A PROGRAMMING COMPARISON: THE APRE vs. LINEAR PERIODIZATION IN SHORT TERM PERIODS

A Dissertation presented to
the Faculty of the Graduate School
at the University of Missouri-Columbia

Submitted in Partial Fulfillment of the
Requirements for the Degree

DOCTOR OF PHILOSOPHY

---

by

J. Bryan Mann

B.S., Missouri State University, 2003
M.Ed., University of Missouri, 2005

Dr. Alex Waigandt, Dissertation Supervisor

MAY 2011

The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled:

A PROGRAMMING COMPARISON: THE APRE vs. LINEAR PERIODIZATION IN SHORT TERM PERIODS

presented by J. Bryan Mann, a candidate for the degree of doctor of philosophy and hereby certify that, in their opinion, it is worthy of acceptance.

_____
Dissertation Advisor
Alex Waigandt, Ph.D.

_____
Inside Department Representative
Richard McGuire, Ph.D.

_____
Inside Department Representative
Steven Osterlind, Ph.D.

_____
Outside Department Representative
Stephen Ball, Ph.D.

DEDICATION

I'd like to thank my wife for understanding what it took to reach this goal. Of all of the extra time that I wasn't home, and when I was home, I wasn't there but thinking of what else needs to be done.

I'd like to thank my Mom and Grandparents for understanding why I'd like to keep going to school instead of "getting a real job."

To my co-workers, thanks for letting me vent.

ACKNOWLEDGEMENTS

I would like to sincerely thank all of those who were influential in helping me achieve this long standing goal- receiving my Doctor of Philosophy Degree. My committee chair, Alex Waigandt has been there every step of the way from the beginning of my Masters. He supported me and encouraged me to continue even though an incredibly hectic work schedule slowed my progress. My committee members Dr. Steven Osterlind, Dr. Rick McGuire, and Dr. Stephen Ball were all there with advice from many different perspectives to help my achieve my end goal. Dr. John Thyfault although not a member of my committee, has been unbelievably helpful in this endeavor being a leader, teacher, mentor and friend.

My boss, Pat Ivey has been incredibly understanding of the additional load, and has been a big part of helping me to finish my degree by giving me time away from the office to work and write.

ABSTRACT

For as long as there has been training, there has been a debate over which training means produced the greatest gains in strength. The gold standard of training has long been the Western Linear Periodization (LP) model of training. Most studies have been done looking at 12 week or longer periods, however in a collegiate athletic setting, 12 week periods are not available. This study compared a different type of training in the form of Autoregulation with the Autoregulatory Progressive Resistance Exercise (APRE) protocol in a 6 week

The athletes were grouped by year, the 2004 group performed the LP program and the 2005 group performed the APRE program. The athletes were tested on strength in the Bench Press, Squat, 225 Bench Press Repetitions Test and Hang Clean. The athletes were tested in power by the use of vertical jump converted to power by the Sayers power equation. Autoregulatory progressive resistance exercise (APRE) is a method by which athletes increase strength by progressing at their own pace based on daily and weekly variations in performance, unlike traditional linear periodization (LP), where there is a set increase in intensity from week to week. This study examined whether 6 weeks of APRE was more effective at improving strength and power than traditional LP in division 1 FBS college athletes. This study compares 57 division I FBS athletes using either the APRE (n = 31) or LP (n = 26) during six weeks of preseason training in 2 separate years. After 6 weeks of training, improvements

in total estimated 1 repetition maximum (1RM) bench press strength, estimated 1RM squat, estimated 1 RM hang clean, number of 225 bench press repetitions to failure test, and power as derived through the use of vertical jump and the Sayers power equation were found by using percentage difference scores. Also examined was the effect of somatotype of the athlete, which was determined by position, and if it played an effect on the ability to gain strength.

Analysis of variance (ANOVA) was used with a Tukey's HSD post hoc when necessary to determine differences between the groups. Statistical significance was accepted at $p \leq 0.05$. Autoregulatory progressive resistance exercise (APRE) demonstrated greater improvement in estimated 1RM bench press strength (APRE: 1.0507±.018 N vs LP: 1.0086±.021 N; $F(1)=5.421$, $p=.024$), estimated squat (APRE: 1.0880±.036 N vs LP: .9947±.041 N; $F(1)=9.299$, $p=.004$), estimated 1RM hang clean (APRE: 1.0927±.039 N vs LP: .9765±.044 N; $F(1)=10.384$, $p=.002$), estimated power (APRE: 1.0809±.050 N vs LP: .9758±.057 N; $F(1)=6.550$, $p=.014$). No Significant difference existed for the 225 bench press repetitions to failure test (APRE: 1.2927±.271 vs LP: 1.0605±.231; $F(1)=1.835$, $p=.182$). A significantly different value was found for somatotype on the squat ($F(2)=3.893$, $p=.027$) and a Tukey's HSD Post Hoc test was performed to find the difference, however an only near significant difference existed (p=.051) between the big position group and the middle position group.

The findings of this study indicate that the APRE was a more effective means of training than LP over a six week period for developing strength in the bench press, squat, hang clean and power development. No significant

difference existed for the 225 bench press repetitions to failure test, or differences in ability to gain strength between the groups.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter One

INTRODUCTION

The objective of this study is to compare two types of organizational programming, specifically the Autoregulatory Progressive Resistance Exercise (APRE) protocol and the Linear (or Western) Periodization. Specifically, this study will focus on how to best develop strength in athletes during the short-term off-season typical of college sports. By utilizing the most effective means of programming organization, an athletic team, such as an NCAA Division I football team, may gain a competitive edge over the opposition.

APRE Origins.

The Autoregulatory Progressive Resistance Exercise (APRE) originates from military surgeon Captain Thomas DeLorme's studies of femoral fracture rehabilitation (T. DeLorme, 1945). DeLorme's paper noted that a regimen of endurance exercises, such as bicycling, did not improve muscular strength and power. As a result, soldiers who returned to duty after surgery for bone and joint repairs were unable to handle normal activity for quite some time. In the 1940's study, investigators successfully added weight training exercises to rehabilitation in order to restore muscle size, strength and power (T. DeLorme, 1945). In the 1950's, DeLorme created a protocol for weight resistance training. The protocol consists of three sets of ten repetitions, increasing weight each set, followed by repetitions to failure during the third set. The subsequent session's weights are

based on the performance of the third set. The weight would either increase or decrease, respectively, for the next workout based on the performance of the third set (T. DeLorme, West, & Schriber, 1950). The authors noted that when weights were used specifically to strengthen legs, individuals were able to return to normal, active duty more quickly and with fewer problems than the contemporary protocol of casting and bone reformation. Strengthening protocol at the time consisted of leg extensions, performed by strapping weights to the bottom of the feet, as there were no leg extension machines yet. The researchers named this new method of training the Progressive Resistance Exercise method (PRE), but it is also referred to as the “DeLorme” method (Fish, Krabak, Johnson-Greene, & DeLateur, 2003).

In the 1970’s, Knight adapted the PRE to suit the needs of clients rehabilitating from various injuries and surgeries (Knight, 1979). This study maintained the 10 repetition basis and included an additional set to failure for a total of four sets. Knight also added an adjustment chart, which gave additional reproducibility. By determining the number of repetitions an individual completed during one session, the researchers would increase, decrease or maintain the same amount of weight for the subsequent sessions. For instance, if the individual completed15 repetitions, they would increase the following set by 10 pounds. In this modification of the PRE, the performance of the third set determined the weights for the fourth set, and the performance of the fourth set determined the weights for the following session. Knight named the changes to this method the Daily Adjustable Progressive Resistance Exercise (DAPRE)

protocol; researchers noted that this was an improvement on the PRE, but not an entirely new method.

In 1985, Knight further altered his DAPRE protocol (Knight, 1985). In this study, researchers adapted a six repetition protocol with the same theories. The first set was 10 repetitions at 50% of the previous session's adjusted weight. The second set was six repetitions at 75% of the previous session's adjusted weight. The third set consisted of repetitions to failure at the previous session's adjusted weight with a goal of performing around six repetitions. The fourth set consisted of repetitions to failure with a weight adjusted from the third set. Again, the goal was to perform around six repetitions. The results of this study indicated increases in strength incongruent with increases in muscle size. The researchers theorized that changes in neural pathways or muscular contractions overcoming neural inhibitors accounted for the improvement in strength following immobilization.

Mel Siff introduced the APRE in his text, *Supertraining* (Siff, 2000). The APRE retained Knight's 10 repetition and six repetition protocol and added the three repetition protocol. Siff retained Knight's adjustment charts for all three protocols. Trainers and doctors consider the 10 repetition protocol effective for hypertrophy, the six repetition protocol effective for strength and hypertrophy, and the three repetition protocol effective for strength and power.

Progressive Overload.

The "PR" in each of the acronyms PRE, DAPRE, and APRE stands for Progressive Resistance, which indicates that the protocols utilize Progressive

Overload. Arizona State researchers Herrick and Stone compared Progressive Overload with Periodization over a 15 week period (Herrick & Stone, 1996). Every three weeks, the researchers examined women's upper and lower body strength with the bench press and the parallel squat, respectively. They noticed no significant differences between the two groups in strength development, but noted that the Progressive Overload group leveled off at the end of the study, while the Periodized group continued gaining strength. They also noted that the Progressive Overload group increased strength more rapidly at the beginning of the study compared to both the end of the study and to the Periodized group during the same time frame.

Progressive Overload programs such as the PRE, DAPRE, APRE and others are based upon the Specific Adaptations to Imposed Demands (SAID) principle. By utilizing increasingly heavier weights, the body is forced to continuously adapt to supporting and lifting heavier loads. Using additional weight in successive training sessions increases muscle size by activating more motor units. The more active the motor units, the more the athlete increases cross bridges within the existing fibers. The result of these adaptations is an increase in strength, found by a repetition maximum. However, if the same loads are used in successive training sessions, no additional demand is placed on the body, so no further adaptations occur.

While the PRE, DAPRE, and APRE are random with regard to changes of volume and resistance, Western or Linear Periodization is not. Linear Periodization (LP) is a training plan in which individuals start at a lighter

percentage of a 1RM and increase intensity by a predetermined percentage while decreasing volume in a predetermined manner. The intensity moves up in a linear manner while the volume moves down in a linear manner.

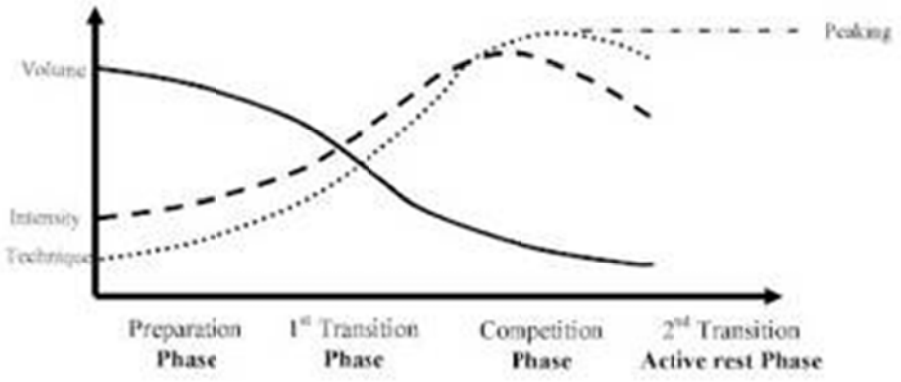

Figure 1 - Matveyey's Periodization Model

Linear Periodization.

Linear Periodization is based on Matveyev's model, Figure 1, in which intensity (weight) increases while volume (repetitions) decreases over time in a linear fashion (Baroga, 1988; National Strength & Conditioning Association, 2000; Siff, 2000). Matveyev's model delineated training into macro, meso and micro-cycles. Macrocycles, the largest division, may constitute one year of training, while mesocycles typically involve several weeks to several months of training. Microcycles range from one to four training weeks. Periodization is broken into five phases: 1) anatomical adaptation, 2) hypertrophy/endurance, 3) basic strength, 4) strength power and 5) peaking or competition. The anatomical adaptation phase uses low to no weight; its purpose is to correct imbalances from the previous season's activities. Successful completion of this phase

ensures that the athlete's muscles will fire properly for the subsequent phases. Hypertrophy is a lower intensity, higher volume phase used to improve endurance. The repetitions are typically 10 or higher, and the intensity ranges from 65-75% 1RM. The goal of the basic strength phase is to build absolute strength with submaximal weights. The intensity ranges from 75-85% 1RM, and the repetitions are lower, typically 4-8 per set. The strength-power phase is used to transition the strength built submaximally into recruitment for athletic activity. The strength-power phase intensity ranges from 85-100% 1RM and the repetitions are typically set from 1-3.

Currently, there are no studies that compare APRE and Linear Periodization. The purpose of this study is to determine if a new training protocol (APRE) is an effective alternative to the traditional method of training known as Western Linear Periodization in the context of short off-season training periods typical of University athletics.

Statement of the Problem.

The goal of this study is to determine the most effective training protocol for increasing maximal strength in short term (five to six week) periods. For strength and conditioning professionals, an off-season may consist of only six weeks. During this time, the coach's goal is to maximize strength. Strength gains are important because they may lead to performance enhancement and reduced injury risk (W. J. Kraemer et al., 2003). Previous studies on the effectiveness of Linear Periodization have defined a short term period as 12-16 weeks (Herrick & Stone, 1996). However, a Strength and Conditioning coach at

the University level often has only half this amount of time. Obviously, a shorter duration affects the capacity to meet the goal. No study has investigated how to maximize strength gains in the short term time period, a major challenge to University athletic programs.

In addition to being the first study to determine the best short term offseason protocol for maximizing strength, this is one of a handful of studies that investigate highly trained individuals, like Division I college football players. Most studies have examined and analyzed results for recreationally trained or untrained individuals (D. G. Baker & Newton, 2008; D. W. C. Baker, 1994; Buford, Rossi, Smith, & Warren, 2007; Byrd et al., 1999; Chiu et al., 2003; Rhea, Alvar, Ball, & Burkett, 2002). Results for highly trained individuals in any given physical test may different significantly from those for untrained individuals (Rhea, Alvar, & Burkett, 2002). Researchers have found, for instance, that while untrained individuals responded nearly the same to one set weight training routines as they did to multiple set weight training routines, trained individuals responded more positively to strength gains with the multiple set routines. Such conclusions support the practical application of this current study: to help determine the best protocol for highly trained athletes. Contributions to the field will be applicable to professionals training elite athletes in collegiate or professional sport organizations.

This is also the first study to look at the response of different somatotype groups to resistance training. No study has examined whether or not the various soma types, including endomorph, ectomorph, and mesomorph, are affected by

various types of resistance training programming. One previous study by Chaouchi (Chaouchi, 2005) examined variance in responses to aerobic training. There existed a significant difference in the results achieved in aerobic capacity and aerobic power across the somatotypes on the same training program (Chaouchi, 2005). The current study will determine whether or not a difference exists between the somatotype groups in relation to strength gains.

Hypothesis.

Both the APRE and the LP groups are expected to improve absolute strength on the squat, bench press, hang clean and 225 repetitions test. However, the APRE trained group will show greater gains in absolute strength compared to LP group following six weeks of training. The two programs will be compared by their influence on power, measured by the vertical jump, and their efficacy in increasing strength. Results will be categorized on a form of somatotype grouping; the subjects will be divided into big positions, mid positions and skill positions.

Basic Assumptions.

For the purposes of this study, it is assumed that 1) athletes will complete every exercise and repetition at the recommended weights and will perform every workout; 2) all athletes are in top condition during the duration of the study; 3) the athletes will put their best effort into every workout.

Delimitations.

The subjects of this study are Division I athletes in a pre-spring practice phase. They will weight train three days a week: Mondays, Wednesdays and

Fridays. On Tuesdays and Thursdays, the athletes perform the Winning Edge Program. Facilitated by the sport coaches, the Winning Edge program focuses on energy. It includes outside activities for skill improvement, such as route running, pass protection, coverage, pass rush, throwing and blocking. The Program consists of three stations: an agility station, where the athletes work on change of direction, a speed station, where the athletes work on top-end speed and a mat drill station.

Every Friday, the athletes will undergo various performance tests, which consist of the I-test, 3-Cone, Vertical Jump, Broad Jump, and the 40-yard dash. On weeks one and three, the athletes will perform a Vertical Jump and I-test. On weeks two and four, the athletes will perform the Broad Jump and 3-Cone. Every week, the athletes will perform a 40-yard dash. On week five, the athletes will choose the test they want to perform in an effort to improve their scores.

Limitations.

The subjects of this study are Division I athletes and, therefore, they are expected to have an exemplary work ethic. However, it is not possible to account for a particular individual's effort, which could impact results. The researcher has no control over how hard the athlete wants to work to improve their strength.

Moreover, energy spent on skill improvement cannot be transferred to strength improvement. The researcher has no control over training for sport skill outside of the experimental protocol. It is possible that such outside activities can lead to overuse and injury. Injuries are a common occurrence during off-season skill improvement, and it may confound the results of the study if an

athlete is not able to train or test an exercise for the study. If any athlete is not able to perform all of the tests, the entire data set for that individual will be eliminated.

One brief caveat about physical typing: most individuals are not properly characterized by only one somatotype. Instead, they are a combination of two somatotypes. Most athletes are the mesomorph in combination with either the ectomorph or endomorph. To simplify the somatotype combination possibilities for the purpose of this study, the athletes will be grouped by position.

Hypothesis.

Hypothesis 1: The APRE will show gains greater than the LP on the Bench Press.

Hypothesis 2: The APRE will show gains greater than the LP on the Squat.

Hypothesis 3: The APRE will show gains greater than the LP on the Hang Clean.

Hypothesis 4: The APRE will show gains greater than the LP on the 225 Bench Press repetitions test.

Hypothesis 5: The APRE will show gains greater than the LP in power.

Hypothesis 6: The APRE will show gains greater than the LP in the big and mid positions in the previously listed independent variables.

Significance of the Study.

Instead of testing average individuals, all of the subjects in this study are elite and highly trained athletes. In addition, this is the first study to compare the

APRE and LP programs, and the only one to consider the shortened off-season time period in University programs. The study also is the first to look at somatotypes and what influence programming has on the individuals' strength gains based on programming. Given these reasons, this study will contribute practical knowledge to the field of strength and conditioning.

Definition of Terms

Linear Periodization- Also known as Western Periodization. This is the training method in which the athlete starts at a lower intensity and higher volume. Each week, he or she works toward a higher intensity, lower volume at a set percentage. All weights, sets and repetitions are pre-determined.

Periodization- Simply, a training plan in which the work is categorized into established periods.

Glutes- Refers to the Gluteus Maximus, Medius, and Minimus muscles, collectively.

RM- Repetition maximum. The RM usually cites a number before it, which represents the weight one can do that number of repetitions, but not one more. For example, a 6RM is a weight you can perform six repetitions with, but not seven.

Autoregulatory- A system of self-governing weights, increases, repetitions and overall volume.

5 Points of Contact- Refers to the head, shoulders, hips, and both feet making contact with either the ground or the bench.

Chapter Two

REVIEW OF THE LITERATURE

Progressive Overload.

The Progressive Overload method is used to get the body to respond to increased stimulus, thereby increasing strength (National Strength & Conditioning Association, 2000). An athlete in a Progressive Overload program begins with a given weight and continues to increase progressively the weight he or she lifts, thereby eventually overloading the muscle system. Progressive Overload is based on the Specific Adaptations to Imposed Demands (SAID) principle (National Strength & Conditioning Association, 2000). This means that the body will adapt to whatever demand is imposed upon it. For instance, a construction worker required to swing a 20 pound sledge hammer will quickly get strong enough to swing exactly that set weight, but no more. If he used a 25 pound sledge hammer, even briefly, fatigue would quickly become a problem. Though the logic of this principle is widely accepted by sports professionals, which method to accomplish the goal of maximum strength capacity in a minimal time frame remains up for debate.

PRE.

The DeLorme method or the 3x10 Progressive Overload method is one of the first to explicitly employ theory in its development of practical applications (T. DeLorme, et al., 1950; T. DeLorme, West, F, Schriber, W, 1958). DeLorme

applied weight selection to improve knee extensor strength during rehabilitation for patients who suffered femoral fractures, primarily. Strengthening the musculature of the knee extensors is key in the rehabilitation process, due to the atrophy from prolonged immobilization. DeLorme also worked with patients to strengthen quadriceps. Quadriceps function as a braking muscle group. The stronger they are, the greater amount of force they can absorb, thereby lowering the likelihood of re-injury. Starting out light and working up to the heaviest set, each set would progress based on previous performance. The DeLorme method pioneered the partnership between strength training and rehabilitation.

DeLorme theorized, however, that in many instances, the initial 10RM did not reflect the individuals' actual strength capacity. He noted that it was not uncommon for one to double, or more than double, strength levels in one to two months. He felt that there were several factors that would not allow an individual to produce the force they were capable of, including an unwillingness to endure the discomfort accompanying momentary muscular failure or fear of injury.

DeLateur examined the DeLorme axiom: would high repetitions improve endurance and low repetitions improve strength? Are the two mutually exclusive in a rehabilitation setting? (DeLateur, Lehmann, & Fordyce, 1968). DeLateur's team studied four groups, total: two who trained only endurance in the form of high repetition protocols with a 25 pound weight, and two groups that worked strength only in the form of low repetition protocols with a 55 pound weight. Their evidence proved that either the strength protocol or the endurance protocol improved both strength and endurance. Therefore, the use of a specific protocol

does not determine success while in rehabilitation. Rather, muscle fatigue is the key to improve strength and endurance.

As with all practices, opposite philosophies co-exist. In direct contrast to DeLorme, the Oxford method evolved. By today's standards, the Oxford method would be known as reverse pyramid with descending sets. Using this method, the subject warms up, then complete the heaviest set first, decreasing weight with each subsequent set. For example, a rehabilitation patient may start lifting at the 10RM, followed by a second set with 75% of the initial 10RM, completing the third set with 50% of the 10RM. Researchers theorized that this plan would flow naturally with the way the human body responds to fatigue, while still taxing the muscles on each set.

In 2003, Fish tested the two methods to see which was best: DeLorme versus Oxford (Fish, et al., 2003). Fish compared methods with 60 healthy men and women over a nine week period. The study determined that both methods led to significant strength gains, but neither one was significantly better than the other. However, this particular study used a low power level, which may affect results. A power analysis revealed that they needed to use a total n=130 and n=65 in each group in order to determine the relative efficacy of each method. They also stated that further research would be needed on gender specific gains.

In weight training, whether Olympic weightlifting, powerlifting or bodybuilding, there is a common misconception: if some is good, more is better. This faulty logic often leads to overtraining.

Single Sets vs Multiple Sets.

The High Intensity method, also known as the 1-set or single set protocol, gained popularity in athletic training through bodybuilder Mike Mentzer. Accomplishing one single heavy set to failure stimulated magnificent gains for Mentzer. The “training to failure” model has been found to elicit significant strength gains among strength training athletes (Braith & Beck, 2008; Drinkwater et al., 2005). Ajan and Baroga stated that when done properly, training to the limit (meaning failure) increases the thickness of the myelin on the nerve. When the myelin cells are stimulated, they stimulate oligodendrocite cells, which, in turn, increase myelin production, thereby adding myelin mass to the cell. Each repetition must be performed with the exact same technique to replicate results.

When individuals switch to a single set from multiple sets at heavy weights, would find experience strength gains within the first few weeks. This initial evidence led some to suggest single set training was superior. In reality, however, most athletes who used this system became overtrained. Reduced volume promotes supercompensation: the reason they experienced significant gains. Ultimately, however, studies generally indicate that multiple sets are more successful in accomplishing long-term strength gains in part because single sets did not stimulate a training response over time. (Byrd, et al., 1999; Rhea, Alvar, & Burkett, 2002; Schlumberger, Stec, & Schmidtbleicher, 2001; Wolfe, LeMura, & Cole, 2004). The significance of this discovery is understanding that it is not necessarily *which* program to use, but *when* to apply each one to accomplish a particular training goal.

Some researchers use a biodex to test knee extensor strength (Kelly et al., 2007) when training single versus multiple sets with a neutral control group. The biodex is a isokinetic trainer used to develop maximal force on each repetition. The study examined dose/response relationship in weight training and thus did not equate volume among the groups. Multiple sets resulted in the greatest gains. Peak power did not change from the single set group to the control group. Surprisingly, the single set group did not experience a significant increase in strength at all.

Rhea (Rhea, Alvar, Ball, et al., 2002) compared single versus multiple sets using a Daily Undulating Periodization Program. The RM varied by workout, but the single and multiple set would remain set. Again, multiple sets were more effective than single sets. In 2002, Rhea conducted a meta-analysis, examining the entire research data on single set and multiple set studies (Rhea, Alvar, & Burkett, 2002) which confirmed that the multiple set workouts were far better than single set workouts at producing strength gains over time. Interestingly, Rhea found that trained individuals displayed an even greater difference between gains compared to untrained individuals. There are two potential reasons. First, untrained individuals may experience significant improvements in strength rather quickly from neural adaptations, as mentioned earlier. Second, Fleck and Kraemer theorized that as an individual becomes more accustomed to weight training, he or she will need a greater volume to elicit a strength training response. Furthermore, Baroga notes that when the athletes become more highly trained, increasing volume to stimulate gains becomes even more

important. (Baroga, 1988; Siff, 2000). In short, however, multiple sets with progressive weight levels creates the best results overall.

One reason why some groups would experience equal gains in strength is that researchers equated volumes for single and multiple sets (D. W. C. Baker, 1994; Ostrowski, 1997). This would seem to negate the effect of performing the multiple sets, since the reason for doing so is to have an increased training volume to create a training effect. If the volume is taken away from the multiple set training protocol, the reason for its use is taken away, thus eliminating its effectiveness.

Kraemer studied female college tennis players at Ball State University (W. J. Kraemer et al., 2000), comparing the results of a control group who did no weight training, a group who used periodized weight training and a group who completed single set weight training. This long-term study was performed over nine months with four total tests: a pre-test, then at months 4, 6, and 9. Over the course of the nine months, there was no significant changes in body mass for any group. However, there was a favorable change in body composition for the periodized group at each of the testing periods.

In his classic study from 1963, Berger compared three types of weight training programs in relation to the bench press. 48 college students were divided into three equal groups and trained three times a week for nine weeks. Group One trained by 6x2RM, Group 2 trained by 3x6RM, and Group three trained by 3x10RM. The initial results were very close, with no appreciable differences among the three groups. All three groups showed significant

improvements in 1RM strength beyond the p<.001 level. The mean increase for all groups was 24.44lbs over nine weeks. An ANCOVA showed no significant differences between group means after nine weeks. The investigator concluded that for this time span, it was not more effective to perform heavy versus lighter loads to increase strength.

In 1962, Berger conducted a study with nine different comparisons. Experimenters worked with 177 freshmen and sophomore male college students who trained in weight lifting classes with a set program every Monday, Wednesday and Friday. The groups were initially broken into sets --I, II, and III -- and into sub groups: I-2, I-6, I-10, II-2, II-6, II-10, III-2, III-6 and III-10. The groups were tested initially and then again at weeks three, six, nine and 12. The study determined whether strength would develop more quickly with fewer repetitions at heavier loads or with more repetitions at lighter loads, as well as whether fewer or more sets were better. Subjects were not told the weight on the bar until after the test was completed to prevent the subsequent scores from being influenced by the knowledge of the previous test. Investigators determined that III-6, or 3 sets at 6RM, was the most effective at increasing strength. Training at loads lighter or heavier did not result in similar gains.

Weight training in Athletics.

Weight training in athletics did not become popular until the 1970's. Some coaches mistakenly assumed that greater strength would make athletes slow and muscle-bound. Beliefs like this stifled progress for athletes who pursued weight

training in order to improve athletic performance. Athletes were not able to train in top-notch facilities like they can today.

Through his text, “The Strongest Shall Survive,” Bill Starr inspired the way athletes strengthened and conditioned their bodies (Starr, 1976). Starr was credited for developing the 5x5 method, a simple Progressive Overload plan in which athlete performs five sets of five repetitions with a given weight. If he or she could perform all sets of in all repetitions, the athlete moved up in weight the next week. Bill Starr was one of the first full time strength coaches who worked with national, international and Olympic teams. He wrote numerous articles and books on the topic of strength and conditioning over the span of his influential career.

The first time that strength and conditioning programs became recognized as a factor in achieving athletic success was in the 1970’s at the University of Nebraska. Boyd Epley founded the National Strength & Conditioning Association (NSCA) in 1978 while employed as the Head Strength Coach at Nebraska. His staff’s work in the field advanced weightlifting from Starr’s 5x5 program. Known as “Husker Power,” the program was not only effective, but simple enough for mass replication. Epley’s program ended up in many high schools and small colleges in the nation.

The strength and conditioning program at the University of Nebraska has an interesting story. Epley was a senior pole vaulter who had a back injury that prevented him from competition. He would go to the weight room several times a week to perform exercises to speed his rehabilitation. Other injured athletes who

did not know what they were doing started following Epley, copying his routine. One day, Epley received a call from then Assistant Football Coach, Dr. Tom Osborne. Osborne noticed that the injured athletes who had lifted with Epley returned faster and were able to jump higher. He asked Epley to help with other athletes, and the professional collaboration was born.

Under Epley's guidance, The University of Nebraska football team produced dominant athletes, proving the value of a formal strength and conditioning program . This was the first program that actually endeavored to develop athletes, rather relying on talent alone. By becoming larger, stronger and more explosive than whatever team they faced, the Huskers dominated the opposition. Even their offense fed into this mentality; the option offense is a grueling run-over, around and through the opponent. With larger, stronger, faster, more explosive athletes, they could endure four quarters, every game, all season long.

In "Husker Power," athletes rotate exercises and repetitions to prevent adaptation while using a Progressive Overload to account for strength gains. In the first four years after the inception of the Strength and Conditioning program, Coach Devaney's record was 42-4. Other coaches started to take notice.

This evolution of one school led to the evolution of an entire field. Weight training was no longer intended solely for rehabilitation, it also helped prevent injury and improve performance. With the founding of the NSCA, researchers began to examine the improvement of performance as well as stabilization for injury prevention. For example, Kraemer examined how training affects tennis

players (W. J. Kraemer, et al., 2000). Kraemer's team compared no training, single set training, and Periodized training over a nine month period and evaluated the training effectiveness by an increase in serve speed at months four, six, and nine. Neither the control group nor the single set group experienced an increase in velocity at any of the testing periods. The Periodized athletes, however, experienced increases in velocity at each of the testing periods. This is important because they showed that by gaining strength and power through weight training, they improved their sporting form. Kraemer stated in this study that resistance training is one of the primary conditioning modalities effective in mediating neuromuscular adaptations. Consequently, this type of training helps prevent injury and improve performance.

Even more specific to this study is the work done by Moore and Fry (Moore & Fry, 2007) at the University of Memphis. The authors examined what happens to the athletes over the course of an off/spring season period. They divided the off/spring season into three phases: 1) weight training only; 2) weightlifting and winter conditioning; 3) practices and scrimmages, with a reduced weightlifting load. Hormonal levels as well as maximal strength were checked during each phase. During the first phase, researchers discovered a great increase in maximal strength for all lifts, as well as improvement in agility and the vertical jump. The first phase also marked a decrease in sprinting speed, which returned to baseline by the end of the third phase. During the second phase, there was a decrease in squat strength that, again, returned to the previous baseline numbers by the end of phase three. All baseline numbers

were established before the training period began. In every case, the gains of phase one were lost with additional strength losses in phase two, while the player to return to baseline in phase three. Vertical jump scores remained at elevated levels throughout the course of the study.

Testosterone and cortisol levels were measured as indicators of overtraining. Testosterone levels decreased during phase two and returned to baseline by phase three. The ratio of testosterone to cortisol never changed, however. Since the body goes into a state of catabolism when overtrained, it has been postulated that the presence of heightened catabolic hormones could indicate overtraining before other problems present. If this is the case, cortisol would rise above the normal ratio of testosterone to cortisol. However, Fry has noted in presentations and personal communications that individual variance in hormonal levels makes reading them as a marker for overtraining difficult. Instead, the athlete's mood state is the best indicator for overtraining. The authors' question then becomes is it too late to do anything about overtraining once the mood state is affected significantly? Is it possible to reduce the volume at that point to prevent damage and reverse problems? Clearly, this indicates the necessity for the strength coach and the sport coach to coordinate their efforts closely in order to help prevent the athlete from overtraining while still maintaining maximum strength and power.

Types of Periodization.

A study by Buford equated volume and intensity for three different types of periodization over a nine week training cycle. Periodization refers to the way a

training program is organized. A linear periodization indicates that one moves from trait to trait and increases by a predetermined amount of intensity from week to week. This standard form of training in the western world is an adaptation of Matveyeev's system developed in the Soviet Union during the 1950's. (National Strength & Conditioning Association, 2000) Buford's team compared Standard Linear Periodization with Daily Undulating Periodization, which changes intensities daily and Weekly Undulating Periodization, which changes intensities weekly. Buford (Buford, et al., 2007) found that all training protocols worked, but none worked significantly better than the other.

Most research indicates that virtually any training protocol will work for a beginning weight lifter. Neurological adaptations will be significant in the novice, as he or she will gain strength rapidly with very little increase in muscle size. The efficiency of the movement pattern performed by the individual will lead to significant improvements, even with the absence of hypertrophy. (Hakkinen, Kallinen, Komi, & Kauhanen, 1991).

Interestingly, Buford's study included women, which is quite uncommon. They noted that there were significant increases in leg circumference from the first to the second period, but not second to the third period. Alternatively, chest circumferences increased from the second to the third period p, but not the first to the second period. This delay in chest circumference size until the second period could be attributed to the lack of testosterone and less upper body strength in women. Therefore, it takes female subjects longer to experience hypertrophy and increase strength.

A previous study by Rhea (Rhea, Ball, Phillips, & Burkett, 2002) compared a Daily Undulating Periodization Program to a Linear Periodization Program with equated volumes. Researchers divided 20 male subjects into two groups: one DUP, the other LP. Over the course of 12 weeks, three strength tests were recorded for both the Bench Press and the Leg Press. For each test, the DUP group gained significantly more strength. By the third testing period, the LP group started to show improvements, but the DUP was still significantly better. While longer test periods may alter results, for short-term periods, DUP is the best method. Short-term training is part of the challenge when training athletes in the college setting. Therefore, training protocols should be selected based on short term gain rather than long term gain.

Progressive Overload (Piercy, 1959) refers to a system of training in which one increases weight progressively, based on the previous week's training. There is no predetermined percentage by which an athlete is expected to increase. Often, in fact, an athlete will perform repetitions to failure on an exercise; weight will be adjusted accordingly. Robb Rogers, a former head strength coach currently at the National Strength & Conditioning Associations (NSCA) Tactical Strength & Conditioning Center, reported that strength generally increases from week to week (Rogers, 2003). Periodized training takes advantage of that fact, thereby maximizing gains.

Herrick and Stone tested the efficacy of Periodized and Progressive Overload over a longer time span: 16 weeks. (Herrick and Stone, 1996). They compared 20 females total: one group of 10 in a Periodized program and the

other group of 10 in a Progressive Overload program. Researchers found that neither group proved better than the other. The study did indicate, however, that Progressive Overload resulted in a rapid increase of strength that leveled off near the end of the study. Perhaps Progressive Overload is most effective in short term training cycles.

A Progressive Overload program is periodized in that it incorporates planned periods in which the athlete attempts to increase in weight by week, improving absolute overall strength. It is not linear in that there are no set increases; the athlete increases strength at their own rate. In a meta-analysis of Periodized versus Non-Periodized programs, Rhea and Aldermann discovered that the former produces greater results than the latter (Rhea & Alderman, 2004). This research proves Joe Kenn's famous quip: "If you fail to plan, you plan to fail." (Kenn, 2003)

The NSCA promoted a whole new body of research in the area of performance enhancement. There are many studies that now look at the influence of different strength training programs on athletic activity as well as how athletes and the professionals who work with them can incorporate injury prevention within the training process. Specifically, researchers note that females and males sustain different kinds of injuries, typically. The female overhead activity athletes have a more unstable shoulder than males, for example. Overhead activity refers to a throwing athlete in the field events: softball, volleyball and tennis. Knowing the risk from instability, trainers can

focus work on different muscles around the shoulder in female athletes who throw.

A recent study done by Niederbracht at Indiana University of Pennsylvania looked at the effects of a shoulder injury prevention strength training program on eccentric external rotator muscle strength and glenohumeral joint imbalance in female overhead activities (Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008). The study examined various muscles of the rotator cuff, some of which eccentrically active, while others are concentrically active. Therefore, there are two distinct activities operative within a muscle group with one function: to rotate the gleno-humeral joint. In 1992, Chandler hypothesized that a simple increase in the strength of the muscles would proportionally decrease the risk of injury (Chandler, Kibler, Stracener, Ziegler, & Pace, 1992). This however, did not work; the incidence of shoulder injury did not decrease. This failure inspired Niederbracht's and subsequent studies.

Concentric and eccentric contractions vary. A concentric contraction occurs, according to the sliding filament theory, as the myelin and actin slide across one another. They are moved by cross bridges which grab and pull them forward. The eccentric contraction occurs in the reverse. Instead of the cross bridges pulling in one direction, they are broken and, in essence, they re-grab the filament. The eccentric contractions function to absorb force, whereas the concentric contractions function to produce force.

Eccentric strength, or yielding strength, as it is referred to in the Secrets of Soviets Sport Fitness (Yessis, 1987), is a vital element of deceleration and force

absorption in movement. The training of the eccentric portion of the exercise could be likened to putting better brakes on the car. It allows the car to stop more quickly and safely. In contrast, the training of the concentric portion of the exercise could be likened to putting a bigger motor and transmission in the car. It generates more horsepower, which leads to greater speed. So in essence, what the previous studies did only further exacerbated injuries. It gave a bigger motor and more horsepower to a joint that needed brakes. Niederbacher's work attempted to train the athlete to maintain motor speed while improving brakes, metaphorically. The improvement of the brakes will better improve shoulder health and decrease the risk of injuries.

A study by Mangine looked at the effects of combined ballistic and heavy resistance training on maximal lower and upper body strength in recreationally trained men (Mangine et al., 2008). This type of training was outlined by Mel Siff in his book *Supertraining* (Siff, 2000) as the Complex Method, in which one combines a speed and a strength exercise. This was found to have a positive effect on the improvement of both speed and strength in athletes. The study compared heavy resistance training to the combined group. They were compared on 1RM Squat, Bench Press, Lean Body Mass, Body Fat Percentage and Peak Power for a ballistic pushup and a jump squat on a force plate. For Lean Body Mass and Body Fat Percentage, both groups experienced an increase in lean body mass and a decrease in body fat. There was a significant increase in strength for both groups on the 1RM Squat, but neither group was significantly better than the other. However, on the 1RM Bench Press, the

combined group had a much greater increase what was observed in the heavy resistance only group. A significant increase in average jump squat power did occur for the combined group (+478W), while the heavy resistance group actually experienced a reduced ability to produce power (-397W). It should be noted that the strength gains were equal, with no significant difference. However, it is obvious that power greatly increases with the ballistic combination.

Rate of Force Development.

In athletics, one only has a short time to demonstrate an amount of force. According to Kramer, in most team sports, an athlete has 400ms to produce the type of force required for athletic movement. Any force that is generated beyond that most likely will not be used in sport. In essence, if an athlete is extremely strong but has not trained any capabilities dealing with Rate of Force Development (RFD), he or she will not be able to impart their full amount of force on the performance event. In reality, an athlete who has a lower absolute strength but is more explosive may be able to demonstrate more power in an athletic event.

Consider this extended excerpt from *Science of Sports Training*:

"There are two athletes (athlete A and athlete B) who are shot putters. Athlete A can bench press 650lbs and athlete B can bench press only 500lbs. At the 400ms mark, athlete A has imparted 375lbs of force on the shot while athlete B, who has a weaker bench press, has imparted 425lbs of force on the shot. Athlete B has imparted more force onto the shot and demonstrated greater amounts of power while he is weaker. This is because athlete A could not

generate the force in the time necessary to impart the force on the shot. Athlete A could continue producing force long past athlete B, but the force is lost on the shot" (Kurz, 2001). In short: an improvement in absolute strength does not always translate into an increase in power.

Multiple sets are more effective than single sets, and one must lift progressively heavier weights through some planned method in order to maximize strength gains. Therefore, one must seriously reconsider Linear Periodization as the standard training protocol. This study will examine the merits of the Autoregulatory Progressive Resistance Exercise (APRE) Protocol as an alternative.

Somatotype.

One study has been done to compare differences in trainability based on somatotype (Chaouchi, 2005). The study was done by using 24 North Africans, 21 years of age (+/- 1.3 years) and separated into 4 groups: endo-mesorphs, ecto-mesomorphs, mesomorphs and ectomorphs. They used a pre/posttest design and trained for 12 weeks based upon their individual VO2 Max. Upon the retest, the results were compared to the pretest numbers and between the groups using a Two-Way ANOVA. The results found that there was a significant difference in the amounts of aerobic capacity gained between the groups; the mesomorphs and ecto-mesomorphs showed the greatest gains.

DAPRE.

The APRE is the product of minor changes to DeLorme's original PRE method. The PRE did not account for individual variances in strength gains, as it

recommended a 4.5kg increase per week. Kenneth Knight devised the Daily Adjustable Progressive Resistive Exercise (DAPRE) to take into account how individuals increase in strength on a daily basis at an individual rate (Knight, 1979). This allows the individual to work consistently at their optimal level throughout training.

Where the PRE used three sets, the DAPRE used four sets. The DAPRE started out the same as the PRE with the 50% 10RM, 75%10RM and 10RM. The difference with the DAPRE is that the repetitions achieved in the third set are used to determine the weight of the fourth set. The repetitions at the given weight of the fourth set were used to determine the 10RM for the following workout. The advantage of this was if the estimated weight was too low or high for the third set, the individual should have this corrected or nearly corrected by the fourth set.

Knight did not view his DAPRE as an opponent to the PRE in the rehabilitation, but an improvement upon the PRE. The practitioner could now know better where the individual should be in order to ensure that they are training at their individual optimal state. In 1985, Knight did a study dealing with 21 males who had gone through a reparative surgery for a collateral ligament or meniscus tear and had been immobilized for three to six weeks. Additionally, there were 13 subjects who had no surgery, but were immobilized for three weeks due to similar complaints. In this study, he determined that the optimal weight would be a 6RM -- as opposed to a 10RM which was previously advocated -- with the same format as before. The adjustment chart let one know

how much to move up or down from the third to fourth set and from the fourth set to the following week.

According to the results of the study, the surgically repaired group had an increase of strength on the injured limb of 141% from the first day to the last day. They also performed the exercises on the non-injured leg; it had an increase of strength of 69%. This indicates that this is a good method for increasing strength generally, not just for rehabilitative purposes.

Chapter Three

METHODS

Purpose.

The purpose of this study was to examine the effectiveness of the Autoregulatory Progressive Resistance Exercise (APRE) protocol compared to traditional Linear Periodization (LP). To test for changes in absolute strength, athletes established a baseline level for the squat, the hang clean and the bench press. These measurements were compared after four and five weeks of training. Changes in power were measured by the vertical jump test.

Subjects.

The subjects were 57 first and second year NCAA Division I football players at a BCS Conference University. They were recruited because of their training experience as a Division I athlete. The data analyzed is archival, which was collected for non-research purposes. The data was used solely to track athletes' progress, allowing coaches to determine any necessary changes in the program for the following training cycles. The subjects were tested as a part of their normal off-season workout routine. The groups were divided by year; the 2005 group performed the LP protocol and the 2006 group performed the APRE protocol.

Collection of Data

Training Protocol.

The APRE and LP groups performed the same exercises once per week. Both groups performed a barbell bench press, a dumb bell bench press and the 225 multiple repetition bench press (225). For the lower body strength training, both groups performed the squat, the front squat, step-ups, lunges, glute hamstring raises and Romanian deadlifts. The LP group increased intensity from 70% to 85% of 1RM over the course of the cycle. The APRE group performed the APRE 6RM protocol with the appropriate daily and weekly adjustments to their training resistance. See Appendix A: Protocol and Adjustment Table.

Autoregulatory Progressive Resistance Exercise Protocols.

The 6RM APRE program was implemented for the hang clean, bench press and squat exercises. During set one, subjects performed 10 repetitions at 50% of the anticipated 6RM. Since the athletes returned to training after a discretionary period, they started out at 75% of their previous 1RM to ensure that they were able to achieve the repetitions in the first workout. Subjects then performed 6 repetitions at 75% of the anticipated 6RM for set two. Finally, for set three, subjects performed repetition to failure, using 100% of the anticipated 6RM. The weight utilized during set four was based on the performance during set three using an adjustment table. During set four, repetitions were performed until failure. The number of repetitions and load utilized in set four were used to determine the initial resistance for the following week's training (Appendix A).

Consider an athlete who has an estimated 6RM of 300lbs. Set one would consist of 10 repetitions at 150lbs (50%). The second set would consist of six repetitions at 225lbs (75%), and the third set would consist of repetitions to failure at 300lbs. An adjustment table (Appendix A) was used to determine the amount of weight for set four. The weight used for set four and the completed number of repetitions was used to determine the estimated 6RM base weight for the next workout (Appendix A). Exercises in this study included the squat, hang clean and bench press. Coaches prescribed all other exercises, sets and repetitions. For the squat, the group performed the APRE 6 protocol during weeks one through four. They were assessed during week five. For the hang clean, the group did the APRE 3 protocol for weeks one through five, with an assessment during week six. For the bench press, the group performed the APRE 6 protocol for weeks one through five, with the assessment during week six.

Linear Periodization Protocols.

The LP group began their resistance training protocol with three sets of eight repetitions at 70% of the previously tested 1RM. Each week, LP subjects increased weight while decreasing repetitions using three tests: the squat, the hang clean and the bench press. By the end of the program, participants completed four sets of five repetitions at 85% 1RM. Specifically for the squat, week one consisted of three sets of eight reps at 70% 1RM; week two consisted of four sets of six reps at 75% 1RM; week three consisted of four sets of five reps

at 80% 1RM; week four consisted of four sets of five reps at 85% 1RM; week five was the assessment.

For the bench press, week one consisted of three sets of eight reps at 70% 1RM; week two consisted of four sets of six reps at 75% 1RM; week three consisted of four sets of five reps at 80%1RM; week four consisted of four sets of five reps at 82%1RM; week five consisted of four sets of five reps at 85%1RM. The assessment was performed during week six.

Instrumentation.

According to the National Strength and Conditioning Association, absolute strength can be determined in two ways: by the use of a 1RM and by the conversion of a repetition maximum. A one repetition maximum is the greatest amount of weight that can be lifted one time (a single repetition), but not two times. If the weight can be lifted for two or more repetitions, then more weight needs to be added to the bar. The second measure of absolute strength is obtained by a multiple repetition maximum and converting it to an estimated 1RM. Multiple repetition maxes have been considered a good way to assess strength and reduce the risk of injury (National Strength & Conditioning Association, 2000). A repetition maximum is a set number beyond which the athlete cannot lift (National Strength & Conditioning Association, 2000). For instance, a 5RM is a weight that can be performed for five repetitions, not six. If six repetitions was achieved, then more weight should be added and the test reattempted.

While the 1RM is the most accurate measurement standard, breakdowns in form often occurs during the 1RM, and there is a greater risk of injury due to the greater amount of weight on the bar. The multiple repetition maximum, on the other hand, uses a lower weight, thereby decreasing risk of injury. Due to this safety concern, coaches chose to estimate the 1RM from a multiple repetition maximum conversion. According to the guidelines put forth by the NSCA in its book, *The Essentials of Strength and Conditioning*, anything less than 10 repetitions is an accurate assessment of an estimated 1RM. This study will examine no more than a 5RM, well within the parameters for validity. The instrument used in the study was NSCA's 1RM chart, which sets 85% as the 5RM equivalent. Therefore, the weight would be divided by .85 in order to find the estimated 1RM. The conversion percentage is as follows: four repetitions is 90%; three repetitions is 92%; two repetitions is 97% ; one repetition is 100% (Appendix B).

Data Treatment.

Data was collected by the Strength and Conditioning staff at the University of Missouri. Each of the five tests -- the squat, bench press, 225, vertical jump, and hang clean -- are dependent variables (DV). Percentage difference scores were used to account for the changes in the estimated 1RM. If data was missing, it was replaced by the mean value of the group for that category. After the data was transformed and replaced, it met all of the four major assumptions: linearity, homoscedascity, normality and independence of observation. Skew, Kurtosis, Q-

Q plots, historgrams and Levene's test were used to ensure normality for the ANOVA. No significant differences were found between the groups at baseline.

Squat.

The Squat Maximum was an estimated 1RM based on five or fewer repetitions to failure. Squat Depth is determined by descending to the point where the hip joint becomes even with the knee joint and returning to a standing position. A coach gives a verbal command of "up" when appropriate depth is reached. If proper depth is not achieved, then no up call is given, and the repetition does not count. The 1 RM was estimated from Appendix B.

Bench Press.

Maximal Bench Press was calculated from an estimated 1RM based on five or fewer repetitions to failure. In order for the repetition to count, the athlete must successfully start the lift from full arm extension, then touch his chest with the bar, and then return the bar to full arm extension; the athlete's glutes must also remain in contact with the bench during the entire repetition. Repetitions that did not meet these two qualifications did not count in the final score.

University of Missouri 225 Bench Press Test.

The 225lbs Bench Press Repetitions Test was done by determining the number of repetitions that 225lbs could be successfully completed. Trainers used the same protocol to measure a successful repetition: full extension and gluteal contact. The athlete followed a specified warm-up progression, based on their 5RM Personal Record Bench Press. With a spotter in position and a coach present, the athlete attempted to barbell bench press 225lbs as many times as

possible. The 225 test has been validated by a 2002 study as a predictor of upper body strength when using either the Chapman or Mayhew equations. (Mayhew, 2002).

Hang Clean.

The Hang Clean was tested by performing repetitions with optimal form for up to five repetitions and a 1RM was estimated from Appendix B. The athlete was required to stand up to complete each repetition, which demonstrated control over the bar.

Power.

Power was calculated through the vertical jump and bodyweight using the Sayers equation (Sayers SP, 1999).

Somatotype.

Somatotype was categorized by position into the big, mid and skill positions. The big positions consist of the offensive and defensive line positions. The mid positions consist of tight ends, line backers and quarterbacks. The skill positions consist of wide receivers, safeties, cornerbacks and running backs.

Profile of the subjects.

The subjects are 18-21 year old male Division 1-FBS athletes in a college football program. Each athlete is approximately 70 to 160kg in bodyweight, as determined during the testing period. The subjects received formal training in technique on all exercises by individuals who have obtained either the Certified Strength and Conditioning Specialist (CSCS) or the Strength and Conditioning Coach for College (SCCC) certification.

Reliability and Validity.

Inconsistencies in form or technique that result from fatigue or poor work ethic would naturally decrease the reliability and validity of the study. To eliminate the confounding effect of fatigue, any observed break down in form or weightlifting technique will result in a cessation of the set. Moreover, any alteration of time of day can interfere with the results. To account for this, the athletes lifted at the same time every day for pre and post measures. For example, if the athlete lifted at 1:30 for baseline testing, they always lifted at 1:30 for follow up testing. To ensure that all exercises are performed with correct and congruent technique, only individuals with certifications of either the Certified Strength and Conditioning Specialist (CSCS) or Strength and Conditioning Coach for College Certified (SCCC) monitored sets. These same coaches were used to determine maxes as well as to count repetitions on a daily basis. The coaches were instructed to give similar level of encouragement to all athletes.

The squat, bench press and hang clean are inherently valid; researchers use them to determine upper body strength (bench press), lower body strength (the squat), and total body explosive strength (the hang clean). Tests were performed once per week with the exception of the squat in week six, which was not performed at all.

Statistical Analysis.

Q-Q plots as well as Z-scores will be used to identify outliers in the data. A 1-way ANOVA was used to determine the variance between the two types of programming for each independent variable.

Hypothesis.

Hypothesis 1: The APRE will show gains greater than the LP on the Bench Press.

Hypothesis 2: The APRE will show gains greater than the LP on the Squat.

Hypothesis 3: The APRE will show gains greater than the LP on the Hang Clean.

Hypothesis 4: The APRE will show gains greater than the LP on the 225 Bench Press repetitions test.

Hypothesis 5: The APRE will show gains greater than the LP in power.

Hypothesis 6: The APRE will show gains greater than the LP in the big and mid positions in the previously listed independent variables.

Testing.

There were no pre-testing or baseline measures taken prior the initiation of the APRE and LP programs during the off-season, as this was not standard practice of the football program at the time. Rather, post-training strength values obtained at the end of the pre-season in July will be compared to strength values obtained at the conclusion of the previous off-season training cycle in March.

The APRE group performed the APRE6 protocol: 1) Subjects performed 10 repetitions at 50% of the anticipated 6RM; 2) subjects performed 6 repetitions at 75% of the anticipated 6RM; 3) subjects performed repetitions to failure, using 100% of the anticipated 6RM; 4) subjects performed repetitions to failure again, using weight calculated from the previous set. A chart with the APRE protocols and adjustment calculations is listed as Appendix A

Chapter Four

PRESENTATION OF FINDINGS

Purpose.

The purpose of this study is to examine the effectiveness of the Autoregulatory Progressive Resistance Exercise (APRE) protocol compared to traditional Linear Periodization (LP). Specifically, changes in absolute strength were compared after four weeks of training for the squat and five weeks of training for the hang clean and bench press. Changes in power were measured by the vertical jump.

Subjects.

The subjects were 57 first and second year NCAA Division I football players at a BCS Conference university. They were recruited because of their training experience as a Division I athlete. The data analyzed is archival, solely collected to track athletes' progress. The subjects were tested as a part of their normal off-season workout routine. The groups were divided by year. The 2005 group performed the LP protocol (N=25), and the 2006 group performed the APRE protocol (N=32). All missing data was replaced using the series mean. There were no significant differences between the programs at baseline.

Descriptive Data.

Continued breakdown of the data will be shared in this section. The differences in the change scores of both the APRE and LP groups are compared

on all variables. This information will allow the researcher to determine which type of programming is most effective over the duration of the study.

Dependent Variable:SMEAN(Bench)

Year	Group		Mean	Std. Error	95% Confidence Interval		Marginal Mean
					Lower Bound	Upper Bound	
LP		1.00	1.004	.018	.967	1.041	1.0086
	Dimension2	2.00	1.008	.023	.962	1.054	
		3.00	1.016	.023	.970	1.062	
APRE		1.00	1.068	.018	1.032	1.105	1.0507
	dimension2	2.00	1.027	.019	.988	1.065	
		3.00	1.049	.019	1.010	1.087	

Figure 2 Means and Marginal Means Bench Press

Figure 3 reports the means and marginal means for the Squat.

Dependent Variable:SMEAN(Squat)

year	Group		Mean	Std. Error	95% Confidence Interval		Marginal Mean
					Lower Bound	Upper Bound	
LP		1.00	1.019	.035	.948	1.089	.9947
	Dimension2	2.00	.961	.044	.873	1.049	
		3.00	.991	.044	.903	1.079	
APRE		1.00	1.175	.035	1.105	1.246	1.0880
	Dimension2	2.00	1.039	.037	.965	1.113	
		3.00	1.045	.037	.971	1.119	

Figure 3 Squat Means and Marginal Means

Figure 4 reports the means and marginal means for the Hang Clean.

Dependent Variable:SMEAN(Clean)

year	Group	Mean	Std. Error	95% Confidence Interval		Marginal Mean
				Lower Bound	Upper Bound	
LP	1.00	.982	.038	.907	1.058	.9765
	Dimension22.00	.958	.047	.864	1.053	
	3.00	.986	.047	.892	1.081	
APRE	1.00	1.128	.038	1.053	1.203	1.0927
	dimension2 2.00	1.041	.039	.962	1.120	
	3.00	1.085	.039	1.006	1.164	

Figure 4 Means and Marginal Means hang clean

Figure 5 reports the means and marginal means for the 225lb Bench Press Repetitions Test.

Dependent Variable:SMEAN(BP225)

Year	Group		Mean	Std. Error	95% Confidence Interval		Marginal Mean
					Lower Bound	Upper Bound	
LP		1.00	1.142	.198	.745	1.539	1.0605
	Dimension2	2.00	.976	.248	.479	1.474	
		3.00	1.017	.248	.519	1.515	
APRE		1.00	1.090	.198	.693	1.487	1.2927
	dimension2	2.00	1.043	.207	.626	1.460	
		3.00	1.728	.207	1.311	2.144	

Figure 5 Means and Marginal Means 225 bench press repetitions test

Figure 6 reports the means and marginal means for power.

Dependent Variable:SMEAN(vert)

year	Group	Mean	Std. Error	95% Confidence Interval		Marginal Means
				Lower Bound	Upper Bound	
LP	1.00	.977	.049	.879	1.075	.9758
	Dimension2 2.00	.966	.061	.843	1.088	
	3.00	.984	.061	.861	1.107	
APRE	1.00	1.036	.049	.938	1.134	1.0809
	dimension2 2.00	1.106	.051	1.004	1.209	
	3.00	1.122	.051	1.020	1.225	

Figure 6 Means and Marginal Means for Power

Figure 7 reports the raw change scores in the data. Bodyweight, bench press, squat, and clean are all in kilograms (kg). Power is measured in watts (W) and 225 bench press repetitions test is number of repetitions.

Descriptive Statistics					
Year	Test	Min	Max	Mean	Std Dev
LP	225 Bench Press	-4.00	5.00	.4583	2.12601
	Power	-499.05	452.29	-96.5465	227.42031
	Bodyweight	-7.73	7.73	-.2622	3.34064
	Bench Press	-15.00	13.18	.2372	7.48511
	Squat	-50.91	18.64	-1.8182	15.89576
	Clean	-25.91	16.82	-3.3409	11.88358
APRE	225 Bench Press	-4.00	6.00	1.1290	1.87513
	Power	-349.33	699.28	85.9028	259.59082
	Bodyweight	-5.45	4.55	-.0147	2.43789
	Bench Press	-11.36	29.55	6.3196	8.70179
	Squat	-5.45	80.45	12.6224	18.34712
	Clean	1.82	60.45	10.5420	12.71754

Figure 7 Mean change scores in raw units.

Figure 8 displays the raw pre and post scores for the data. Bodyweight, bench press, squat, and clean are all in kilograms (kg). Power is measured in watts (W) and 225 bench press repetitions test is number of repetitions.

Variable	LP Pre	LP Post	APRE Pre	APRE Post
Bench Press	154.7628	155.4545	139.6334	145.9531*
225 Bench Press	15.54	16.12	11.68	12.81
Squat	225.1082	221.3636	208.2143	218.2143*
Clean	146.2955	128.1034	128.1034	136.8344*
Power	7728.7453	7487.1855	7567.8518	7687.3621*
Age	19.6154		19.1290	
BMI	31.6359	31.6833	31.4735	31.4506

Figure 8 raw pre and post scores

Hypothesis 1: The APRE will show gains greater than the LP on the Bench Press.

Figure 9 displays data on the ANOVA for bench press. The ANOVA shows that the effect of programming was significant ($F(1)=5.421$, $p=.024$), indicating that the APRE was better than the LP at improving strength for the bench press test. No post-hoc tests were run since the omnibus test indicated that group ($F(2)=.478$, $p=.623$) and year*group ($F(2)=.731$, $p=.487$) were not statistically significantly which indicates that there were no differences in strength gains by position. Hypothesis 1 was accepted.

Tests of Between-Subjects Effects

Dependent Variable:SMEAN(Bench)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.032[a]	5	.006	1.732	.145
Intercept	57.067	1	57.067	15584.521	.000
Year	.020	1	.020	5.421	.024
Group	.004	2	.002	.478	.623
year * group	.005	2	.003	.731	.487
Error	.183	50	.004		
Total	59.707	56			
Corrected Total	.215	55			

a. R Squared = .148 (Adjusted R Squared = .062)

Figure 9 ANOVA for Bench Press

Hypothesis 2: The APRE will show gains greater than the LP on the Squat.

Figure 10 displays data on the ANOVA for the squat. The ANOVA found a significant difference between the programs ($F(1)=9.299$, $p=.004$), which indicates that the APRE is more effective than the LP at improving strength in this test. The ANOVA revealed a significant difference within the group ($F(2)=3.893$, $p=.027$) , thereby prompting the need for a post hoc test. A Tukey's HSD Post-Hoc was used, as shown in Figure 11. There was a near significant difference ($p=.051$). The ANOVA found no significant difference with year*group ($F(2)=1.050$, $p=.358$). Hypothesis 2 was accepted.

Tests of Between-Subjects Effects

Dependent Variable:SMEAN(Squat)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.265[a]	5	.053	3.933	.004
Intercept	58.141	1	58.141	4314.288	.000
Year	.125	1	.125	9.299	.004
Group	.105	2	.052	3.893	.027
year * group	.028	2	.014	1.050	.358
Error	.674	50	.013		
Total	62.338	56			
Corrected Total	.939	55			

a. R Squared = .282 (Adjusted R Squared = .211)

Figure 10 ANOVA for squat

Multiple Comparisons

SMEAN(Squat)

Tukey's HSD

(I) group		(J) group				95% Confidence Interval	
			Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
dimension2	1.00	2.00 dimension3	.0902	.03749	.051	-.0004	.1807
		3.00	.0742	.03749	.128	-.0163	.1648
	2.00	1.00 dimension3	-.0902	.03749	.051	-.1807	.0004
		3.00	-.0160	.03982	.915	-.1121	.0802
	3.00	1.00 dimension3	-.0742	.03749	.128	-.1648	.0163
		2.00	.0160	.03982	.915	-.0802	.1121

Based on observed means.

The error term is Mean Square(Error) = .013.

Figure 11 Tukey's HSD for squat

Hypothesis 3: The APRE will show gains greater than the LP on the Hang Clean.

Figure 12 displays data on the ANOVA for the Hang Clean. The ANOVA indicated a significant difference between the programs ($F(1)=10.384$, $p=.002$). This indicates that the APRE was more effective than the LP for improving strength. Neither group ($F(2)=.938$, $p=.398$) nor year*group ($F(2)=.336$, $p=.716$) were significant which indicates that there were no differences in strength gains by position, so no post-hoc tests were performed. Hypothesis 3 was accepted.

Tests of Between-Subjects Effects

Dependent Variable:SMEAN(Clean)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.209[a]	5	.042	2.696	.031
Intercept	57.219	1	57.219	3693.948	.000
Year	.161	1	.161	10.384	.002
Group	.029	2	.015	.938	.398
year * group	.010	2	.005	.336	.716
Error	.774	50	.015		
Total	61.221	56			
Corrected Total	.983	55			

a. R Squared = .212 (Adjusted R Squared = .134)

Figure 12 ANOVA for hang clean

Hypothesis 4: The APRE will show gains greater than the LP on the 225 Bench Press repetitions test.

Figure 13 displays data on the ANOVA for the 225 Bench Press repetitions test. The ANOVA revealed no significant difference ($F(1)=1.835$, $p=.182$). This indicates that there neither group was significantly better than the other, even though the mean of the APRE was higher. Neither group ($F(2)=1.344$, $p=.270$) nor year*group ($F=1.738$, $p=.186$) was found to be significant which indicates that there were no differences in strength gains by position, so no post-hoc tests were performed. Hypothesis 4 was rejected.

Tests of Between-Subjects Effects

Dependent Variable:SMEAN(BP225)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3.770[a]	5	.754	1.753	.140
Intercept	73.323	1	73.323	170.466	.000
Year	.789	1	.789	1.835	.182
Group	1.156	2	.578	1.344	.270
year * group	1.495	2	.748	1.738	.186
Error	21.507	50	.430		
Total	103.567	56			
Corrected Total	25.276	55			

a. R Squared = .149 (Adjusted R Squared = .064)

Figure 13 ANOVA for 225 bench press repetitions test

Hypothesis 5: **The APRE will show gains greater than the LP in power.**

Figure 14 displays data for the ANOVA on power output. The ANOVA indicated a significant difference between the programs ($F(1)=6.550$, $p=.014$). This indicates that the APRE was more effective than the LP for improving power output. Neither group ($F(2)=.417$, $p=.661$) nor year*group ($F(2)=.407$, $p=.668$) was found to be significant which indicates that there were no differences in strength gains by position, so no post-hoc tests were performed. Hypothesis 5 was accepted.

Tests of Between-Subjects Effects

Dependent Variable:SMEAN(vert)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.216[a]	5	.043	1.654	.163
Intercept	57.424	1	57.424	2198.759	.000
Year	.171	1	.171	6.550	.014
Group	.022	2	.011	.417	.661
year * group	.021	2	.011	.407	.668
Error	1.306	50	.026		
Total	61.751	56			
Corrected Total	1.522	55			

a. R Squared = .142 (Adjusted R Squared = .056)

Figure 14 ANOVA for power

Hypothesis 6: The APRE will show gains greater in the big and mid positions than in the skill positions.

Referring back to Figure 9, neither group's data indicated a significant effect on the Bench Press ($F(2)=.478$, $p=.623$), referring back to Figure 12, neither group demonstrated a significant difference in the Hang Clean ($F(2)=.938$, $p=.398$), referring back to Figure 13, neither group's data indicated a significant effect on 225 Bench Press repetitions test: ($F(2)=1.344$, $p=.270$), referring back to Figure 14, neither group indicated a significant effect on power output, ($F(2)=.417$, $p=.661$). Referring back to Figure 10, the ANOVA showed a significant effect on the Squat ($F(2)=3.893$,$p=.027$). A Tukey's HSD Post Hoc test was performed to find the differences, shown in Figure 11. The Tukey's HSD found no significant differences between the groups. However, a minor difference between groups 1 and 2 posted near significant ($p=.051$). This indicates that the big position athletes demonstrated improvement at a slightly better rate than the skill positions on the squat, but there were no significant or near significant differences for the other groups. As there were no significant values, Hypothesis 6 was rejected.

Chapter Five

DISCUSSION

Summary

The purpose of this study was to first, find the most effective means of programming to improve strength and power in Division 1 college football players over a short term (six week) time period and, second, to determine if a particular group, based on size and position, improved more rapidly than another. The analysis of differential scores in the data allowed the researcher to draw conclusions about the relative merits of the APRE and LP programs. It was determined that the APRE was significantly better at improving power and increasing strength in the bench press, squat and hang clean, while neither program showed a significant difference in the number of repetitions achieved in the 225 bench press repetitions test. Tukey's HSD post hoc tests showed that no position group gained significantly more strength than the other**,** causing the researcher to accept the null hypothesis.

Findings.

Pre to post training test changes in absolute strength were found for the bench press ($F(1)=5.421$, $p=.024$) (Figure 4), squat ($F(1)=9.299$, $p=.004$) (Figure 6), and hang clean ($F(1)=10.384$, $p=.002$)(Figure 13). This evidence indicates that the APRE was significantly better at improving strength over a six week time period with the highly trained athletes in this study. Pre to post training test

changes in power were found to be significant ($F(1)=6.550$, $p=.014$) (Figure 14), indicating that the APRE was significantly better at improving power during this time frame. Pre to post training test changes in upper body strength endurance, as measured by the 225lb bench press repetitions test were insignificant ($F(1)=1.835$, $p=.182$)(Figure 13), indicating that neither group was significantly better than the other for this particular test. Interestingly, improvements in upper body strength (bench press) did not translate to improvements in upper body strength endurance (225lb bench press repetitions test).

Pre to post training test changes were also measured in each position group. The big group consisted of the offensive and defensive line positions. The middle group consisted of the linebackers, tight ends, running backs and quarterback positions. The skill group consisted of the wide receiver and defensive back positions. Of all variables tested, only the results for the squat demonstrated significant difference in strength gains between the groups ($F(2)=3.893$,$p=.027$)(Figure 10). However, a Tukey's HSD post-hoc test found only a near significant difference existing between groups one and two ($p=.051$) (Figure 11), indicating that no position group gained strength significantly greater than any other. The near significance lay between the big group and the mid group, with the former gaining strength at a slightly better rate.

Discussion.

This study was the first to compare the effects of the APRE with the LP among NCAA Division I football players in a major university program. APRE was more effective than the LP at improving bench press strength, squat strength

and upper body endurance in Division I athletes over a six week period. The results suggest that autoregulation is an important consideration when choosing a program intended to elicit maximal gains in minimal time, particularly for highly trained athletes.

Programs that use the Progressive Overload method to improve muscle strength systematically were first described in the research by DeLorme with his PRE protocol (T. DeLorme, 1945; T. DeLorme, et al., 1950; T. L. DeLorme, Schwab, & Watkins, 1948; T. L. DeLorme & Watkins, 1948; T. L. DeLorme, West, & Shriber, 1950). Knight modified the original DeLorme PRE program for the purposes of leg rehabilitation through Daily Autoregulated Progressive Resistance Exercise (Knight, 1979). For DAPRE, the principles of PRE were utilized to determine the appropriate resistance for two sets of five to seven repetitions. A third set was used to determine the training load during the fourth set, and the fourth set was used to determine the training loads for the following session. This method resulted in increased strength improvement for quadriceps (Giessing, 2007). APRE utilized in the present study varies slightly from the DAPRE, but the rationale is similar. APRE has two working sets, followed by sets adjusted according to individual daily variations in strength and performance. Like PRE or DAPRE, the goal of APRE is to work toward a repetition maximum. The difference between APRE and other protocols -- as well as the difference within APRE protocols itself -- is that they are designed for different training needs. There is an APRE 3 for strength and power, an APRE 6 for strength and hypertrophy and an APRE 10 for hypertrophy. DeLorme's PRE

only included the original 10RM protocol (T. L. Delorme, West, Francis, Schriber, William, 1958), and the DAPRE evolved to an additional 6RM protocol (Knight, 1985). The present study focused primarily on APRE 6 protocol for strength and hypertrophy since these are favorable adaptations for collegiate football players.

Although APRE has not been compared to LP in the literature, Herrick and Stone compared Progressive Overload training, of which APRE is one type, to Linear Periodization. Researchers reported no significant differences in strength between the Progressive Overload and LP groups in untrained women at the conclusion of the 15 week study. However, the LP group continued to gain strength, while the Progressive Overload group appeared to reach a plateau in their strength gains. These findings led the researchers to theorize that LP might be a better method to use in a yearly plan. Strength improvements observed during short term APRE training in the present study conflicts with Stone's findings (Herrick & Stone, 1996). The discrepancy may be due to the benefits of autoregulation or perhaps due to the focus on trained versus untrained individuals.

The APRE could be considered a form of Kraemer's Flexible Non-Linear Periodization, which has proven successful among collegiate athletes (W. J. Kraemer, Fleck, Steven, 2008). However, in Flexible Non-Linear Periodization, the practitioner makes daily choices about the athlete's status and workout based on the demands that will be placed on the athlete for that given day. For example, a day in which a training session follows a three hour practice with heavy loads of conditioning would require different strength workout than a pre-

practice strength training session (W. J. Kraemer, Fleck, Steven, 2008). Flexible Non-Linear Periodization allows adaptation by the coach or practitioner based on demands, such as increased conditioning or periods of increased competition. APRE, on the other hand, allows adaptation of a particular workout by the individual athlete based on their abilities for that particular day. The mechanisms by which the APRE works may well be the same as Flexible Non-Linear Periodization; alternating repetition schemes gives the body new stimuli for adaptation, the basis of strength gains.

The data suggests that the APRE is more effective than LP for short-term gains. All of the reasons for this are not known. However, it could be that the greater strength gains resulting from APRE were due to a constant adjustment of repetitions. Experts postulate that when a constant training protocol is utilized over a period of weeks to months, the body adapts, which leads to reduced effectiveness (Rhea, Ball, et al., 2002). APRE training prevents this adaptation because repetitions are governed by the athletes' ability on that given day. Therefore, the number of repetitions will change from set to set and week to week. Theoretically, the athlete could continue a typical six-week training cycle and never repeat the same repetition and intensity scheme.

The APRE fits well with the theoretical basis of Undulating Periodization (Rhea, Ball, et al., 2002), as workouts utilize a repetition maximum which will not only vary from week to week, but within the workout as well. For example, researchers found that by alternating the RM trained in each workout, strength was improved to a greater degree than by changing the RM every four weeks.

Undulating Periodization also proved effective at improving endurance (Rhea et al., 2003). The variation in repetitions from set to set and week to week allows APRE training to work like Undulating Periodization, which helps explain its success.

One interesting and unexpected result of this study is the lack of significant differences in upper body strength endurance as found by the 225 bench press repetitions test. Common sense suggests that as strength increases, so does endurance. However, this assumption was not demonstrated in this study. One confounding variable may be the study's time frame. Six weeks may simply not be sufficient time for strength gains to affect strength endurance.

The groups did not show a difference for gaining strength or power as expected. This is most likely a factor of incorrect grouping. By simply grouping by position, this does not take into account the variance of athletes at each position. For instance, within the big group, there can be endomorphs, endomesomorphs, mesomorphs, and ectomesomorphs. This wide range of somatotypes collected into one group does not effectively demonstrate proper selection.

Implications for Future Research.

There were several limitations to this study which should be accounted for in future research. First, the study was not set up as a traditional pre-post design, which is a methodological limitation. However, the novel aspect of this study is the application of these training protocols on strength-trained NCAA

Division I college football players at a major Big-12 program. Because the football program was so structured in its off-season and pre-season agendas, obtaining baseline measures of strength prior to the implementation of APRE and LP was not possible. The researcher believes the findings, however, are intriguing enough to warrant future evaluations of the benefits of APRE in competitive athletes. Future studies utilizing a traditional pre/post design would be recommended. Second, the generalizability of these findings is limited to strength-trained football players. However, the benefits of APRE would likely be applicable to the untrained population as well. Finally, there was no way to completely equalize the volume and intensity of training between APRE and LP, which may affect the study's results. Further research to determine the role of volume and intensity is warranted.

This is the first study to compare the effectiveness of APRE with LP in trained Division I college football players. The data suggests that the Autoregulatory Progressive Resistance Exercise protocol elicits greater strength gains than Linear Periodized programs in terms of strength gains in the bench press strength, squat, hang clean and power. It is reasonable to conclude that other strength performance events would likely benefit from this type of training. Future studies using more extended time periods (eight, 12, 16 weeks and greater) need to be done to examine effects, especially with regard to strength endurance.

While the somatotype breakdown in this study was ineffective, the near significance of the squat shows that this may be an area of promise for the

future. The Heath-Carter Anthropometric Somatotype Rating could not be done as the data was archival and no new measurements could be taken. An exact somatotype, rather than grouped by position may in fact reveal differences between the groups. Furthermore, formulas may be developed to find somatotypes using data that most professionals already collect, thereby improving the efficiency of training if differences exist.

Practical Application.

Due to the short duration of typical off-season and pre-season programs for University athletics, it is critical for athletes to achieve maximal gains in strength as efficiently as possible. Practitioners theorize that Progressive Overload training, such as the PRE and APRE, might be an excellent tool for shorter training periods typical of pre-season or off-season cycles. For practical purposes, coaches should use the APRE method with highly trained athletes during short training cycles because it is appears to be more effective than LP for strength gains in the shortest amount of time, these data indicate that the APRE training seems to be best.

Appendix A

APRE (Autoregulatory Progressive Resistance Exercise)			
Set	3 RM Routine	6 RM Routine	10 RM Routine
0	Warmup	Warm-up	Warm-up
1	6 reps@ 50% 3RM	10 reps@ 50% 6RM	12 Reps@ 50% 10RM
2	3 reps@ 75% 3RM	6 reps@ 75% 6RM	10 reps@ 75% 10RM
3	Reps to Failure@ 3RM	Reps to failure@ 6RM	Reps to failure@ 10RM
4	Adjusted reps to failure	Adjusted reps to failure	Adjusted reps to Failure

Adjustment Table for APRE					
3 RM Routine		6 RM Routine		10 RM Routine	
Repetitions	Set 4	Repetitions	Set 4	Repetitions	Set 4
1-2	Decrease 5 - 10	0-2	Decrease 5-10	4-6	Decrease 5-10
3-4	Same	3-4	Decrease 0-5	7-8	Decrease 0-5
5-6	Increase +5-10	5-7	Same	9-11	Same
7+	Increase +10-15	8-12	Increase 5-10	12-16	Increase 5-10
		13+	Increase 10-15	17+	Increase 10-15

Appendix B

1	2	3	4	5	6	7	8	9	10	11	12
5	5	5	6	6	6	6	6	7	7	7	7
10	11	11	11	12	12	13	13	13	13	14	14
15	16	16	17	18	18	19	19	20	20	21	21
20	21	22	23	24	24	25	26	26	27	27	28
25	26	27	28	29	30	31	32	33	33	34	35
30	32	33	34	35	36	38	38	39	40	41	42
35	37	38	40	41	42	44	45	46	47	48	49
40	42	43	45	47	48	50	51	52	53	55	56
45	47	49	51	53	54	56	58	59	60	62	63
50	53	54	57	59	60	63	64	66	67	69	70
55	58	60	62	65	66	69	70	72	73	75	76
60	63	65	68	71	72	75	77	79	80	82	83
65	69	71	74	76	78	81	83	85	87	89	90
70	74	76	80	82	84	88	90	92	93	96	97
75	79	81	85	88	90	94	96	98	100	103	104
80	84	87	91	94	96	100	102	105	107	110	111
85	90	92	97	100	102	106	109	111	113	116	118
90	95	98	102	106	108	113	115	118	120	123	125
95	100	103	108	112	114	119	122	124	127	130	132

1	2	3	4	5	6	7	8	9	10	11	12
100	105	109	114	118	121	125	128	131	134	137	139
105	111	114	119	123	127	131	134	138	140	144	146
110	116	119	125	129	133	138	141	144	147	151	153
115	121	125	131	135	139	144	147	151	154	158	160
120	126	130	136	141	145	150	154	157	160	164	167
125	132	136	142	147	151	156	160	164	167	171	174
130	137	141	148	153	157	163	166	170	174	178	181
135	142	147	153	159	163	169	173	177	180	185	188
140	148	152	159	165	169	175	179	183	187	192	195
145	153	157	165	171	175	181	186	190	194	199	202
150	158	163	170	176	181	188	192	197	200	206	209
155	163	168	176	182	187	194	198	203	207	212	215
160	169	174	182	188	193	200	205	210	214	219	222
165	174	179	187	194	199	206	211	216	220	226	229
170	179	185	193	200	205	213	218	223	227	233	236
175	184	190	199	206	211	219	224	229	234	240	243
180	190	195	204	212	217	225	230	236	240	247	250
185	195	201	210	218	223	231	237	242	247	253	257
190	200	206	216	223	229	238	243	249	254	260	264
195	206	212	222	229	235	244	250	255	260	267	271
200	211	217	227	235	241	250	256	262	267	274	278
205	216	223	233	241	247	256	262	269	274	281	285
210	221	228	239	247	253	263	269	275	280	288	292

1	2	3	4	5	6	7	8	9	10	11	12
215	227	233	244	253	259	269	275	282	287	295	299
220	232	239	250	259	265	275	282	288	294	301	306
225	237	244	256	265	271	281	288	295	300	308	313
230	242	250	261	270	277	288	294	301	307	315	320
235	248	255	267	276	283	294	301	308	314	322	327
240	253	261	273	282	289	300	307	314	320	329	334
245	258	266	278	288	295	306	314	321	327	336	341
250	264	272	284	294	301	313	320	328	334	343	348
255	269	277	290	300	307	319	326	334	340	349	354
260	274	282	295	306	313	325	333	341	347	356	361
265	279	288	301	312	319	331	339	347	354	363	368
270	285	293	307	318	325	338	346	354	360	370	375
275	290	299	312	323	331	344	352	360	367	377	382
280	295	304	318	329	337	350	358	367	374	384	389
285	300	310	324	335	343	356	365	373	380	390	396
290	306	315	329	341	349	363	371	380	387	397	403
295	311	320	335	347	355	369	378	386	394	404	410
300	316	326	341	353	362	375	384	393	401	411	417
305	321	331	346	359	368	381	390	400	407	418	424
310	327	337	352	365	374	388	397	406	414	425	431
315	332	342	358	370	380	394	403	413	421	432	438
320	337	348	364	376	386	400	410	419	427	438	445
325	343	353	369	382	392	406	416	426	434	445	452

1	2	3	4	5	6	7	8	9	10	11	12
330	348	358	375	388	398	413	422	432	441	452	459
335	353	364	381	394	404	419	429	439	447	459	466
340	358	369	386	400	410	425	435	445	454	466	473
345	364	375	392	406	416	431	442	452	461	473	480
350	369	380	398	412	422	438	448	459	467	480	487
355	374	386	403	417	428	444	454	465	474	486	493
360	379	391	409	423	434	450	461	472	481	493	500
365	385	396	415	429	440	456	467	478	487	500	507
370	390	402	420	435	446	463	474	485	494	507	514
375	395	407	426	441	452	469	480	491	501	514	521
380	401	413	432	447	458	475	486	498	507	521	528
385	406	418	437	453	464	481	493	504	514	527	535
390	411	424	443	459	470	488	499	511	521	534	542
395	416	429	449	465	476	494	506	517	527	541	549
400	422	434	454	470	482	500	512	524	534	548	556
405	427	440	460	476	488	506	518	531	541	555	563
410	432	445	466	482	494	513	525	537	547	562	570
415	437	451	471	488	500	519	531	544	554	569	577
420	443	456	477	494	506	525	538	550	561	575	584
425	448	462	483	500	512	531	544	557	567	582	591
430	453	467	488	506	518	538	550	563	574	589	598
435	458	472	494	512	524	544	557	570	581	596	605
440	464	478	500	517	530	550	563	576	587	603	612

1	2	3	4	5	6	7	8	9	10	11	12
445	469	483	506	523	536	556	570	583	594	610	619
450	474	489	511	529	542	563	576	590	601	617	626
455	480	494	517	535	548	569	582	596	607	623	632
460	485	500	523	541	554	575	589	603	614	630	639
465	490	505	528	547	560	581	595	609	621	637	646
470	495	510	534	553	566	588	602	616	627	644	653
475	501	516	540	559	572	594	608	622	634	651	660
480	506	521	545	564	578	600	614	629	641	658	667
485	511	527	551	570	584	606	621	635	647	664	674
490	516	532	557	576	590	613	627	642	654	671	681
495	522	538	562	582	596	619	634	648	661	678	688
500	527	543	568	588	603	625	640	655	668	685	695
505	532	548	574	594	609	631	646	662	674	692	702
510	538	554	579	600	615	638	653	668	681	699	709
515	543	559	585	606	621	644	659	675	688	706	716
520	548	565	591	612	627	650	666	681	694	712	723
525	553	570	596	617	633	656	672	688	701	719	730
530	559	576	602	623	639	663	678	694	708	726	737
535	564	581	608	629	645	669	685	701	714	733	744
540	569	586	613	635	651	675	691	707	721	740	751
545	574	592	619	641	657	681	698	714	728	747	758
550	580	597	625	647	663	688	704	721	734	754	765
555	585	603	630	653	669	694	710	727	741	760	771

1	2	3	4	5	6	7	8	9	10	11	12
560	590	608	636	659	675	700	717	734	748	767	778
565	596	614	642	664	681	706	723	740	754	774	785
570	601	619	648	670	687	713	730	747	761	781	792
575	606	624	653	676	693	719	736	753	768	788	799
580	611	630	659	682	699	725	742	760	774	795	806
585	617	635	665	688	705	731	749	766	781	801	813
590	622	641	670	694	711	738	755	773	788	808	820
595	627	646	676	700	717	744	762	779	794	815	827
600	632	652	682	706	723	750	768	786	801	822	834
605	638	657	687	711	729	756	774	793	808	829	841
610	643	662	693	717	735	763	781	799	814	836	848
615	648	668	699	723	741	769	787	806	821	843	855

Appendix C

Squat

Exercise description for the back squat is as follows: This exercise is used to develop hip, leg, and low back strength. This lift will also strengthen the ligaments in the knee joint and will assist in overall body development. Performing the back squat correctly will improve lower body strength, enhance quickness, speed, and jumping ability.

Beginning Position: grasp the bar with a closed pronated grip slightly wider than shoulder width. Step under the bar and place the bar on the upper back and shoulders (below the 7^{th} cervical vertebrae, which is the bone that sticks out of the bottom of the neck). Tuck the elbows to create a shelf for the bar using the upper back and shoulder muscles. Hold the chest up and out by pulling the scapulae toward each other and back. Tilt the head slightly up and step out with the bar. Feet should be shoulder width apart or wider, the feet should be even, and the toes should be pointed slightly outward.

Downward movement: inhale and hold the breath on the downward movement. Push the hips to the rear and allow the hips and knees to slowly flex while keeping the torso to floor angle relatively constant. Maintain a position with the black flat or slightly arched, elbows tucked, and chest up and out. Keep the heels flat on the floor and the knees aligned over the feet during the descent. Make sure to not round the back while continuing to flex the hips and knees until

the thighs are parallel to the floor. Do not accelerate the bar or relax the torso at the bottom of the movement. The descent depth should be until the femur is parallel to the ground.

Upward movement: continue holding the breath until ½ way through the upward movement before beginning to exhale. Extend the hips and knees at the same rate, do not allow the hips to rise before the chest, which would place the low back into a dangerous and compromising position. Continue to maintain a position with the chest up and out, back flat, tucked elbows and the heels flat on the ground. Do not flex the torso or round the back. Continue to extend the hips and knees until the beginning position is reached. Repeat until desired number of repetitions have been achieved.

Hang Clean

Exercise description for the hang clean is as follows: the beginning position. The feet should be about shoulder width with the hands grasping the bar outside of the thighs with a pronated grip. The back should be set with a slight arch by sticking the chest out and the glutes back. The knuckles of the hand should be pointed down, turning the elbows out.

Downward movement: push the hips to the rear with a slight knee bend until the bar comes just above the knee cap.

Upward movement: from this position, explosively drive the hips forward and up in a vertical jump movement, extending with the knee, ankle, and hip joints simultaneously (triple extension). Once a full triple extension has been reached, rapidly shrug the shoulders upward and then pull with the arms keeping

the elbows high. Continue to pull the arms as high as possible until the bar reaches its' maximal height. At this point, pull the body under the bar and rotate the arms around and under the bar shooting the elbows directly out in front of the body in a high catch position simultaneously the hips and knees should flex into a quarter squat position with the feet flat on the ground.

Bench Press

Exercise description for the bench press is as follows: assume a supine position on the bench in a five point body contact position (meaning head, shoulders, glutes, and both feet in contact with the bench or ground) with the eyes are below the edge of the supports and grasp the bar with a closed pronated grip.

Downward movement: inhale on the downward movement while lowering the bar to touch the chest at approximately mid chest level, keeping the wrists rigid and directly above the elbows while maintaining five-point body contact position.

Upward movement: exhale through the sticking point of the upward movement. The bar should be pushed upward and slightly back with the wrists rigid and directly above the elbows while maintaining five-point body contact position.

BIBLIOGRAPHY

Baker, D. G., & Newton, R. U. (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *J Strength Cond Res, 22*(1), 153-158.

Baker, D. W. C. (1994). The Effect on Strength of Manipulating Volume and Intesnsity. *Journal of Strength and Conditioning Research, 8*(4), 7.

Baroga, T. A. L. (1988). *Weightlifting: Fitness for All Sports* (First ed.). Budapest, Hungary: International Weightlifint Federation.

Braith, R. W., & Beck, D. T. (2008). Resistance exercise: training adaptations and developing a safe exercise prescription. *Heart Fail Rev, 13*(1), 69-79.

Buford, T. W., Rossi, S. J., Smith, D. B., & Warren, A. J. (2007). A comparison of periodization models during nine weeks with equated volume and intensity for strength. *J Strength Cond Res, 21*(4), 1245-1250.

Byrd, R., Chandler, T. J., Conley, M. S., Fry, A. C., Haff, G. G., Koch, A., . . . Wathen, D. (1999). Strength training: single versus multiple sets. *Sports Med, 27*(6), 409-416.

Chandler, T. J., Kibler, W. B., Stracener, E. C., Ziegler, A. K., & Pace, B. (1992). Shoulder strength, power, and endurance in college tennis players. *Am J Sports Med, 20*(4), 455-458.

Chaouchi, M., Chaouachi, A, Chamari, K et al. (2005). Effects of dominant somatotype on aerobic capacity trainability. *British Journal of Sports Medicine, 39*, 5. doi: 10.1136

Chiu, L. Z., Fry, A. C., Weiss, L. W., Schilling, B. K., Brown, L. E., & Smith, S. L. (2003). Postactivation potentiation response in athletic and recreationally trained individuals. *J Strength Cond Res, 17*(4), 671-677.

DeLateur, B. J., Lehmann, J. F., & Fordyce, W. E. (1968). A test of the DeLorme axiom. *Arch Phys Med Rehabil, 49*(5), 245-248.

DeLorme, T. (1945). Restoration of Muscle Power By Heavy Resistance Exercises. *Journal of Bone and Joint Surgery 27*, 645-667.

DeLorme, T., West, F., & Schriber, W. (1950). Influence of progressive resistance exercises on knee function following femoral fractures. *J Bone Joint Surg Am, 32*(A:4), 910-924.

DeLorme, T., West, F, Schriber, W. (1958). Influence of Progressive Resistance Exercises on Knee Function Following Femoral Fracture *The Journal of Bone and Joint Surgery, 32*, 910-924.

DeLorme, T. L., Schwab, R. S., & Watkins, A. L. (1948). The response of the quadriceps femoris to progressive-resistance exercises in poliomyelitic patients. *J Bone Joint Surg Am, 30A*(4), 834-847.

DeLorme, T. L., & Watkins, A. L. (1948). Technics of progressive resistance exercise. *Arch Phys Med Rehabil, 29*(5), 263-273.

DeLorme, T. L., West, F. E., & Shriber, W. J. (1950). Influence of progressive resistance exercises on knee function following femoral fractures. *J Bone Joint Surg Am, 32*(A:4), 910-924.

Delorme, T. L., West, Francis, Schriber, William. (1958). Influence of Progressive Resistance Exercises on Knee Function Following Femoral Fracture *The Journal of Bone and Joint Surgery, 32*, 910-924.

Drinkwater, E. J., Lawton, T. W., Lindsell, R. P., Pyne, D. B., Hunt, P. H., & McKenna, M. J. (2005). Training leading to repetition failure enhances bench press strength gains in elite junior athletes. *J Strength Cond Res, 19*(2), 382-388.

Fish, D. E., Krabak, B. J., Johnson-Greene, D., & DeLateur, B. J. (2003). Optimal resistance training: comparison of DeLorme with Oxford techniques. *Am J Phys Med Rehabil, 82*(12), 903-909.

Giessing, J. (2007). How intense are your weight training workouts? [Journal]. *NSCA's Performance Training Journal, 6*(1), 2.

Hakkinen, K., Kallinen, M., Komi, P. V., & Kauhanen, H. (1991). Neuromuscular adaptations during short-term "normal" and reduced training periods in strength athletes. *Electromyogr Clin Neurophysiol, 31*(1), 35-42.

Herrick, A., & Stone, W. (1996). The Effects of Periodization Versus Progressive Resistance Exercise on Upper and Lower Body Strength in Women. *Journal of Strength and Conditioning Research, 10*(2), 5.

Kelly, S. B., Brown, L. E., Coburn, J. W., Zinder, S. M., Gardner, L. M., & Nguyen, D. (2007). The effect of single versus multiple setson strength. *J Strength Cond Res, 21*(4), 1003-1006.

Kenn, J. (2003). *The Coach's Strength Training Playbook* (1 ed.). Monterey, CA: Coaches Choice.

Knight, K. L. (1979). Knee rehabilitation by the daily adjustable progressive resistive exercise technique. *Am J Sports Med, 7*(6), 336-337.

Knight, K. L. (1985). Quadriceps strengthening with the DAPRE technique: case studies with neurological implications. *Med Sci Sports Exerc, 17*(6), 646-650.

Kraemer, W. J., Fleck, Steven. (2008). *Optimizing Strength Training, Designing Nonlinear Perioldization Workouts* (1 ed. Vol. 1). Champaign, IL: Human Kinetics.

Kraemer, W. J., Hakkinen, K., Triplett-Mcbride, N. T., Fry, A. C., Koziris, L. P., Ratamess, N. A., . . . Knuttgen, H. G. (2003). Physiological changes with periodized resistance training in women tennis players. *Med Sci Sports Exerc, 35*(1), 157-168.

Kraemer, W. J., Ratamess, N., Fry, A. C., Triplett-McBride, T., Koziris, L. P., Bauer, J. A., . . . Fleck, S. J. (2000). Influence of resistance training volume and periodization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med, 28*(5), 626-633.

Mangine, G. T., Ratamess, N. A., Hoffman, J. R., Faigenbaum, A. D., Kang, J., & Chilakos, A. (2008). The effects of combined ballistic and heavy

resistance training on maximal lower- and upper-body strength in recreationally trained men. *J Strength Cond Res, 22*(1), 132-139.
Mayhew, J. L. (2002). Validation of the NFL-225 test for predicting 1-RM bench press performance in college football players. *Journal of Sports Medicine and Physical Fitness, 42*(3), 5.
Moore, C. A., & Fry, A. C. (2007). Nonfunctional overreaching during off-season training for skill position players in collegiate American football. *J Strength Cond Res, 21*(3), 793-800.
National Strength & Conditioning Association. (2000). *Essentials of Strength Training and Conditioning* (2 ed.). Champaign, IL: Human Kinetics.
Niederbracht, Y., Shim, A. L., Sloniger, M. A., Paternostro-Bayles, M., & Short, T. H. (2008). Effects of a shoulder injury prevention strength training program on eccentric external rotator muscle strength and glenohumeral joint imbalance in female overhead activity athletes. *J Strength Cond Res, 22*(1), 140-145.
Ostrowski, W., Weatherby, Murphy, Lyttle. (1997). The Effect of Weight Training Volume on Hormonal Output and Muscular Size and FUnction. *Journal of Strength and Conditioning Research, 11*(1), 6.
Piercy, J. M. (1959). Progressive resistance exercise. *Physiotherapy, 45*, 186-190.
Rhea, M. R., & Alderman, B. L. (2004). A meta-analysis of periodized versus nonperiodized strength and power training programs. *Res Q Exerc Sport, 75*(4), 413-422.
Rhea, M. R., Alvar, B. A., Ball, S. D., & Burkett, L. N. (2002). Three sets of weight training superior to 1 set with equal intensity for eliciting strength. *J Strength Cond Res, 16*(4), 525-529.
Rhea, M. R., Alvar, B. A., & Burkett, L. N. (2002). Single versus multiple sets for strength: a meta-analysis to address the controversy. *Res Q Exerc Sport, 73*(4), 485-488.
Rhea, M. R., Ball, S. D., Phillips, W. T., & Burkett, L. N. (2002). A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J Strength Cond Res, 16*(2), 250-255.
Rhea, M. R., Phillips, W. T., Burkett, L. N., Stone, W. J., Ball, S. D., Alvar, B. A., & Thomas, A. B. (2003). A comparison of linear and daily undulating periodized programs with equated volume and intensity for local muscular endurance. *J Strength Cond Res, 17*(1), 82-87.
Rogers, R. (2003). *Sequence and order "Getting the most out of your program".* Paper presented at the 22nd Annual Tennessee Strength Clinic, Knoxville, TN.
Sayers SP, H. D., Harman EA, Frykman PN, Rosenstein MT. (1999). Cross-validation of three jump power equations. *Med Sci Sports Exerc, 31*(4), 1271-1277.
Schlumberger, A., Stec, J., & Schmidtbleicher, D. (2001). Single- vs. multiple-set strength training in women. *J Strength Cond Res, 15*(3), 284-289.
Siff, M. C. (2000). *Supertraining* (5th ed.). Denver, Co.

Starr, B. (1976). *Sthe Strongest Shall Survive*: Fitness Consultants and Supply.
Wolfe, B. L., LeMura, L. M., & Cole, P. J. (2004). Quantitative analysis of single- vs. multiple-set programs in resistance training. *J Strength Cond Res, 18*(1), 35-47.
Yessis, M., PhD. (1987). *Secrets of Soviet Sports Fitness Training* (First ed.): Arbor House.

Vita

Bryan Mann was born in Joplin, MO in 1979. He was raised in northeast Oklahoma and southwest Missouri. Mann attended Glendale High School, followed by Southwest Missouri State University (SMSU, which is now Missouri State University) for his bachelor's degree which was in Health and Wellness Promotion. While at Southwest Missouri State University, Mann began volunteering in the athletic weight room, eventually earning an assistantship while an undergraduate.

Mann left SMSU to do an internship to complete his degree, which he did at Arizona State University and the University of Tulsa. While at Tulsa, he worked for Pat Ivey who would bring Mann to the University of Missouri as a Graduate Assistant Strength & Conditioning Coach.

During his undergraduate assistantship, Mann stumbled across a protocol called the Autoregulatory Progressive Resistance Exercise protocol (APRE) which he reluctantly decided to implement with his athletes for the sole reason of wanting to try something new. At the end of the training cycle, the athletes were performing 6-8 repetitions with their old 1RM. This gain in strength was remarkable and led Mann to believe it warranted more work.

In 2006, Mann convinced the coaching staff at the University of Missouri to give the APRE a try, and this dissertation is the result of that. The APRE again

improved absolute strength significantly better than Linear Periodization (LP) resulting in this study.