as strength, endurance and power, and job-specific tasks. The results of these studies have been mixed, with some showing undulating periodization to be superior (Baker, 1994; Kraemer, 1997; Rhea, et al., 2002a) and some showing no significant difference between the two (Buford, 2007; Hoffman, 2009; Peterson, 2008; Rhea, 2003).

One possible factor that could contribute to nonlinear periodization being more effective than traditional linear periodization is a decreased chance of an athlete reaching a state of overreaching (Peterson, 2008). Overreaching is typically characterized as either the lack of an increase in performance or a short term decrease in performance caused by increased training volume and or intensity (Armstrong, 2002; Baechle & Earle, 2000; Borselen, 1992; Bushie, 2007). Overreaching and its more serious form, overtraining, are characterized by increases in resting heart rate, decreases in sports performance, decreases in maximal power output, decreased muscular strength, muscle soreness, weight loss, decreased appetite, sleep disturbances, frequent illness, and other related symptoms (Armstrong, 2002; Borselen, 1992; Fry, 1997; Stone, 1991; Urhausen, 2002).

While much research has been dedicated to the study of overtraining, very little has been done using a training program that would typically be used in an athletic or recreational setting (Fahlman & Engels, 2005). Instead, extreme overtraining protocols were developed in an effort to most effectively elicit measureable signs of overreaching (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992). This study utilized a more practical resistance training program to monitor potential overreaching with easily used outcome measures.

Subjects of this study consisted of 25 (18 female and 7 male) Kinesiology students currently attending Western Washington University. All subjects were between the ages of 18 and 25 years old, had at least one year of weight training experience, and were familiar with the bench press and back squat exercises. Subjects had no previous history of orthopedic injuries that would limit exercise. Participants were randomly assigned to a control, linear periodized (LP), or nonlinear periodized (daily undulating) (DUP) group for the duration of the 8 week study. The two resistance training groups performed resistance training 3 times per week for 8 weeks. The exercises, numbers of repetitions, % of 1RM, sets, and rest periods between sets for the two training groups were equated over the 8 weeks, but the order in which they were changed differed between the two. The LP group performed 8 training sessions focusing on a specific goal (strength, endurance, hypertrophy) before changing to the next in a sequential manner. This process started with the muscular endurance focus, followed by hypertrophy for 8 sessions, then the strength focus for the last eight sessions. The DUP group used the same three workout types for the same number of workout sessions in each group, but the workouts were varied from one training session to the next.

One-repetition max lifts using the back squat and bench press were performed by each participant at the beginning of the study and after training was completed (8-weeks). After completion of the 1RM's, subjects then performed the standing broad jump, vertical jump, 10-yard dash, and seated medicine ball throw. Each of these tests was performed 3 times with no limit on rest between trials. The best of the three trials was recorded for each subject. These performance tests were conducted a total of three times in the study. Subjects also recorded their average sleeping heart rate twice a week throughout the 8-weeks. The mean changes in all of these dependent variables were recorded and a P value of 0.05 was accepted as reflecting statistical significance.

At the conclusion of the 8-week study it was demonstrated that both training programs elicited significant increases in 1RM bench and 1RM back squat, while the control group did not improve significantly in either strength measure. This is in agreement with previous research that has shown both periodization models to be effective at increasing strength measures (Buford, 2007; Hoffman, 2009; Peterson, 2008; Rhea, 2003). All three groups significantly increased their standing broad jump distance, demonstrating that practicing the activity may have increased performance regardless of training. Only the DUP group significantly increased their performance in the seated medicine ball throw test throughout the course of the study, suggesting that the DUP may elicit better performance in this test. The 10-yard dash times of both training groups decreased significantly, while the control group's times did not change over the course of the study. Average sleeping heart rate and RPE did not change significantly in any of the groups. Since no significant decrease in performance measures or increase in heart rate or RPE was found in either training group, overreaching was not found to occur in either periodization model. This lack of overreaching may be due to the short duration of the study (8 weeks) and moderate intensity and volume. The research that has demonstrated overreaching or overtraining in a resistance population typically used much higher intensities than utilized in the current study (Fry, 1994a; Fry, 1994b; Fry, 2000; Pistilli, 2008; Warren, 1992). With this in mind, a longer study utilizing more volume and or intensity using these two periodization models may elicit overreaching even though none occurred in this investigation.

Conclusions

Based on the findings of this study it was demonstrated that both training groups significantly increased their maximum upper and lower body strength measures from pretest to posttest for the 1RM bench press and 1RM back squat. Neither program was significantly more effective at improving these results. This study adds to the previous body of literature demonstrating that nonlinear periodization is as effective as linear periodization at increasing maximum strength (Buford, 2007; Hoffman, 2009; Peterson, 2008; Rhea, et al., 2003).

Based on the performance measures used in this study it was not apparent that overreaching occurred in either of the training groups. The only decrease in performance found with any of the performance measures was a non-significant decrease in seated medicine ball throwing distance at midtesting in the LP group. However, the performance measures of 10-yard dash and standing long jump both increased in this group at the same testing time (midtesting). The outcome measures of average sleeping heart rate and RPE did not significantly change over the course of the study in any of the groups, failing to support an indication of overreaching in either group. The lack of significant decreases in multiple performance and/or strength measures failed to demonstrate that either group was more susceptible to overtraining using the current training protocol. In order to achieve a state of overreaching as defined by these simple measures, it may be necessary to use a much greater volume or intensity.

Recommendations

The following recommendations are suggested for further investigations:

1. Repeat the same study over a longer period of training or with more total training volume to increase the chance of overreaching occurring.

2. Conduct the same study with more subjects in order to increase statistical power and increase the chance of showing significant trends in the various outcome measures.

3. Perform 1RM back and bench press measures at midtesting to identify if any decreases in strength occurred during any time period.

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APPENDIX A

INFORMED CONSENT

"Comparison of linear and daily undulating periodization

using simple measures of overreaching"

Western Washington University

Physical Education, Health and Recreation Department

Print Name:____

The purpose of this study is to determine if simple measurements can be used to determine the onset of overreaching in a college-aged resistance training population performing two difference modes of periodization and a control group. This study will add to the existing body of literature on overreaching and the possible ways to monitor its onset. The benefit of this research is that the subjects may increase their total body strength, muscular endurance, and power. This will be the result of an 8-week resistance training program.

Overreaching is a term used to describe an individual involved in physical training that is experiencing either the lack of an increase in performance or a short term decrease in performance caused by increased training volume and or intensity. This phenomenon will be looked at in groups performing resistance training using different strategies of varying their resistance training repetitions, weight used, and amount of total work performed. These different strategies are referred to as modes of periodization.

In order to participate in this study as a subject it is required that you currently attend Western Washington University and are between the ages of 18 and 25. It is also mandatory that you have at least one year of resistance training experience that included the back squat exercise. You will be required to complete a Medical Background and Physical Activity Questionnaire that must be given directly to the study's head investigator. Each week of resistance training will consist of 3 workout sessions. If you miss four sessions in the 8-week period, you will not be eligible to continue. Please exclude yourself from this study if you anticipate missing a large number of sessions or if you have any previous musculoskeletal injuries that would be worsened and/or prevent you from being able to perform the exercises used in this study.

All participants will be required to complete testing on three different occasions. These testing sessions will be approximately 30-45 minutes in duration. These will include two 1-repetition maximum (1RM) tests utilizing the bench press and back squat the first week of training and after the last week of training. The 1RM tests will require participants to warm-up, and then progressively lift heavier weights under the supervision of two spotters until only 1 controlled repetition can be performed. Tests of power will also be conducted the first week of training, mid-training (week 4), and post-training. These tests will include a standing long jump, 10-yard dash, and seated medicine ball throw. Participants will also be required to record their average sleeping heart every three days throughout the duration of the study. This will be accomplished by wearing a wireless heart rate monitor strap while sleeping, with a recording monitor near by.

Participants in this study will be randomly assigned to one of three groups. These will include a control, linear periodization (LP), and daily undulating periodization (DUP) group. Linear periodization is a strategy of organizing resistance training workouts so that the intensity of the workouts increases over time. Daily undulating periodization is a different strategy, where the intensity of the workouts increases and decreases each subsequent workout in a non-linear fashion. The control group will be required to complete all tests, but will not have any instruction regarding a training program. The LP and DUP groups will perform an 8-week training program consisting of 3 total body resistance training sessions per week. Each session will last approximately 45 to 60 minutes. Missing more than three sessions will result in your exclusion from the study. Both groups will perform their first two resistance training sessions with the lead researcher who is a Certified Strength and Conditioning Specialist (CSCS). After these sessions, the researcher will be available for monitoring and assistance with future sessions if desired.

The LP group will be performing an 8-week resistance training program that will focus on improving different objectives every 8 sessions. These will include muscular endurance, increasing muscle size, and strength. The DUP group will also be performing an 8-week resistance training program that will focus on the same three goals. The DUP group, however, will change the focus of its workout every session. This will result in 8 sessions focusing on endurance, increasing muscle size, and strength, but performed in a cycling manner.

Risks

Possible risks of exercise participation include and are not limited to lightheadedness, shortness of breath, muscle soreness, delayed onset muscle soreness, nausea, and physical injury. The lead investigator is CPR, AED, and first-aid trained, as well as CSCS certified. In the event of a medical emergency, emergency medical services will be called to the site. Any medical expenses related to this study are the responsibility of you, the participant. Please convey any discomforts you are feeling to the investigator/trainer in a prompt manner.

Benefits

You may or may not experience increases in strength, muscular endurance, muscle size, and power as a result of participating in this study. You will also learn your one repetition maximum strength on the bench press and back squat as well as your standing broad jump, 10-yard dash, and seated medicine ball throw ability.

Confidentiality

All information gathered in this study will be treated and handled confidentially. No personal information will be shared or released without your written consent. All subject information will be transferred from computer to removable disk drives and stored in a secure location. Information from this study may be used for research purposes without reference to identity. Your name will remain confidential and will be referred to numerically as opposed to using your name.

Voluntary Participation

You are participating in this study as a volunteer and you are free to withdraw from participation at any point in the study.

Inquiries

If at any time you have questions regarding your participation in the study, you can contact the principle investigator Matt Sweeny by telephone at 360-650-7269 or Dr. Lorrie Brilla at 360-650-3056. Any questions regarding your participation or rights as a research participant should be directed to Geri Walker, WWU Human Protections Administrator at 360-650-3220.

Acknowledgment

I have read this form and give my consent to participate in this study. I comprehend the test procedures and training protocol and understand the potential risk and discomforts. I am aware that I can withdraw my consent and discontinue my participation at any time. I understand that I must follow the guidelines of the exercise program. I agree that my individual results can be utilized anonymously and confidentially in publications and presentations. All my questions pertaining to this informed consent form and the study have been answered to my complete understanding and satisfaction. A copy of this consent form will be given to me for my records. My following signature serves as written consent to participate in this study.

Subject Name (print) ______________________________

Subject Name (signature) ___________________________ Date _________

Investigator Signature _______________________________Date _______

Human Subjects Activity Review Form

Appendix B

1. What is your research question or specific hypothesis?

The purpose of this study is to determine if simple outcome measures can be used to determine the onset of overreaching in a college-aged resistance training population performing two different modes of periodization. Overreaching is typically defined as a short term decrease in performance caused by increased training volume or intensity (Armstrong, 2002; Baechle & Earle, 2000; Borselen, 1992; Bushie, 2007).

Subjects will resistance train for 8-weeks utilizing either a linear periodization (LP) or a daily undulating periodization model (DUP). A 1 repetition maximum (1RM) test for the back squat and bench press exercises will be conducted pre- and post-training to determine if the training resulted in any strength improvements. The standing broad jump, 10-yard dash, and seated medicine ball throw will be conducted pre-, mid, and post-training to measure any changes in performance that may indicate overreaching. Subjects' average sleeping heart rate will be recorded every three days to monitor any possible changes due to overreaching. Resting heart rate may increase as a result of increased training volume. This will be accomplished using wireless heart rate monitor straps that will be worn by the subject overnight. The Rating of Perceived Exertion (RPE) for each resistance training session will be recorded to monitor the perceived difficulty of each workout. Salivary Immunoglobulin A (IgA) will be collected pre- and post-training to identify immune system suppression due to resistance training. Determining if simple tests can effectively monitor the onset of overreaching in a resistance training population is the main objective of this study.

2. What are the potential benefits of the proposed research to the field?

    This study will add to the existing body of literature on monitoring the onset of overreaching in resistance training individuals. This study is important to the athletic and resistance training populations, because it may reveal an easily administered set of tests that can gauge if an individual's body is responding positively to training stimuli. This study would also allow programs to be more personalized to individuals' current physiological state, as it would be possible to increase or decrease their training intensity or volume as indicated by their overreaching outcome measures.

3. What are the potential benefits, if any, of the proposed research to the subjects?

    The benefits of this research are that the subjects in both training groups may increase their upper and lower body strength and power, decrease fat mass and increase lean body mass (Baechle & Earle, 2000; Buford, 2007; Hoffman, et al., 2009; Rhea, et al., 2002a). The subjects in both the experimental and control groups will gain the knowledge of knowing their true one repetition maximum strength on the bench press and back squat as well as their standing broad jump, 10-yard dash, and seated medicine ball throw capability.

4. a. Describe how you will identify the subject population, and how you will contact key individuals who will allow you access to that subject population or database.
   b. Describe how you will recruit a sample from your subject population, including possible use of compensation, and the number of subjects to be recruited.

The subject population will consist of 36 male and female students from Western Washington University between the ages of 18 and 25. All subjects will be required to have at least one year of weight training experience that included the use of the back squat exercise. These 36 subjects will be divided into two training groups and a control group, having 12 subjects per group. The lead researcher will inform students in the Kinesiology major of the opportunity to participate through various classes. The general student population will also be informed of the opportunity to participate by way of fliers on campus .The putative performance benefits as well as measures of strength and performance will be used as a means to recruit subjects.

5. Briefly describe the research methodology. Attach copies of all test instruments/questionnaires that will be used.

A multiple participant repeated measure design will be conducted for the 1RM tests using the bench press and back squat exercises, salivary IgA collection, standing broad jump, 10-yard dash, and seated medicine ball throw. Two 1RM maximum tests and salivary IgA collections are completed in all, one before training begins and one after the completion of training (8-weeks). The performance tests of standing broad jump, 10-yard dash, and seated medicine ball throw are performed three times at pre-, mid-, and post-training. One-repetition max lifts using the back squat and bench press will be performed by each participant in the Wade King Recreation Center under the supervision of the lead researcher. The protocol for accomplishing this will involve a light, movement specific dynamic warm up followed by a light 10 repetition set on the exercise that is being tested. The load will then be increased according to the NSCA guidelines for 1RM testing until a 1RM is attained (Baechle & Earle, 2000).

Average sleeping heart rate will be measured in every subject every 3 days in order to allow rotation of the 12 available heart rate monitors to the 36 total subjects. Heart rate monitors will be cleaned between subjects using a bleach solution, followed by an Alconox bath and water rinse. The subjects will also report the RPE of all 24 of their exercise sessions (3 sessions a week for 8 weeks). These measures will be conducted to determine if there is any significant change in the values due to 8-weeks of resistance training.

The independent variables of the study are the linear and undulating periodization models of resistance straining as well as no intervention in the control group. The dependent variables are the 1RM strength measurements on the bench press and back squat; maximum distance on the standing broad jump and seated medicine ball throw; time in the 10-yard dash; concentration of IgA antibodies from the salivary IgA test; average heart rate recorded during sleep; and rating of perceived exertion (RPE) of resistance training workouts.

The subjects will meet with the lead researcher (Certified Strength and Conditioning Specialist; CSCS) for their first two resistance training sessions to ensure proper exercise technique and to help answer any questions that may arise with the resistance exercise prescription. Following this, the researcher will make himself available for optional assistance with future workouts. The subjects will perform three resistance training sessions per week for eight weeks. The resistance training workout for each day of the study will be provided to each subject, including a log that must be filled out with each set and repetition to ensure compliance (appendix B). The subjects will be instructed to utilize a spotter during their resistance training sessions for any exercise where the weight will be positioned over their body. Examples of this are the back squat, bench press and shoulder press. To accomplish this the subjects will be encouraged to work out with a partner or ask the weight room attendant to act as a spotter when performing these lifts.

After initial testing, subjects will be randomly assigned to one of three groups. These will consist of a control group and two training groups performing an 8-week resistance training program. The control group will be advised to continue their current exercise regime throughout the study. This will be monitored by obtaining activity logs in all three groups pre- and post-training. The training groups will consist of a traditional linear periodization (LP) and a non-linear daily undulating periodization (DUP) training group. Subjects will train three days per week with a minimum of 48 hours between sessions. Monday, Wednesday, Friday, or Tuesday, Thursday, Saturday are examples of acceptable training schedules. The exercises performed each week are listed in Table 2. These will be identical for both groups with the exception of one upper body pull, upper body push, and biceps or triceps exercise. These will be left open for the participant to choose an exercise from the list in Table 3. This will be done to allow some individualization and to decrease monotony over the 8 weeks.

Table 6. Exercises performed by day for both training groups.

Day 1 (Ex. Monday)	Day 2 (Ex. Wednesday)	Day 3 (Ex. Friday)
Back Squat	Leg Press	Back Squat
Bench Press	Incline DB Bench Press	Bench Press
Leg Curl	Upright Row	Leg Extension
Upper Body Pull [a]	Upper Body Push [b]	Upper Body Pull [a]
Upper Body Push [b]	Upper Body Pull [a]	Upper Body Push [b]
Biceps [c]	Back Extension	Triceps [d]
Plank		Plank

Table 7. List of exercises subjects can choose from to train upper body pull, upper body push, biceps, and triceps.

Upper Body Pull	Upper Body Push	Biceps	Triceps
Pull-ups	Incline press (barbell or dumbbell)	Bicep Curl (dumbbell or barbell)	Dips (Keep body vertical to emphasize triceps)
Rows (seated, bent-over, one-arm, etc…)	Shoulder press (seated or standing with dumbbells or barbell)	Preacher Curl (dumbbell or barbell)	Triceps extension (seated, standing, or lying down with dumbbell or barbell)
Pulldowns (lat pulldown, close-grip pulldown, etc…)	Dips (lean forward to emphasize chest)	Hammer Curl	Tricep cable pushdown

The numbers of repetitions, % of 1-Reptition Maximum (1RM), sets, and rest period between sets for the three mesocycles or training types are shown in Table 4. The LP group will perform 8 training sessions using each mesocycle in a sequential manner. This will start with the muscular endurance mesocycle, followed by hypertrophy for 8 sessions, then the strength focus for the last eight sessions. The

DUP group will use the same three workout types for the same number of workout sessions in each group, but the workouts will vary from one training session to the next. This is displayed in Table 4. This scheduling will ensure that both groups have equated volume and intensity over the entire training program.

Table 8. Training goal characteristics.

Training Type	Muscular Endurance	Hypertrophy	Strength
Rep Range	12-15 RM	8-12 RM	4-6 RM
% 1RM	≤ 67%	75-85%	85-95%
Sets	3	3	3
Rest Period between sets	30 seconds	≥ 1.5 min	2 min

Table 9. LP and DUP workout schedule for the study.

Linear Periodization Group (LP)		
Training Sessions 1-8	Training Sessions 9-16	Training Sessions 17-24
Muscular Endurance	Hypertrophy	Strength
Daily Undulating Periodization (DUP)		
Monday	Wednesday	Friday
Strength	Hypertrophy	Muscular Endurance

Subjects will be instructed to fill out a workout log for each training session to ensure that they are aware of the previous weights they used for every set on each exercise. An example will be given to each participant and it will be explained how to use the log effectively. This will ensure that the subjects knew exactly what weights they used in previous sessions. They will be instructed to increase the amount of weight used in each exercise by about 5% if the maximum number of repetitions in a rep range were completed. For example, if subject A completes 15 repetitions on the bench press using 180 lbs during an endurance workout, he would then increase his weight by about 5% in his next workout. In this case 5% is 9 lbs, so 10 lbs would be recommended. The exceptions to this rule are the strength specific workouts or mesocycle. During these training days, weight can be increased after every set that the maximum number of repetitions was performed. This will be done in an effort to most effectively elicit continued progress.

All of the statistics will be calculated by using Microsoft Excel and SPSS. Means and standard deviations are calculated and a Repeated Measures ANOVA used. The probability is set at $p \leq 0.05$, with a Bonferroni correction for the performance tests.

a. As with any exercise, muscle fatigue may be experienced and muscle injury cannot completely be avoided. In the event of a muscle injury any exercise will be stopped immediately and the participant will be referred to the Health Center or their personal physician. Additionally, there are available first aid kits in the Recreation Center, whose locations are known by the working staff.

b. All proper procedures will be taken to reduce the risk of exercise-induced injuries. The CSCS certified lead investigator will be present during the first two resistance training workouts and correct any improper form. The investigator will then be available for future workouts by request.

c. This research will add to the existing literature on overreaching and may result in a set of easily administered set of tests to monitor an athlete's state of overreaching.

6. Give specific examples (with literature citations) for the use of your test instruments/questionnaires, or similar ones in previous similar studies in your field.

The 1RM using the bench press and back squat has been used in many resistance training studies to measure changes in strength. This includes studies similar to this one, comparing linear and nonlinear periodization (Baker, 1994; Buford, 2007; Hoffman, et al., 2009; Rhea, Ball, Phillips, & Burkett, 2002b).

The measures of overreaching that will be utilized in this study have all been used in previous studies examining overreaching or its prolonged state known as overtraining. Sleeping and resting heart rate has been utilized in aerobic overreaching studies, but never in overreaching caused by resistance training (Jeukendrup, 1998; Jeukendrup, 1992; Mischler, 2003). The rating of perceived exertion scale has been used to quantify subjects' perceived exertion of an entire resistance training workout session in previous studies (Day, 2004; Lagally, 2007; Sweet, 2004) . The salivary immunoglobulin test that will be part of this investigation has been used to identify overreaching athletes utilizing both anaerobic (Fahlman & Engels, 2005) and aerobic (Mackinnon, 1994) training regimes.

The performance tests that will be utilized in this study include the standing broad jump, seated medicine ball throw, and 10-yard dash. All three of these tests have been used as measures of performance in previous studies that utilized resistance training populations (Fry, 1994b; Fry, 2000; Peterson, 2008) or competing athletic populations (Hoffman, 2000).

7. Describe how your study design is appropriate to examine your question or specific hypothesis. Include a description of controls used, if any.

This training study will allow the comparison of two different training groups and a control group using many different simple measures of overtraining. All of the measures have been used in previous studies to identify overreaching, but which are most effective or indicate overreaching first is unknown. By utilizing all of these measures in one study it will be possible to most effectively see the differences between linear and nonlinear periodization as well as what indicators of overreaching are related. A control group will also be used to account for any changes in overreaching measures that may be a result of confounding variables.

8. Give specific examples (with literature citations) for the use of your study design, or similar ones, in previous similar studies in your field.

The resistance training protocol that is being used in this study has been used in previous studies that compared linear and nonlinear periodization in college-aged populations (Buford, 2007; Hoffman, 2009; Peterson, 2008; Rhea, et al., 2002a). These studies utilized training programs that were 8 or 9 weeks in length with 3 resistance training sessions per week, using similar set and repetition assignments.

As noted previously, the tests used to monitor overreaching have also been used in similar study designs (Jeukendrup, 1998; Jeukendrup, 1992; Mischler, 2003).

9. Describe the potential risks to the human subjects involved.
   - If the research involves potential risks, describe the safeguards that will be used to minimize such risks.

Possible risks of exercise participation include and are not limited to lightheadedness, shortness of breath, muscle soreness, delayed onset muscle soreness, nausea, and physical injury. The lead investigator is CPR, AED, and first-aid trained, as well as CSCS certified. Assistant investigators are also CPR trained and Wade

King Recreation Center staff will be on duty to assist with calling for emergency help if needed. Proper form on every exercise will be demonstrated to prevent unnecessary risk. In the event of a medical emergency, emergency medical services will be called to the site. The subjects will be instructed to convey any and all discomforts to the investigator in a prompt manner.

10. Describe how you will address privacy and/or confidentiality.

All information gathered in this study will be treated and handled confidentially. No personal information will be shared or released without written consent. All subject information will be transferred from computer to removable disk drives and stored in a secure location. Information from this study may be used for research purposes without reference to identity. Names will remain confidential and will be referred to numerically as opposed to using names.

Muscular Endurance
Workout

Workout day of week:	Rest between sets:	30 seconds
Day 1	Repetitions per set:	12 to 15

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Curl				
Upper Body Pull				
___________________				
Upper Body Push				
_________________				
Biceps				
_________________				
Plank				

RPE of workout session: _______________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Muscular Endurance
Workout

Workout day of week:	Rest between sets:	30 seconds
Day 2	Repetitions per set:	12 to 15

Exercises	Warm-up	Set 1	Set 2	Set 3
Leg Press				
Incline DB Bench Press				
Upright Row				
Upper Body Push				
___________________				
Upper Body Pull				
_________________				
Back Extension				

RPE of workout session: _______________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Muscular Endurance
Workout

Workout day of week:	Rest between sets:	30 seconds
Day 3	Repetitions per set:	12 to 15

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Extension				
Upper Body Pull				
___________________				
Upper Body Push				
_________________				
Triceps				
_________________				
Plank				

RPE of workout session: _______________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Hypertrophy Workout

Workout day of week:	Rest between sets:	≥ 1.5 minutes
Day 1	Repetitions per set:	8 to 12

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Curl				
Upper Body Pull				
____________________				
Upper Body Push				
__________________				
Biceps				
__________________				
Plank				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Hypertrophy Workout

Workout day of week:	Rest between sets:	≥ 1.5 minutes
Day 2	Repetitions per set:	8 to 12

Exercises	Warm-up	Set 1	Set 2	Set 3
Leg Press				
Incline DB Bench Press				
Upright Row				
Upper Body Push				
____________________				
Upper Body Pull				
__________________				
Back Extension				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Hypertrophy Workout

Workout day of week:	Rest between sets:	≥ 1.5 minutes
Day 3	Repetitions per set:	8 to 12

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Extension				
Upper Body Pull				
___________________				
Upper Body Push				
_________________				
Triceps				
_________________				
Plank				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Strength Workout

Workout day of week:	Rest between sets:	2 minutes
Day 1	Repetitions per set:	4 to 6

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Curl				
Upper Body Pull				
____________________				
Upper Body Push				
__________________				
Biceps				
__________________				
Plank				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Strength Workout

Workout day of week:	Rest between sets:	2 minutes
Day 2	Repetitions per set:	4 to 6

Exercises	Warm-up	Set 1	Set 2	Set 3
Leg Press				
Incline DB Bench Press				
Upright Row				
Upper Body Push				
______________________				
Upper Body Pull				
____________________				
Back Extension				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

Linear Periodization
Strength Workout

Workout day of week:	Rest between sets:	2 minutes
Day 3	Repetitions per set:	4 to 6

Exercises	Warm-up	Set 1	Set 2	Set 3
Squat				
Bench Press				
Leg Extension				
Upper Body Pull				
____________________				
Upper Body Push				
__________________				
Triceps				
__________________				
Plank				

RPE of workout session: ________________
(0-10 scale)
0 - Nothing at all
1 - Very light
2 - Fairly light
3 - Moderate
4 - Some what hard
5 - Hard
6
7 - Very hard
8
9
10 - Very, very hard

APPENDIX C

Health History Questionnaire

Date__________

Name ______________________ Age ______ Gender _____

Height__________ Weight____________

Please answer the following questions as honestly as you can. Your patterns of responses will determine whether you may participate in either an exercise test or training program.

Known Diseases (Medical Conditions)

1. List the medications you take on a regular basis.
   (Include aspirin, vitamins & minerals, prescription and non-prescription)

   ____
   ____
   ____
   ____

2. Do you have diabetes? No
   Yes
   a. If yes, please indicate if it is insulin dependent diabetes mellitus (IDDM) or non-insulin dependent diabetes mellitus (NIDDM).

   IDDM NIDDM

3. Have you had a stroke? No

   Yes

4. Have you ever had a heart attack or heart trouble? No

   Yes

5. Do you take asthma medication? No
Yes

6. Are you, or do you have reason to believe, you may be pregnant No
Yes

7. Is there any other physical reason that prevents you from participating in an exercise program (e.g. cancer, osteoporosis, severe arthritis, mental illness, thyroid, kidney or liver disease)? No
Yes

Signs and Symptoms of Disease

8. Do you often have pains in your heart, chest, neck, jaw, arms or other areas, especially during exercise? No
Yes

9. Do you often feel faint or have spells of severe dizziness during exercise? No
Yes

10. Do you experience unusual fatigue or shortness of breath at rest or with mild exertion? No
Yes

11. Have you had an attack of shortness of breath that came on after you stopped exercising? No
Yes

14. Do you often get the feeling that your heart is beating faster, racing, or skipping beats, either at rest or during exercise? No
Yes

15. Do you regularly get pains in you calves or lower legs during

    exercise which are not due to soreness or stiffness? No

    Yes

16. Has your doctor ever told you that you have a heart murmur? No

    Yes

Cardiac Risk Factors

17. Do you or did you smoke cigarettes on a daily basis?
18. No Yes
    a. If you did smoke when did you quit? (mm/dd/yy)

       ____

19. Has your doctor ever told you that you have high blood pressure? No

    Yes

20. Has a first degree relative (e.g. father, mother, sister, brother, or child) suffered from a heart attack or diagnosed cardiovascular disease? No

    Yes

Relative	Age	Did they pass away?

20. What is your systolic blood pressure?

    __________mmHg

21. What is your diastolic blood pressure?

    __________mmHg

Injuries

22. List all of your current injuries:

23. List any and all previous injuries that may be effected by an exercise program:

APPENDIX D

Raw Data

Subject Characteristics

Group	Age (years)	Height (cm)	Weight (kg)
Control Group	21	175.26	107.27
	22	162.56	56.82
	22	185.42	70.45
	22	165.10	54.55
Linear Periodization Group	22	170.18	59.09
	22	182.88	70.45
	22	167.64	75.00
	21	172.72	61.36
	21	172.72	68.18
	22	172.72	60.91
	21	180.34	77.27
	21	165.10	66.82
	21	170.18	62.73
	22	165.10	51.36
Daily Undulating Periodization Group	22	170.18	52.27
	20	160.02	83.64
	22	152.40	47.73
	21	182.88	73.64
	21	175.26	84.09
	23	157.48	49.55
	22	177.80	70.45
	22	170.18	73.64
	21	177.80	72.73
	22	170.18	56.82
	22	167.64	70.45

Raw Data

1RM Bench Press Values and 1RM Back Squat Values

Group	1RM Bench (lbs)	1RM Bench 2 (lbs)	1 RM Squat (lbs)	1RM Squat 2 (lbs)
Control	265	270	365	375
	80	80	135	135
	105	115	175	180
	95	95	155	160
LP	65	75	110	125
	100	105	205	225
	75	85	85	110
	70	70	125	145
	185	205	265	275
	65	70	115	145
	230	230	300	295
	85	100	100	120
	75	95	185	195
	80	90	155	215
DUP	75	80	95	110
	85	95	145	195
	75	90	115	135
	155	175	205	225
	105	110	145	175
	75	90	115	135
	195	205	185	235
	75	80	105	125
	125	135	235	265
	70	80	115	125
	85	90	165	195

Raw Data

Subject Standing Long Jump Values

Group	Long Jump Pre-Test (in)	Long Jump Mid-Test (in)	Long Jump Post-Test (in)
Control	79	85	86
	68	74	73.5
	79.5	83	86
	75	75	76
LP	57.5	63	64.5
	82.5	85.5	86
	56.5	65	63.5
	72	76	77
	97	100	107
	56.6	57.5	59
	100	100	104
	80	84	82
	76.5	79	80.5
	66	67.5	74
DUP	60.5	61	63.5
	53	60	66.5
	65.5	65	71
	100.5	98.5	100.5
	76.5	77	79
	70	74.5	74
	92.5	101	101.5
	67.5	66	70
	99	101	103
	66.5	66	68.5
	60	64	64.5

Raw Data

Seated Medicine Ball Throw Values

Group	Seated Medicine Ball Throw Pre-Test (in)	Seated Medicine Ball Throw Mid-Test (in)	Seated Medicine Ball Throw Post-Test (in)
Control	193	195	199
	144	146	145.5
	170.5	168	170
	149	151	150
LP	126	142	137
	162	156	157
	176.5	169	176.5
	146	146.5	144
	182	162	188
	173	174.5	170
	230	220	232.5
	176.5	177	183
	173	167	177
	127.5	139	141
DUP	136	154.5	156
	151	162	162
	128	138	138
	199.5	195	200
	201	204	204
	148	149.5	158.5
	198.5	186	218
	132.05	181	187.5
	196	201	201
	135.5	152	151
	145	157	154

Raw Data

10-Yard Dash Values

Group	10-Yard Dash Pre-Test (sec)	10-yard Dash Mid-Test (sec)	10-yard Dash Post-Test (sec)
Control	1.60	1.65	1.67
	1.95	1.81	1.81
	1.80	1.82	1.89
	1.80	1.81	1.79
LP	1.96	2.00	1.87
	1.89	1.85	1.68
	1.90	2.00	2.05
	1.85	1.88	1.69
	1.50	1.55	1.53
	2.03	1.88	1.87
	1.69	1.56	1.43
	1.93	1.87	1.81
	1.88	1.78	1.75
	1.82	1.81	1.81
DUP	1.98	1.90	1.85
	1.90	2.00	1.83
	1.84	1.96	1.75
	1.64	1.59	1.66
	1.81	1.75	1.72
	2.07	1.83	1.83
	1.65	1.53	1.56
	1.90	2.03	2.00
	1.69	1.66	1.60
	2.00	2.03	1.94
	1.80	1.80	1.75

APPENDIX E

1RM Bench Statistics

Tests of Within-Subjects Effects

Measure:Benchweight

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test	Sphericity Assumed	613.009	1	613.009	34.088	.000	.608
	Greenhouse-Geisser	613.009	1.000	613.009	34.088	.000	.608
	Huynh-Feldt	613.009	1.000	613.009	34.088	.000	.608
	Lower-bound	613.009	1.000	613.009	34.088	.000	.608
test * Group	Sphericity Assumed	61.375	2	30.688	1.706	.205	.134
	Greenhouse-Geisser	61.375	2.000	30.688	1.706	.205	.134
	Huynh-Feldt	61.375	2.000	30.688	1.706	.205	.134
	Lower-bound	61.375	2.000	30.688	1.706	.205	.134
Error(test)	Sphericity Assumed	395.625	22	17.983			
	Greenhouse-Geisser	395.625	22.000	17.983			
	Huynh-Feldt	395.625	22.000	17.983			
	Lower-bound	395.625	22.000	17.983			

Tests of Between-Subjects Effects

Measure:Benchweight

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	564254.551	1	564254.551	89.906	.000	.803
Group	6410.102	2	3205.051	.511	.607	.044
Error	138072.898	22	6276.041			

1RM Squat Statistics

Tests of Within-Subjects Effects

Measure:weightlifted

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Sphericity Assumed	3104.032	1	3104.032	31.497	.000	.589
	Greenhouse-Geisser	3104.032	1.000	3104.032	31.497	.000	.589
	Huynh-Feldt	3104.032	1.000	3104.032	31.497	.000	.589
	Lower-bound	3104.032	1.000	3104.032	31.497	.000	.589
test * Group	Sphericity Assumed	698.932	2	349.466	3.546	.046	.244
	Greenhouse-Geisser	698.932	2.000	349.466	3.546	.046	.244
	Huynh-Feldt	698.932	2.000	349.466	3.546	.046	.244
	Lower-bound	698.932	2.000	349.466	3.546	.046	.244
Error(test)	Sphericity Assumed	2168.068	22	98.549			
	Greenhouse-Geisser	2168.068	22.000	98.549			
	Huynh-Feldt	2168.068	22.000	98.549			
	Lower-bound	2168.068	22.000	98.549			

Tests of Between-Subjects Effects

Measure:weightlifted

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1351715.935	1	1351715.935	146.279	.000	.869
Group	14011.659	2	7005.830	.758	.480	.064
Error	203295.341	22	9240.697			

Standing Long Jump Statistics

Tests of Within-Subjects Effects

Measure:distancejumped

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Sphericity Assumed	255.856	2	127.928	30.183	.000	.578
	Greenhouse-Geisser	255.856	1.855	137.963	30.183	.000	.578
	Huynh-Feldt	255.856	2.000	127.928	30.183	.000	.578
	Lower-bound	255.856	1.000	255.856	30.183	.000	.578
test * Group	Sphericity Assumed	7.306	4	1.827	.431	.785	.038
	Greenhouse-Geisser	7.306	3.709	1.970	.431	.772	.038
	Huynh-Feldt	7.306	4.000	1.827	.431	.785	.038
	Lower-bound	7.306	2.000	3.653	.431	.655	.038
Error(test)	Sphericity Assumed	186.492	44	4.238			
	Greenhouse-Geisser	186.492	40.800	4.571			
	Huynh-Feldt	186.492	44.000	4.238			
	Lower-bound	186.492	22.000	8.477			

Tests of Between-Subjects Effects

Measure:distancejumped

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	365083.744	1	365083.744	552.667	.000	.962
Group	57.581	2	28.790	.044	.957	.004
Error	14532.890	22	660.586			

Standing Long Jump Statistics

(from pretest to midtest)

Tests of Within-Subjects Effects

Measure:Distance

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	96.202	1	96.202	21.113	.000	.490
	Greenhouse-Geisser	96.202	1.000	96.202	21.113	.000	.490
	Huynh-Feldt	96.202	1.000	96.202	21.113	.000	.490
	Lower-bound	96.202	1.000	96.202	21.113	.000	.490
time * Group	Sphericity Assumed	6.627	2	3.313	.727	.495	.062
	Greenhouse-Geisser	6.627	2.000	3.313	.727	.495	.062
	Huynh-Feldt	6.627	2.000	3.313	.727	.495	.062
	Lower-bound	6.627	2.000	3.313	.727	.495	.062
Error(time)	Sphericity Assumed	100.242	22	4.556			
	Greenhouse-Geisser	100.242	22.000	4.556			
	Huynh-Feldt	100.242	22.000	4.556			
	Lower-bound	100.242	22.000	4.556			

Tests of Between-Subjects Effects

Measure:Distance
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	236244.404	1	236244.404	534.749	.000	.960
Group	42.058	2	21.029	.048	.954	.004
Error	9719.283	22	441.786			

Standing Long Jump Statistics

(all 3 groups from midtest to posttest)

Tests of Within-Subjects Effects

Measure:JumpDistance

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Sphericity Assumed	36.463	1	36.463	11.804	.002	.349
	Greenhouse-Geisser	36.463	1.000	36.463	11.804	.002	.349
	Huynh-Feldt	36.463	1.000	36.463	11.804	.002	.349
	Lower-bound	36.463	1.000	36.463	11.804	.002	.349
test * Group	Sphericity Assumed	3.043	2	1.521	.492	.618	.043
	Greenhouse-Geisser	3.043	2.000	1.521	.492	.618	.043
	Huynh-Feldt	3.043	2.000	1.521	.492	.618	.043
	Lower-bound	3.043	2.000	1.521	.492	.618	.043
Error(test)	Sphericity Assumed	67.957	22	3.089			
	Greenhouse-Geisser	67.957	22.000	3.089			
	Huynh-Feldt	67.957	22.000	3.089			
	Lower-bound	67.957	22.000	3.089			

Tests of Between-Subjects Effects

Measure:JumpDistance
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	251900.133	1	251900.133	576.136	.000	.963
Group	53.908	2	26.954	.062	.940	.006
Error	9618.912	22	437.223			

Seated Medicine Ball Throw Statistics

Tests of Within-Subjects Effects

Measure:distancethrown

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Sphericity Assumed	448.285	2	224.142	3.768	.031	.146
	Greenhouse-Geisser	448.285	1.748	256.524	3.768	.037	.146
	Huynh-Feldt	448.285	2.000	224.142	3.768	.031	.146
	Lower-bound	448.285	1.000	448.285	3.768	.065	.146
test * Group	Sphericity Assumed	552.024	4	138.006	2.320	.072	.174
	Greenhouse-Geisser	552.024	3.495	157.944	2.320	.082	.174
	Huynh-Feldt	552.024	4.000	138.006	2.320	.072	.174
	Lower-bound	552.024	2.000	276.012	2.320	.122	.174
Error(test)	Sphericity Assumed	2617.560	44	59.490			
	Greenhouse-Geisser	2617.560	38.446	68.084			
	Huynh-Feldt	2617.560	44.000	59.490			
	Lower-bound	2617.560	22.000	118.980			

Tests of Between-Subjects Effects

Measure:distancethrown

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1714035.068	1	1714035.068	845.604	.000	.975
Group	144.330	2	72.165	.036	.965	.003
Error	44593.911	22	2026.996			

10-Yard Dash Statistics

Tests of Within-Subjects Effects

Measure:dashtime

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Sphericity Assumed	.032	2	.016	3.647	.034	.142
	Greenhouse-Geisser	.032	1.793	.018	3.647	.040	.142
	Huynh-Feldt	.032	2.000	.016	3.647	.034	.142
	Lower-bound	.032	1.000	.032	3.647	.069	.142
test * Group	Sphericity Assumed	.017	4	.004	.963	.437	.081
	Greenhouse-Geisser	.017	3.586	.005	.963	.432	.081
	Huynh-Feldt	.017	4.000	.004	.963	.437	.081
	Lower-bound	.017	2.000	.008	.963	.397	.081
Error(test)	Sphericity Assumed	.192	44	.004			
	Greenhouse-Geisser	.192	39.447	.005			
	Huynh-Feldt	.192	44.000	.004			
	Lower-bound	.192	22.000	.009			

Tests of Between-Subjects Effects

Measure:dashtime

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	198.480	1	198.480	3290.665	.000	.993
Group	.008	2	.004	.067	.935	.006
Error	1.327	22	.060			

Average Sleep Heart Rate Statistics

Tests of Within-Subjects Effects

Measure:BPM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	Sphericity Assumed	4.407	2	2.204	.536	.589	.026	1.073	.132
	Greenhouse-Geisser	4.407	1.622	2.718	.536	.553	.026	.870	.124
	Huynh-Feldt	4.407	1.921	2.295	.536	.582	.026	1.030	.131
	Lower-bound	4.407	1.000	4.407	.536	.472	.026	.536	.107
time * Group	Sphericity Assumed	28.971	4	7.243	1.763	.155	.150	7.053	.490
	Greenhouse-Geisser	28.971	3.243	8.933	1.763	.170	.150	5.719	.432
	Huynh-Feldt	28.971	3.841	7.542	1.763	.158	.150	6.773	.478
	Lower-bound	28.971	2.000	14.486	1.763	.197	.150	3.527	.325
Error(time)	Sphericity Assumed	164.306	40	4.108					
	Greenhouse-Geisser	164.306	32.432	5.066					
	Huynh-Feldt	164.306	38.412	4.278					
	Lower-bound	164.306	20.000	8.215					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:BPM

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	239278.130	1	239278.130	992.228	.000	.980	992.228	1.000
Group	133.235	2	66.618	.276	.761	.027	.552	.088
Error	4823.046	20	241.152					

a. Computed using alpha = .05

RPE Statistics

(Both Groups)

Tests of Within-Subjects Effects

Measure:RatingofPerceivedExertion

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
RPEMeasures	Sphericity Assumed	.033	2	.017	.047	.954	.003
	Greenhouse-Geisser	.033	1.793	.019	.047	.940	.003
	Huynh-Feldt	.033	2.000	.017	.047	.954	.003
	Lower-bound	.033	1.000	.033	.047	.830	.003
RPEMeasures * Group	Sphericity Assumed	.633	2	.317	.900	.416	.048
	Greenhouse-Geisser	.633	1.793	.353	.900	.407	.048
	Huynh-Feldt	.633	2.000	.317	.900	.416	.048
	Lower-bound	.633	1.000	.633	.900	.355	.048
Error(RPEMeasures)	Sphericity Assumed	12.667	36	.352			
	Greenhouse-Geisser	12.667	32.267	.393			
	Huynh-Feldt	12.667	36.000	.352			
	Lower-bound	12.667	18.000	.704			

Tests of Between-Subjects Effects

Measure:RatingofPerceivedExertion

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2996.267	1	2996.267	621.823	.000	.972
Group	1.667	1	1.667	.346	.564	.019
Error	86.733	18	4.819			

RPE Statistics

(LP)

Tests of Within-Subjects Effects

Measure:RPE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.200	2	.100	.310	.737	.033
	Greenhouse-Geisser	.200	1.824	.110	.310	.718	.033
	Huynh-Feldt	.200	2.000	.100	.310	.737	.033
	Lower-bound	.200	1.000	.200	.310	.591	.033
time * Group	Sphericity Assumed	.000	0	.	.	.	.000
	Greenhouse-Geisser	.000	.000	.	.	.	.000
	Huynh-Feldt	.000	.000	.	.	.	.000
	Lower-bound	.000	.000	.	.	.	.000
Error(time)	Sphericity Assumed	5.800	18	.322			
	Greenhouse-Geisser	5.800	16.419	.353			
	Huynh-Feldt	5.800	18.000	.322			
	Lower-bound	5.800	9.000	.644			

RPE Statistics

(DUP)

Tests of Within-Subjects Effects

Measure:RPE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.467	2	.233	.612	.553	.064
	Greenhouse-Geisser	.467	1.625	.287	.612	.523	.064
	Huynh-Feldt	.467	1.932	.242	.612	.548	.064
	Lower-bound	.467	1.000	.467	.612	.454	.064
time * Group	Sphericity Assumed	.000	0	.	.	.	.000
	Greenhouse-Geisser	.000	.000	.	.	.	.000
	Huynh-Feldt	.000	.000	.	.	.	.000
	Lower-bound	.000	.000	.	.	.	.000
Error(time)	Sphericity Assumed	6.867	18	.381			
	Greenhouse-Geisser	6.867	14.624	.470			
	Huynh-Feldt	6.867	17.388	.395			
	Lower-bound	6.867	9.000	.763			