Tiered vs. Traditional Daily Undulating Periodization for Improving Powerlifting Performance in Trained Males

Andres Vargas
*University of South Florida, andresvargas@mail.usf.edu*

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Tiered vs. Traditional Daily Undulating Periodization for Improving Powerlifting Performance in Trained Males

by

Andres Vargas

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
Department of Exercise Science
College of Education
University of South Florida

Major Professor: Bill I. Campbell, Ph.D., FISSN, CSCS
Marcus Kilpatrick, Ph.D.
Layne Norton, Ph.D.

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ABSTRACT

Daily undulating periodization represents an increasingly popular trend in exercise science with which a traditional model has been established. Tiered daily undulating periodization pairs the DUP approach with a tiered training system which allows volume and intensity to be more evenly distributed throughout a given graining cycle. The concept of tiered daily undulating periodization is a novel form of periodization and has not been investigated. As such, a comparison of traditional and tiered daily undulating periodization has yet to be examined. Therefore, the purpose of this study was to compare the effects of traditional and tiered daily undulating periodization models as they relate to strength adaptations in trained males.

Twenty-seven resistance trained males (22.0 ± 4.5 years) completed an 8 week resistance training protocol. Subjects were randomly assigned to either the traditional daily undulating periodization group (DUP, n = 12) or tiered daily undulating periodization group (TDUP, n = 15). Participants were recruited from the campus recreation center and met the minimum strength requirements of bench pressing their bodyweight, squatting 125% of their bodyweight, and deadlifting 150% of their bodyweight. Strength measures included squat 1RM, bench press 1RM, deadlift 1RM, powerlifting total, and Wilk’s Coefficient. Each variable was measured at baseline and again after the 8 week training period. Each group performed the same number of sets, reps, and exercises throughout each training week. DUP specified all exercises in a given training bout to be performed the same intensity and repetition scheme. TDUP specified
performance of one high intensity exercise each day with each subsequent exercise being performed with lower intensity and differing repetition scheme. Data was analyzed via a 2x2 mixed factorial ANOVA with the alpha criterion for significance set at 0.05.

There were no significant differences between groups at baseline and no significant differences were observed between groups for total volume or intensity. With respect to strength dependent variables, there was a main effect for time (p < 0.001) for back squat 1RM (DUP pre = 140.5 ± 33.9 kg, DUP post = 163.3 ± 29.8 kg; TDUP pre = 147.3 ± 34.0 kg, TDUP post = 166.5 ± 30.7 kg), bench press 1RM (DUP pre = 104.2 ± 12.9 kg, DUP post = 114.9 ± 14.2 kg; TDUP = 110.4 ± 12.7 kg, TDUP post = 120.6 ± 11.9 kg), deadlift 1RM (DUP pre = 177.7 ± 26.4 kg, DUP post = 194.1 ± 20.2 kg; TDUP pre = 169.6 ± 37.5, TDUP post = 188.3 ± 37.5), powerlifting total (DUP pre = 422.4 ± 67.8 kg, DUP post = 472.4 ± 60.6 kg; TDUP pre = 427.1 ± 79.2 kg, TDUP post = 476.5 ± 74.1 kg), and Wilk’s score (DUP pre = 287.5 ± 49.3, DUP post = 320.0 ± 45.6; TDUP pre = 298.3 ± 45.8, TDUP post = 331.6 ± 38.7). However, no interaction effects were observed between DUP and TDUP for any of the strength dependent variables.

These results suggest that 8 weeks of tiered DUP resistance training leads to similar gains in strength compared to the traditional DUP model in trained males. This could be a result of the similar workload between both groups. While not significant, traditional DUP may be more efficacious for improving back squat 1RM (DUP = 16%; TDUP = 13%), while TDUP may elicit greater strength gains in the deadlift (DUP = 9%; TDUP = 12%). Furthermore, this study demonstrates that exercise order and training intensity can be manipulated throughout each training session according to personal preference while maintaining strength adaptations within a DUP model. Lastly, dropout rates in this study lead researchers to conclude that the DUP protocols investigated should be transient and not used as a long term training approach.
CHAPTER 1:
INTRODUCTION

Background

Resistance training has grown increasingly popular within the past several decades. This has led to a great deal of research being conducted to investigate the effects that resistance training can produce. Several benefits have been identified which include increased muscular strength, muscular hypertrophy, decreased body fat, improved connective tissue integrity, improved athletic performance, and numerous health improvements (Baechle & Earle, 2008; Pollack et al., 2000). Individuals will often rely on specific training designs in order to produce a desired outcome (i.e. increased strength or muscular hypertrophy). This programming of resistance training has come to be known as Periodization. This refers to a “logical and systematic sequencing of training factors in an integrative fashion in order to optimize specific training outcomes at predetermined time points” (Bompa & Haff, 2009). While most studies have established that periodized resistance training is superior to a nonperiodized model (O’Bryant & Stone, 1988; Willoughby, 1993; Ahmadizad, Ghorbani, Ghasemikaram, & Bahmanzadeh, 2014), much debate still exists over the most effective form of periodization.

Two major subtypes exist within the periodized model - Linear Periodization (LP) and Non-Linear Periodization (NLP). Linear Periodization is characterized by the division of a training program into different microcycles (1-7 days), mesocycles (3-6 microcycles), and macrocycles (3-6 mesocycles). Intensity and volume are manipulated as one progresses through
Each cycle and generally becomes more intense over time. NLP does not rely on this same structure but rather has regular and more randomized changes to volume and intensity. LP has been extensively researched and has long been thought to be the most effective form of periodization for increasing strength. However, recent studies have investigated several forms of NLP with impressive results. More specifically, Daily Undulating Periodization (DUP) has been shown to be superior to LP for increasing strength and hypertrophy in both an untrained and resistance trained population (Rhea, Ball, Phillips, & Burkett, 2002; Miranda et al., 2012; Ahmadizad et al., 2014; Prestes, De Lima, Frollini, Donatto, & Conte, 2009). DUP utilizes a segmented structure similar to the LP model while also undulating training volume and intensity throughout each cycle.

**Problem Statement**

Daily Undulating Periodization utilizes different training volumes and intensities for each training session with each exercise being performed with the same intensity on each given session. This presents a possible limitation in the performance of the exercise during higher intensity training sessions. It has been hypothesized that an athlete will see a decrease in maximal performance as they progress through several exercises of a high intensity/strength focused workout (Kenn, 2003). Instead, a tiered system of training has gained support as a possible improvement to the DUP model. In the tiered model, training intensity would be kept high for only one exercise with moderate and low intensity being used for each subsequent exercise during each session (Kenn, 2003). Additionally, the high intensity exercise would be rotated from session to session so that every core exercise is performed with equal intensity throughout the week. This would allow perhaps for a more efficient use of exercise effort and would negate the performance decrements that may manifest in the traditional DUP model. This
would ideally lead to enhanced performance and recovery from each training session as well as
greater strength improvements over time.

**Purpose of This Study**

This study will be conducted to compare the traditional DUP model against a tiered DUP model for increasing maximal muscular strength. To the researchers’ knowledge, there has yet to be a study that has compared these two training models. While tiered training has been used in practice for powerlifters and professional athletes alike, it is not well established whether a tiered structure will improve maximal muscular strength. This study will investigate if a tiered DUP model is superior to the traditional DUP model, which has been shown to be effective for improving strength, power, and hypertrophy. These variables are of great importance to many recreational and professional athletes. Improving the strength training model would allow for a more efficient increase in these training variables in a shorter period of time.

**Study Variables**

The independent variables in this study will include the performance of either a tiered undulating training program or a traditional uniform undulating training program. Additionally time will serve as a second independent variable with measures taken at baseline (the week prior to the 8-week training program) and again at week 10 (the week following the 8-week training program). The dependent variables will include 1RM in the back squat, bench press, and deadlift along with powerlifting total, and Wilk’s Coefficient.

**Hypotheses**

- **H₀(1)**: There will be no significant difference between TDUP and DUP with regard to Back Squat 1RM.
- **Hᵢ(1)**: There will be a significant difference between TDUP and DUP with regard to Back Squat 1RM.
- **H₀(2)**: There will be no significant difference between TDUP and DUP with regard to Bench Press 1RM.
HA(2): There will be a significant difference between TDUP and DUP with regard to Bench Press 1RM.

HO(3): There will be no significant difference between TDUP and DUP with regard to Deadlift 1RM.

HA(3): There will be a significant difference between TDUP and DUP with regard to Deadlift 1RM.

HO(4): There will be no significant difference between TDUP and DUP with regard to powerlifting total.

HA(4): There will be a significant difference between TDUP and DUP with regard to powerlifting total.

HO(5): There will be no significant difference between TDUP and DUP with regard to Wilk’s Coefficient.

HA(5): There will be a significant difference between TDUP and DUP with regard to Wilk’s Coefficient.

Operational Definitions

Back Squat

This exercise involves placing a standard barbell across the posterior deltoids or trapezius, bending at the knees and hips until the hip joint is below the knee joint and then extending the knees and hips to return to a standing position. This is the first exercise that is completed in a powerlifting competition.

Bench Press

This exercise involves lying flat on a bench press apparatus with shoulders and buttocks flat on the bench and feet flat on the floor. The individual will un-rack a barbell from the apparatus and lower the barbell to the middle sternum, pausing the movement on the sternum, and pressing the barbell back up to starting position. This is the second lift performed in a powerlifting competition.

Deadlift

This exercise involves bending down to grab a barbell positioned on the ground, and then extending at the knees and hips to lift the barbell up above the knees so that the individual is
standing in an erect position with barbell still in hands. This is the third and final lift performed in a powerlifting competition.

*Powerlifting Total*

The total amount of weight when adding together the heaviest squat, bench press, and deadlift that an individual successfully completes. The powerlifting total is used to award placing in each weight class of a powerlifting competition.

*Wilk’s Score*

A measure of powerlifting performance that can be used to identify the best overall lifter regardless of weight class, age group, or gender. This is calculated by multiplying the Powerlifting Total by the Wilks Coefficient associated with that person’s gender and bodyweight. The Wilks Coefficient can be determined from several charts which show the calculated value for each specific bodyweight and gender.

*Volume*

A quantitative measure of the amount of work performed by an individual. It is calculated by multiplying the weight used on an exercise by the number sets multiplied by the number of reps performed. This calculation is often done for each individual session, week, month, or even year of training.

*Intensity*

The percentage of an individuals’ 1RM that is used for the training session.

*Frequency*

The number of times a lifter performs an exercise throughout each training week.

*1 Rep Max (1RM)*
The amount of weight that an individual can successfully lift with proper technique with a maximal effort. No additional repetitions could be completed with the weight used in a true 1 rep max.

**Plus Set**

A set performed for maximal repetitions to absolute volitional fatigue in which a participant would be unable to complete an additional repetition. This is often completed as the last set of a given exercise.

**Linear Periodization**

A style of periodization which breaks the resistance training into segments which begin with high volume and low intensity sessions and progress toward low volume and high intensity sessions.

**Non-Linear Periodization**

A method of periodization in which volume and intensity are varied throughout each training microcycle, or macrocycle. A lifter would choose what intensity or volume they would like to perform during each cycle.

**Daily Undulating Periodization (DUP)**

A form of non-linear periodization in which the volume and intensity is varied between training sessions in a week. Training sessions often rotate between a hypertrophy, power, and strength focus throughout each training week with plus sets being performed for all lifts on the strength focused day.

**Tiered Daily Undulating Periodization (TDUP)**
A form of DUP in which each lift is performed with a strength, power, or hypertrophy focus during each training session rather than rotating them all uniformly for each day. One plus set is performed for only the strength focused lift during each training session.

Assumptions

The researcher assumes that truthful and accurate information will be given by the participants of this study in regards to pre-screening information, diet, use of ergogenic aids (supplements, anabolic steroids, medication), health status, and any other pertinent information. Additionally, it is assumed that subjects will put forth maximal effort during each plus set as well as during the pre and post-test assessment. The researcher also assumes that participants will not engage in additional resistance training outside of this research study. It is assumed that researchers and assistants are capable of judging proper squat, bench press, and deadlift technique and have the ability to determine whether a repetition would be considered successful under powerlifting regulations.

Limitations

Although conditions will be set to simulate a real world gym environment, the participants will be training in a lab that could limit the transferability of the results to actual gym or competition setting. Participants in this study will be healthy and resistance trained which may also limit the translation of the results to other populations such as those in untrained or unhealthy populations. Maximal strength measures will be taken in line with the interests of those who compete in powerlifting which may not be as beneficial for those who do not participate in powerlifting.
**Delimitations**

This study will include only male participants which may limit the transferability to females. Treatment will consist of only resistance training and will be absent of conditioning work such as agility, cardiovascular, or plyometric training. This could hinder the carryover to those who engage in concurrent training such as elite team sport athletes. Training will be conducted “raw” with no powerlifting gear being utilized to provide supplemental benefit. Geared powerlifters may not benefit as well from the results of this study. Inclusion criteria will be restricted to those who are capable of bench pressing their bodyweight, squatting 1.25 times their bodyweight and deadlifting 1.5 times their bodyweight. This may limit the carryover to those who do not meet these thresholds. Lastly, the study will take place over 10 weeks in order to accommodate a typical college semester.

**Significance**

The aim of this study is to investigate the efficacy of a tiered approach to daily undulating periodization in regards to strength improvement in comparison to the traditional DUP model. Many recreational and professional powerlifters employ a tiered approach within DUP currently. This study will determine whether a tiered approach is beneficial for those looking to increase maximal strength. Additionally, this study will help to identify whether a tiered approach to training yields greater motivation and satisfaction from the training experience. This would be important for understanding what factors contribute toward an individuals’ participation in resistance training.
CHAPTER 2:
LITERATURE REVIEW

Resistance Training and Muscular Strength

There has long been an association between the amount of resistance training that one performs and the magnitude of their strength. Historically, those whose daily tasks or hobbies involve moving or lifting heavy objects often possess greater muscular strength compared to the average human being. This association has led to a great deal of research that has shown resistance training to be highly effective for increasing strength. Early studies utilized quite basic designs and testing procedures but were successful in establishing a trend which showed that resistance training would increase muscular strength (Pipes, 1978). A classic study by Staron et al. (1994) measured skeletal muscle adaptations to lower extremity resistance training in an untrained population. Both males and females participated in an eight-week resistance training program designed to increase the strength and size of the muscle. The investigators found significant increases in maximal muscular strength following the eight-week program but no significant differences in muscle cross sectional area.

More recent studies have used more robust interventions while producing similar results. Campos et al. (2002) conducted a study in which 32 healthy untrained males were randomly assigned to three different resistance training groups in order to investigate the effect of different repetition schemes on strength, hypertrophy, and local muscular endurance. Participants were divided into either a low, moderate, or high repetition group and asked to complete an eight week
high intensity lower body resistance training program. The results of this study showed resistance training to be effective for significantly increasing maximal strength regardless of the repetition scheme used. A very similar study performed by Weiss, Conex, and Clark (1999) investigated low, moderate, and high repetition squat training. This seven-week intervention conducted on novice subjects led to significant increases in a concentric-only squat one rep max (1RM) ranging from an average of 34kg in the high repetition group to 75kg in the low repetition group. Collectively, the findings of these studies establish evidence that resistance training is effective for increasing muscular strength, at least in an untrained population.

**Strength Adaptations in Trained Individuals**

It has been theorized that early strength adaptations to resistance training are mainly a byproduct of neural adaptations rather than muscular augmentation (Kraemer, 1996). Thus, general guidelines have been established which state that moderate intensity and volume will effectively increase muscular strength in beginners (Baechle, 2008). However, research has shown that resistance training is still effective for increasing muscular strength in a trained population. Mangine et al. (2015) aimed to investigate the difference between a high volume and a high intensity training protocol with respect to changes in maximal upper body and lower body strength. Thirty-three physically active, resistance trained males were recruited to complete an eight week, four day per week resistance training protocol. Both the high volume and high intensity groups increased their 1RM bench press by 6.4 and 15 kilograms respectively. This represented a statistically significant increase in strength for both groups as well as a significant difference between groups.
Similar findings were found in a study investigating the effects of either a full body workout routine or a split body part routine on maximal strength and muscle hypertrophy (Schoenfeld, Ratamess, Peterson, Contreras, & Tiryaki-Sonmez, 2015). Twenty subjects were recruited to participate in this eight week intervention and were limited to young resistance trained males with a minimum of one year of regular resistance training experience. Average increases of 8.5kg and 13kg in 1RM bench press and 1RM back squat were observed among both groups. These results were statistically significant with no significant difference between groups. These data seem to establish that resistance training can effectively increase muscular strength regardless of training status. However this is true only if the training stimulus is of sufficient quality for the training age of the individual.

The efficacy of resistance training for increasing muscular strength has been shown even in advanced level athletes. Naclerio et al. (2013) investigated the effect of three different resistance training protocols on muscular strength. Thirty two men and women athletes were recruited to participate in the intervention in which each were randomly assigned to either a low, moderate, or high volume training protocol. Results showed significant increases in upper body strength for all three training groups. Additionally, lower body maximal strength was increased in the high volume group but not the low or moderate training groups.

Similar results were seen in a study by Izquierdo et al. (2006) in which 42 professional Basque ball players with over 12 years of training experience were recruited to participate in a resistance training protocol. Their goal was to investigate the effect of training to failure on muscular strength, power, and endurance. Participants were assigned to either a failure group or non failure group for 11 weeks, followed by a five week peaking protocol. The researchers found that both training protocols produced statistically significant increases in upper and lower body
strength with no difference between groups. The collective results of these two studies conclude that resistance training can effectively increase muscular strength even in a well trained population. However, special attention should be paid to the nature of the resistance training that is utilized for each population.

**Importance of Training Volume**

Indirect observation of the research mentioned thus far has uncovered a possible relationship between training volume and the effects seen from the resistance training intervention. It was shown that studies which utilized an untrained population, a rather large increase in muscular strength was reported. The increase in strength did not seem to be dependent on training volume in this population. Campos et al. (2002) found no significant difference between low, moderate, or high volume training in terms of muscular strength. The same was true in a study conducted by Starkey et al. (1996). Researchers recruited 59 untrained individuals to complete a 14-week resistance training protocol. Participants were randomly assigned to a low volume, high volume, or control group. Low volume consisted of one set of leg training three times per week, while high volume consisted of three sets completed three times per week. Results showed that both training groups saw significant increases in maximal dynamic strength with no significant difference seen between the groups. While no significant difference existed between different volumes of training, there did seem to be a trend for greater strength increases with higher volume training.

The apparent positive relationship between volume and muscular strength becomes more apparent when investigating a resistance trained population. Results from Naclerio et al. (2013) seem to show that upper body strength will increase to a similar degree regardless of the training
volume used. However, results from the same study looking at lower body strength showed that only high volume training was effective for increasing strength. This trend continued in a study by Robbins, Marshall, and McEwen (2012). The investigators recruited 43 healthy, resistance trained individuals to participate in a total of 12 weeks of resistance training. Subjects were randomly assigned to either a low (1 set), moderate (4 sets), or high (8 sets) volume condition with equal intensity. It was shown that all three volume groups showed significant improvements in muscular strength by the end of the study. However, high volume training produced significantly greater increases in strength compared to low volume training.

**Importance of Intensity**

Looking at volume alone, the research would seem to suggest that the higher the volume utilized in training, the greater the expected increase in strength. However, quite a few variables work in conjunction with training volume to elicit muscular strength increases. Workout intensity plays a crucial role in the development of strength, perhaps more so than even workout volume. A positive relationship seems to exist between training intensity and strength. Looking again at Campos et al. (2002), results showed that increases in strength were seen in all participants regardless of the intensity of the training. However, those in the high intensity training group had significantly greater increases in strength compared to moderate and low intensity training. Another study investigated the effects of low load versus high load bench press training on upper body strength and hypertrophy (Ogasawara, Loenneke, Thiebaud, Abe, 2013). The study utilized nine untrained males with each participant completing both the high load and low load training protocol with 12 months separating the protocols. Results showed that high load resistance training increased muscular strength to a significantly greater degree than low load training.
Mitchell et al. (2013) looked at unilateral knee extension exercise utilizing either 80% or 30% of 1RM and the effect that each had on knee extension strength. Eighteen untrained males participated in this 10 week study in which three sets of knee extensions were performed to volitional fatigue. Results showed that both groups had a significant increase in strength after 10 weeks of training. However, those who utilized the higher intensity training had significantly greater increases in strength.

This trend for greater strength increases from higher intensity training has also been shown in a well trained population. Schoenfeld and partners investigated the effect of different training intensities on muscular strength in well trained males (Schoenfeld, Ratamess, Peterson, Contreras, Sonmez, & Alvar, 2014). Twenty resistance trained males participated in either a lower intensity 10 repetition training style or a higher intensity three repetition training style. Volume was equated for both groups to eliminate any confounding effect of training volume. Researchers found that higher intensity training led to significantly greater upper body strength as well as a trend toward greater lower body strength. These results are in agreement with the findings of Holm et al. (2008) which showed that higher intensities at 70% 1RM were superior to lower intensities of 15.5% 1RM for increasing strength.

The importance of intensity can be attributed, in part, to neuromuscular adaptations which result in improved strength. As the intensity of contraction increases, higher threshold motor units must be recruited according to Henneman’s Size Principle (Conwit, Stashuk, Tracy, McHugh, Brown, & Metter, 1999). This recruitment of high threshold motor units is also accompanied by a change in firing frequency to most efficiently produce adequate muscular force (Milner-Brown, Stein, & Yemm, 1973). Del Valle and Thomas (2005) showed that higher intensity contractions resulted in higher firing rates compared to lower intensity. Additionally,
Custem, Duchateau, and Hainaut (2008) found that maximal firing rates in muscle fibers is increased following resistance exercise. These changes in neuromuscular physiology seem to increase strength and thus, high intensity training is an essential component of resistance training.

**Periodization**

The importance of utilizing adequate volume and intensities in a resistance training protocol has been well established in the literature. However, special attention must be paid to the fashion in which the volume and intensity of training are manipulated throughout micro, meso, and macrocycles. Periodization is a concept of manipulating training volume and intensity over given periods of time to most efficiently elicit improvements from a training program (Kraemer, Fleck, & Evans, 1999). Several different forms of periodization have been shown to successfully increase strength in both trained and untrained populations including linear, block, and undulating periodization. What seems to be clear from the literature is that utilizing periodization within a resistance training program is quite beneficial and perhaps necessary as training age increases over time. This was demonstrated by Schiotz and partners as they compared periodized and constant intensity training on strength and performance (Schiotz, Potteiger, Huntsinger, & Denmark, 1998). Fourteen trained, male, ROTC cadets were recruited to complete 10 weeks of resistance training with six subjects in a periodized group and eight subjects in a constant intensity group. Periodized training was found to significantly increase upper body strength while constant intensity training produced a non-significant increase.

Monteiro et al. (2009) compared the efficacy of periodized vs. non-periodized training for improving muscular strength. Twenty-nine well trained males were recruited to complete this 12 week study. Results showed that periodized training lead to significantly greater increases in
strength compared to the non-periodized approach. These findings favor the use of periodization within a weight training program.

**Linear Periodization**

The most popular form of periodization utilized by strength training professionals is linear periodization. This form of periodization was adapted from Matveyev’s classical model for periodizing training with specific sport seasons (Matveyev, 1966). Traditionally, this style promoted increasing intensity and decreasing volume over the course of a training block. Kerksick et al. (2009) investigated the effects of linear periodized resistance training program on 49 resistance trained young and middle aged men. Training consisted of traditional strength training exercises performed four days per week for eight weeks. Results showed significant increases in upper body and lower body strength at the completion of the study. Prestes et al. (2009) compared linear periodization (LP) with reverse linear periodization (RLP) and their effects on strength. This study once again utilized a resistance trained group but limited their sample to 20 women subjects between the ages of 20 and 35 years old. Training lasted 12 weeks with progressive intensity increases for the LP group and intensity decreases in the RLP group. It was found that both periodization models produced significant increases in upper and lower body strength. However, linear periodization produced a greater increase in strength compared to reverse linear periodization. This would seem to agree with the studies mentioned previously which found that strength increases to greater extent as the intensity becomes greater.

**Daily Undulating Periodization vs. Linear Periodization**

A different approach to periodizing training programs that has been popularized is non-linear periodization. This style utilizes an undulating pattern in which intensity and volume are
manipulated constantly at regular intervals but do not necessarily move toward higher intensity and lower volume over time (Bradley-Popovich, 2001). This form of periodization has been promoted as a more practical model for athletes as competition days can be more easily designed into the training program. Common adaptations have involved manipulating training variables from week to week and, perhaps more commonly, from day to day. Recently, Daily Undulating Periodization (DUP) has gained tremendous popularity among the powerlifting and bodybuilding communities. Due to the impressive success and strength improvement in those who utilize a DUP approach, this training style has seemingly replaced the traditional linear model for many in this population.

Several studies have been conducted to compare the efficacy of DUP and Linear Periodization for strength improvement. Monteiro et al. (2009) investigated a 12 week resistance training program utilizing either a Linear Periodization or Nonlinear/Undulating Periodization model. Twenty-seven resistance trained males were recruited and randomly assigned to each training group. They showed that although both groups saw significant strength increases, the nonlinear group had significantly greater increases in both upper and lower body strength. While this study utilized a weekly undulating pattern, it still lends credence to the effectiveness of an undulating pattern overall.

Miranda et al. (2011) directly investigated a linear periodization and daily undulating periodization resistance training program and their effects of maximal strength. Twelve weeks of training took place with four sessions being completed each week for each participant. Subjects were limited to 20 recreationally trained males. Data for 1RM tests in the bench press and leg press exercises showed a significant increase in strength for both training groups. Additionally, there was no significant difference between groups despite a higher magnitude of strength
increase for the DUP group. However, data obtained from the DUP group was found to have a larger effect size compared to the LP group. This seems to indicate that DUP was trending toward greater efficacy and perhaps a larger sample would have revealed a significant difference between groups.

Direct comparison of DUP and LP was seen in the classic study by Rhea et al. (2002). Twenty total subjects completed the 12 week training protocol. Investigators found that LP led to an increase of 14 and 26% in bench press and leg press strength. In contrast, DUP led to increases of 29 and 56% in those two measures. This represented a statistically significant advantage for DUP in terms of increasing strength. This result was corroborated by Ahmadizad et al. (2013) which compared non-periodized, linear periodized, and daily undulating periodized training and their effectiveness for increasing muscular strength. Thirty two sedentary males completed eight weeks of resistance training which consisted of intensities ranging from 50-85% of 1RM. Researchers found that all three training groups increased their muscular strength significantly. However, DUP was found to be significantly better for increasing upper body strength and, while not statistically significant, DUP did result in greater lower body strength as well.

**Improving the DUP Model**

Daily Undulating Periodization can be seamlessly adapted to many various athletic populations and thus research that investigates DUP can be beneficial for many individuals. However, gaining access to high level athletes can be quite difficult. One population that is both accessible and open to participating in resistance training research would be those in the powerlifting community. For this reason some research has attempted to improve the DUP model
for powerlifters looking to gain strength most efficiently. Zourdos et al. (2015) aimed to compare
a new approach to DUP training against the traditional DUP model. The modified DUP model
utilized a sequence of training days which consisted of hypertrophy on day 1, power on day 2,
and strength on day 3. This differed from the traditional model of hypertrophy followed by
strength, and then power on the last day. Results showed that participants in the modified DUP
group produced significantly greater amounts of total and relative volume compared to the
traditional group. This led to significantly greater upper body strength improvement in the
modified group as well as stronger effect sizes in both squat and bench press for the modified
group.

**Rationale for Tiered Daily Undulating Periodization**

To further improve the DUP model beyond the work of Zourdos et al. (2016), the level of
effort used during each training session should be carefully considered. Recent studies have
utilized a “plus set” on the last set of each strength day (meaning that multiple plus sets are
conducted during the strength day workout) in order to adjust the weight used for the following
week (Zourdos, 2016; Colquhoun, 2017). While the first movement of this day receives 100% of
the individuals’ best effort, subsequent movements during the training session that are still
utilizing a plus set could see an exponential decline in performance. This perhaps could be a
result of both neural and muscular fatigue that would occur as max effort is applied to multiple
movements with insufficient recovery time. A possible improvement would be to spread the plus
sets across several training sessions by performing a plus set for only one exercise per training
session. An individual would emphasize max effort with one movement during each training
session while using moderate, and then light effort for each subsequent exercise. This concept
was introduced in “The Coach’s Strength Training Playbook” by Joe Kenn (Kenn, 2003). Kenn
suggested that traditional “heavy days” in which many exercises are performed with high intensity loads causes performance decrements during the middle, and later portions of the workout. This results in an athlete’s inability to perform at maximum ability and may blunt the effectiveness of the resistance exercise. Instead, Kenn recommended a tiered approach in which maximum effort is emphasized on one movement per session, while rotating the max effort movement throughout the week.

The research has demonstrated DUP to provide significantly greater strength improvement compared to LP. Additionally, it has been shown that the original DUP model can be improved upon to produce greater strength increases. A tiered approach can be applied to Daily Undulating Periodization to perhaps further improve the effectiveness of the model. To the researchers knowledge, no studies have investigated the efficacy of Tiered Daily Undulating Periodization (TDUP). By placing emphasis on one powerlifting movement per day, a greater amount of effort can be applied over the course of the training week compared to the traditional DUP model. This could theoretically lead to greater strength improvement for each of the core exercises. Additionally, by performing moderate and/or light training on the remaining powerlifts during each session, the athlete benefits from increased frequency and practice of the lift. Combining these factors with constant adjustment of the load and intensity used within the training, maximal improvements in strength and hypertrophy should be seen with the TDUP model that will be explained in the following section.
CHAPTER 3:
METHODS

Participants

Thirty six total participants were recruited to participate in this study. Subjects were limited to young (18-45 years), healthy, resistance trained males. In order to ensure that participants met these parameters, they were required to meet all necessary inclusion criteria. This included the ability to bench press their bodyweight in pounds, squat one and a quarter times their bodyweight in pounds, and deadlift one and a half times their bodyweight in pounds. Additionally, subjects needed to have participated in regular resistance training prior to this study. Lastly, subjects were required to self-report their health status to ensure the inclusion of only healthy participants.

Determination of Sample Size

Using data from a recent investigation (Zourdos et al., 2015), the effect size calculated for the increase in maximal squat strength was 0.75. Using this calculated effect size, an alpha level of 0.05, and a power of 0.9, a sample size of approximately 17 subjects per group was set in order to see a significant difference in maximal squat strength, if one existed. This effect size was calculated based on the increase in maximal squat strength, which is the same measurement that was assessed in this study. For these reasons it was believed that recruiting 40 subjects (20 per group) was sufficient to detect a significant difference in our primary outcome variable if a true difference existed. In total, 45 subjects were originally recruited to begin this study with 36
of those subjects meeting all requirements and agreeing to participate. The above calculation and resulting sample size estimates were based on Kirk (1999).

**Screening and Entry Procedures**

This study was limited to healthy, physically active male participants between the ages of 18-45 years old that were not deemed "high risk" for cardiovascular disease according to guidelines established by the American College of Sports Medicine. Potential subjects were screened based on age, risk factors for cardiovascular disease, and presence of pulmonary, cardiovascular, and/or metabolic disease symptoms. Additionally, subjects demonstrated the ability to bench press a minimum of 1.0 times their body weight in pounds, squat a minimum of 1.25 times their body weight in pounds, and deadlift a minimum of 1.5 times their body weight in pounds.

Male participants deemed to be ‘high’ risk according to the American College of Sports Medicine’s risk stratification categories were excluded from participation in this study. ‘High’ risk is the classification given to participants who have known cardiovascular, pulmonary, or metabolic disease or one or more of the following conditions: pain or discomfort in the chest, neck, jaw, arms or other areas that may result from ischemia; shortness of breath at rest or with mild exertion; dizziness during exercise; orthopnea; ankle edema; tachycardia; intermittent claudication; known heart murmur; unusual fatigue or shortness of breath with usual activities. In addition, participants were excluded from participating if they possessed any preexisting medical condition including but not limited to: high or low blood pressure, high or low cholesterol, cardiac arrhythmia, stroke, heart, liver, kidney or thyroid disease, seizure disorder, psychiatric disease, osteoporosis, diabetes, or if taking any medications for these conditions. The use of a
pre-activity screening questionnaire was used to obtain this health information. Furthermore, participants who did not meet the required minimum 1 repetition maximums relative to body weight were excluded from this study. Subjects were instructed to cease all supplementation for at least 6 weeks prior to the study with the exception of vitamin, branch chain amino acid, and protein supplements. Both groups were instructed to refrain from supplementation throughout the entirety of this study. Lastly, participants were asked to refrain from all outside training during the duration of this study.

**Instrumentation**

Prior to participation in the study, potential subjects completed a basic health history document which indicated any major health concern. Individuals then filled out a PASQ as well as a basic demographics survey to determine training status, age, race, training history, injury history, and any potential use of performance enhancing supplements. Lange Skinfold Calipers and BodyMetrix Portable Ultrasound devices were used to assess body composition in this study. One repetition max testing was delivered by individuals with the Certified Strength and Conditioning Specialist (CSCS) credential to determine maximum strength both pre-study and post-study.

**Equipment**

Strength training equipment that was used in this study included Rogue Power Racks, Texas Power Barbells, a Rogue Ohio Power Bar, and a York Barbell. Additionally, York Barbell and Rogue olympic lifting platforms were used for deadlifting. York Barbell and Ivanko weight plates and dumbbells were utilized along with MAXWOD adjustable benches. Lastly, subjects
were permitted to use weight belts, knee sleeves, and weightlifting shoes throughout the study and 1RM testing.

Procedures

This study took place over 10 weeks with week 1 serving as a familiarization and pre-training one rep max testing week, weeks 2-9 serving as the training intervention, and week 10 serving as the post-training on rep max testing week. A general time flow of progression from week one to week ten is illustrated in Table 1 below.

Table 1. Flow of study progression from week 1 to week 10.

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td>1RM Testing</td>
<td>1RM Testing</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td><strong>Weeks 2-9</strong></td>
<td>DUP Workout</td>
<td>Off</td>
<td>DUP Workout</td>
<td>Off</td>
<td>DUP Workout</td>
</tr>
<tr>
<td><strong>Week 10</strong></td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>1RM Testing</td>
<td>1 RM Testing</td>
</tr>
</tbody>
</table>

Pre-Test

Subjects were instructed to discontinue the use of any performance enhancing supplements including creatine, and β-Hydroxy β-methylbutyric acid (HMB) for at least 6 weeks prior to the study. These substances in addition to any pre-workout supplements were not to be used throughout the entirety of the 10 week study. Multivitamins, fish oil, whey protein, branched chain amino acids and any medically necessary compounds were permitted. Prior to the
start of the training protocol, participants underwent one rep max testing for the squat, bench press, and deadlift in order to confirm that they met the minimum strength requirements. 1RM testing was conducted in the Performance & Physique Enhancement Laboratory under the guidance of Certified Strength and Conditioning Specialists. Any persons who failed to meet the minimum strength requirements were excluded from the study.

**Familiarization/1RM Testing Week**

Participants demonstrated proper technique and form of the movements under the supervision of a Certified Strength and Conditioning Specialist. Participants’ exercise form was critiqued and improved upon if necessary. Subjects then worked up to a one repetition max for the squat, bench press, and deadlift in accordance with USAPL standards for successful lifts. 1RM testing was also supervised and judged by a Certified Strength and Conditioning Specialist. In addition, a Squat Beeper device was worn by each participant for 1RM squat testing. The purpose of this device was to standardize the depth that each participant was required to hit in the squat. The beeper produced an audible beeping noise when participants achieved a parallel/90 degree upper leg position in the squat.

**Body Composition Testing**

Initial tests during Week 1 of this study involved obtaining the following personal information: height, weight, and body composition (Lange Skinfold Calipers and BodyMetrix Portable Ultrasound). Subjects were required to fast from food and drink for at least eight hours prior to the body composition testing. Body composition measurement sites included the pectoral, mid-axillary, abdominal, tricep, subscapular, suprailliac, and thigh. These procedures
were then repeated for post-testing procedures during Week 10 of this study. All body composition assessments were conducted by the same technician to ensure reliability.

Experimental Protocol

Two experimental groups were used for this study which involved the use of either a traditional DUP training protocol or a tiered DUP training protocol. Following the baseline testing period, participants were pair matched and randomized into one of the two training groups based on their maximal strength. The two strongest subjects were randomized into either group based on the flip of a coin, followed by the next two strongest, and so on for the entire sample. The randomization process was led by the principle investigator. Both training protocols included three training sessions per week and contained the same exercises and number of total sets and reps each week. Total lifting volume was equated between training groups. Subjects were afforded volitional rest between each set of exercise. Traditional DUP involved completing high, moderate, and low intensity training sessions throughout the week. Plus sets were performed for the squat, bench press, and deadlift during the high intensity day for the traditional DUP group. This involved the individual completing as many reps as possible on the last set of the given exercise until they could no longer complete an additional repetition or failed the lift. The traditional DUP training overview can be seen in Table 2 and Table 3 below.

Tiered DUP involved three training sessions that had a squat, bench press, or deadlift emphasis. Emphasis was rotated throughout the week so that a high intensity strength protocol was applied to the exercise of emphasis for each session. One plus set was completed each day for the high intensity exercise for that session so that one plus set was performed for each main lift by the end of each week (this is in comparison to the traditional DUP training group which
only performed plus sets on one day per week for each lifting exercise [only performed on day 3 as can be seen in table 2 and 3 below]. Non-emphasized main lifts were completed using either a moderate or low intensity training protocol after the completion of the exercise of emphasis.

This information is summarized in Table 4 and Table 5 below. Additionally, both groups completed assistance exercises following their powerlifting movements on Day 2 of each week (Table 6).

**Table 2.** Resistance training protocol for the traditional DUP group.

<table>
<thead>
<tr>
<th>Training Session - Intensity</th>
<th>Exercise</th>
<th>Week 1-2</th>
<th>Week 3-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1 – Low</td>
<td>Squat</td>
<td>4 sets; 8 reps</td>
<td>4 sets; 7 reps</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 8 reps</td>
<td>4 sets; 7 reps</td>
</tr>
<tr>
<td></td>
<td>Deadlift</td>
<td>4 sets; 8 reps</td>
<td>4 sets; 7 reps</td>
</tr>
<tr>
<td>Day 2 – Moderate</td>
<td>Squat</td>
<td>4 sets; 6 reps</td>
<td>4 sets; 5 reps</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 6 reps</td>
<td>4 sets; 5 reps</td>
</tr>
<tr>
<td>Day 3 – High</td>
<td>Squat</td>
<td>4 sets; 4 reps (+)</td>
<td>4 sets; 3 reps (+)</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 4 reps (+)</td>
<td>4 sets; 3 reps (+)</td>
</tr>
<tr>
<td></td>
<td>Deadlift</td>
<td>4 sets; 4 reps (+)</td>
<td>4 sets; 3 reps (+)</td>
</tr>
</tbody>
</table>

**Table 3.** Resistance training protocol for the traditional DUP group continued.

<table>
<thead>
<tr>
<th>Training Session - Intensity</th>
<th>Exercise</th>
<th>Week 5-6</th>
<th>Week 7-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1 – Low</td>
<td>Squat</td>
<td>4 sets; 6 reps</td>
<td>4 sets; 5 reps</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 6 reps</td>
<td>4 sets; 5 reps</td>
</tr>
<tr>
<td></td>
<td>Deadlift</td>
<td>4 sets; 6 rep</td>
<td>4 sets; 5 reps</td>
</tr>
<tr>
<td>Day 3 – Moderate</td>
<td>Squat</td>
<td>4 sets; 4 rep</td>
<td>4 sets; 3 reps</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 4 rep</td>
<td>4 sets; 3 reps</td>
</tr>
<tr>
<td>Day 4 – High</td>
<td>Squat</td>
<td>4 sets; 2 reps (+)</td>
<td>4 sets; 1 reps (+)</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>4 sets; 2 reps (+)</td>
<td>4 sets; 1 reps (+)</td>
</tr>
<tr>
<td></td>
<td>Deadlift</td>
<td>4 sets; 2 reps (+)</td>
<td>4 sets; 1 reps (+)</td>
</tr>
</tbody>
</table>
**Table 4.** Training protocol for the tiered DUP group.

<table>
<thead>
<tr>
<th>Tiered DUP Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Session - Intensity</td>
</tr>
<tr>
<td>Day 1 – Squat Emphasis (Bench - Moderate) (Deadlift – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Day 2 – Bench Emphasis (Squat – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Day 3 – Deadlift Emphasis (Squat – Moderate) (Bench – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Table 5 – Training protocol for the tiered DUP group continued.**

<table>
<thead>
<tr>
<th>Tiered DUP Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Session - Intensity</td>
</tr>
<tr>
<td>Day 1 – Squat Emphasis (Bench - Moderate) (Deadlift – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Day 2 – Bench Emphasis (Squat – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Day 3 – Deadlift Emphasis (Squat – Moderate) (Bench – Low)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Table 6.** Assistance exercises.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets</th>
<th>Reps (Odd Weeks)</th>
<th>Reps (Even Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pullups</td>
<td>4</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Glute-Ham Raise</td>
<td>4</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Bicep Curls</td>
<td>4</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Skull Crushers</td>
<td>4</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Rope Abdominal Pulldown</td>
<td>4</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>
General Training Session Overview

Subjects reported to the Performance & Physique Enhancement Laboratory, checked in at the lab supervisor table, and then had the opportunity to engage in a self-prescribed individual warm-up prior to the start of their workout for the day. Those assigned to the traditional DUP protocol trained each movement with the same intensity with either a hypertrophy, power or strength focus as outlined in Tables 2 and 3 above. Subjects assigned to the tiered DUP program emphasize a high intensity “strength” focus on one main lift with hypertrophy and power work being used for the other main lifts. Upon completion of the workout, subjects ingested 25g of whey protein.

Progression of Training Weight

The working weight used during the 8-week training program was dependent upon the performance for the plus sets completed during the prior week. Increases or decreases in working weight were progressed in accordance with Table 7 below.

Table 7. Progression chart.

<table>
<thead>
<tr>
<th>Number of Reps Completed</th>
<th>Progression for Following Weeks of Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 reps below goal</td>
<td>Decrease working weight by 4%</td>
</tr>
<tr>
<td>3 reps below goal</td>
<td>Decrease working weight by 3%</td>
</tr>
<tr>
<td>2 reps below goal</td>
<td>Decrease working weight by 2%</td>
</tr>
<tr>
<td>1 rep below goal</td>
<td>Decrease working weight by 1%</td>
</tr>
<tr>
<td>Meets goal reps</td>
<td>Keep working weight the same</td>
</tr>
<tr>
<td>1 rep above goal</td>
<td>Increase working weight by 1%</td>
</tr>
<tr>
<td>2 reps above goal</td>
<td>Increase working weight by 2%</td>
</tr>
<tr>
<td>3 reps above goal</td>
<td>Increase working weight by 3%</td>
</tr>
<tr>
<td>4+ reps above goal</td>
<td>Increase working weight by 4%</td>
</tr>
</tbody>
</table>
Statistical Analysis

Data was analyzed using a 2x2 mixed factorial ANOVA for each of the dependent variables. This choice was due to the use of a pre and post assessment in conjunction with 2 different treatment conditions. Additionally, baseline measurements were analyzed by way of independent t-tests to reveal any possible baseline differences. Alpha criterion for significance was set at 0.05 for all tests. Measurement of effect size for each independent variable were analyzed via Cohen’s D measurements. Lastly, all data analysis were completed using the SPSS software package.
CHAPTER 4:
RESULTS

Baseline Characteristics

Analysis of descriptive characteristics between the two groups revealed no significant differences. Both groups were of similar age (DUP = 20.5 ± 1.57 years; TDUP = 23.2 ± 5.62 years; p = 0.12), height (DUP = 179.1 ± 9.3 cm; TDUP = 174.9 ± 7.4 cm; p = 0.208), and weight (DUP = 82.5 ± 11.8 kg; TDUP = 78.3 ± 10.5 kg; p = 0.34) to begin the study. Baseline characteristics for body composition, and strength measures showed no significant differences. Dietary intakes were statistically similar between groups at baseline with the exception of baseline protein intake which was significantly different (DUP = 145.6 ± 20.6 g; TDUP = 170.2 ± 34.9 g; p = 0.034). All data pertaining to baseline measurements can be seen in Table 8.

Strength Hypothesis Testing

Maximal strength was measured via five criterion which included total strength, back squat 1RM, bench press 1RM, deadlift 1RM, and Wilk’s score. H_{0(1)} stated that there would be no significant difference between TDUP and DUP with respect to back squat 1RM. Data analysis revealed no significant difference between groups for back squat 1RM following the ten week intervention (DUP = 163.3 ± 29.8, Δ = 22.8 kg; TDUP = 166.5 ± 30.7, Δ = 19.2; p = 0.414). Based on this result, we fail to reject the null hypothesis. Although an interaction effect was not observed for back squat 1RM, a significant main effect for time was seen (p = <0.001). Both the
DUP and TDUP training groups significantly increased their back squat 1RM by 16.2% and 13.0% respectively. This data can been seen in Table 9 below.

$H_{0(2)}$ stated that there would be no significant difference between TDUP and DUP over the 10 week intervention for bench press. Statistical analysis revealed no significant difference between groups ($DUP = 114.9 \pm 14.2 \text{ kg}, \Delta = 10.7 \text{ kg}; TDUP = 120.6 \pm 11.9 \text{ kg}, \Delta = 10.2 \text{ kg}; p = 0.814$). Based on these results, we fail to reject the null hypothesis. While there was no interaction effect present in this measure, there was an observed main effect for time ($p = <0.001$). Both the DUP and TDUP groups increased their bench press 1 rep max by 10.3% and 9.2% respectively following ten weeks of resistance training. This data can been seen in Table 9 below.

In reference to deadlift maximal strength, $H_{0(3)}$ stated that there would be no significant difference between TDUP and DUP with respect to deadlift one rep max over the ten week intervention. Results showed that there was no significant difference between groups over time ($DUP = 194.1 \pm 20.2 \text{ kg}, \Delta = 16.4 \text{ kg}; TDUP = 188.3 \pm 37.5 \text{ kg}, \Delta = 18.7 \text{ kg}; p = 0.554$). Based on these results, we fail to reject the null hypothesis. Although no interaction effect was observed, it should be noted that there was a main effect for time ($p = <0.001$). Both the DUP and TDUP groups increased their deadlift one rep max by 9.2% and 11.0% respectively following ten weeks of resistance training. This data can been seen in Table 9 below.

With respect to total strength, $H_{0(4)}$ stated that there would be no difference between TDUP and DUP in terms of total strength over the ten week intervention (defined as the powerlifting total). Data analysis revealed no significant difference between the groups over time ($DUP = 472.4 \pm 60.6 \text{ kg}, \Delta = 50 \text{ kg}; TDUP = 476.5 \pm 74.1 \text{ kg}, \Delta = 49.4 \text{ kg}; p = 0.937$). Based on
these findings, we fail to reject the null hypothesis. Although no interaction effect was observed for total strength, it is important to note that a main effect for time was observed (p = <0.001). Both the DUP and TDUP groups increased their total strength by 11.8% and 11.6% respectively following ten weeks of resistance training. This data can been seen in Table 9 below.

$H_{0(5)}$ stated that there would be no significant difference between TDUP and DUP with respect to Wilks Score over the ten week intervention. Data analysis revealed no significant difference between groups over time (DUP = 320.0 ± 45.6, $\Delta = 32.5$; TDUP = 331.6 ± 38.7, $\Delta = 33.3$; $p = 0.750$). Based on these results, we fail to reject the null hypothesis. Although an interaction effect was not observed for Wilks Score, it should be noted that a main effect for time did exist (p = <0.001). Both the DUP and TDUP groups increased their Wilks Score by 11.3% and 11.2% respectively following ten weeks of resistance training. This data can been seen in Table 9 below.

**Nutrient Intake**

Caloric and macronutrient intake was assessed via 3-day food diary at baseline and at the end of the intervention. All reported food was analyzed via the USDA Nutrient Database to determine intake amounts. Results showed no significant post-training differences between groups for kilocalories (DUP = 2734.9 ± 509.4 kcal; TDUP = 2693.1 ± 522.4 kcal; $p = 0.600$), carbohydrates (DUP = 299.2 ± 63.7 g; TDUP = 298.0 ± 74.7 g; $p = 0.940$), protein (DUP = 149.6 ± 23.2 g; TDUP = 167.9 ± 30.8 g; $p = 0.171$), or fat (DUP = 104.3 ± 24.8 g; TDUP = 92.3 ± 25.3 g; $p = 0.891$) intake over the ten week study. Although there was a significant difference at baseline for protein intake between DUP and TDUP, post-training protein intake was not significantly different. A main effect for time was observed for carbohydrate (p = 0.028) and fat
(p = 0.031) such that both groups significantly increased their carbohydrate intake and significantly decreased their fat intake over time.

**Body Composition**

Analysis of body composition measures revealed no significant differences between DUP and TDUP over time. Both groups had similar body fat percentage (DUP = 10.9 ± 3.8; TDUP = 11.5 ± 3.8; p = 0.519), fat free mass (DUP = 74.9 ± 9.4 kg; TDUP = 69.6 ± 8.6 kg; p = 0.507), and fat mass (DUP = 9.6 ± 4.8 kg; TDUP = 69.6 ± 4.1; p = 0.435) after ten weeks. A main effect for time was observed for fat free mass (p = 0.008) such that both groups had significant increases in their fat free mass over time. No main effect for time was seen for body fat percentage or fat mass.

**Table 8.** Baseline data for each variable measured.

<table>
<thead>
<tr>
<th>Variable</th>
<th>DUP (Mean ± SD)</th>
<th>TDUP (Mean ± SD)</th>
<th>P-Value (Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.5 ± 1.6</td>
<td>23.2 ± 5.6</td>
<td>0.120</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>179.1 ± 9.3</td>
<td>174.9 ± 7.4</td>
<td>0.208</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.5 ± 11.8</td>
<td>78.3 ± 10.5</td>
<td>0.340</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>10.7 ± 3.6</td>
<td>11.9 ± 4.3</td>
<td>0.428</td>
</tr>
<tr>
<td>Fat Free Mass (kg)</td>
<td>73.3 ± 8.3</td>
<td>68.7 ± 8.2</td>
<td>0.162</td>
</tr>
<tr>
<td>Fat Mass (kg)</td>
<td>9.1 ± 4.3</td>
<td>9.5 ± 4.3</td>
<td>0.809</td>
</tr>
<tr>
<td>Total Strength (kg)</td>
<td>422.4 ± 67.8</td>
<td>427.1 ± 79.2</td>
<td>0.872</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>140.5 ± 33.9</td>
<td>147.3 ± 34.0</td>
<td>0.612</td>
</tr>
<tr>
<td>Bench (kg)</td>
<td>104.2 ± 12.9</td>
<td>110.4 ± 12.7</td>
<td>0.227</td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>177.7 ± 26.4</td>
<td>169.6 ± 37.5</td>
<td>0.533</td>
</tr>
<tr>
<td>Wilks</td>
<td>287.5 ± 49.3</td>
<td>298.3 ± 45.8</td>
<td>0.569</td>
</tr>
<tr>
<td>Kilocalories</td>
<td>2704.4 ± 542.0</td>
<td>2701.1 ± 606.0</td>
<td>0.989</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>285.5 ± 66.8</td>
<td>285.1 ± 82.0</td>
<td>0.992</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>145.6 ± 20.6</td>
<td>170.2 ± 34.9</td>
<td>*0.034</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>109 ± 31.2</td>
<td>97.7 ± 29.6</td>
<td>0.355</td>
</tr>
</tbody>
</table>

* = indicates statistical significance
Table 9. Post intervention data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>DUP Baseline (mean ± SD)</th>
<th>DUP Post (mean ± SD)</th>
<th>TDUP Baseline (mean ± SD)</th>
<th>TDUP Post (mean ± SD)</th>
<th>P-Value (Time)</th>
<th>P-Value (Group x Time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Fat %</td>
<td>10.7 ± 3.6</td>
<td>10.9 ± 3.8</td>
<td>11.9 ± 4.3</td>
<td>11.5 ± 3.8</td>
<td>0.241</td>
<td>0.519</td>
</tr>
<tr>
<td>Fat Free Mass (kg)</td>
<td>73.3 ± 8.3</td>
<td>74.9 ± 9.4</td>
<td>68.7 ± 8.2</td>
<td>69.6 ± 8.6</td>
<td>*0.008</td>
<td>0.507</td>
</tr>
<tr>
<td>Fat Mass (kg)</td>
<td>9.1 ± 4.3</td>
<td>9.58 ± 4.8</td>
<td>9.5 ± 4.3</td>
<td>9.3 ± 4.1</td>
<td>0.812</td>
<td>0.435</td>
</tr>
<tr>
<td>Total Strength (kg)</td>
<td>422.4 ± 67.8</td>
<td>472.4 ± 60.6</td>
<td>427.1 ± 79.2</td>
<td>476.5 ± 74.1</td>
<td>*&lt;.001</td>
<td>0.937</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>140.5 ± 33.9</td>
<td>163.3 ± 29.8</td>
<td>147.3 ± 34.0</td>
<td>166.5 ± 30.7</td>
<td>*&lt;.001</td>
<td>0.414</td>
</tr>
<tr>
<td>Bench (kg)</td>
<td>104.2 ± 12.9</td>
<td>114.9 ± 14.2</td>
<td>110.4 ± 12.7</td>
<td>120.6 ± 11.9</td>
<td>*&lt;.001</td>
<td>0.814</td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>177.7 ± 26.4</td>
<td>194.1 ± 20.2</td>
<td>169.6 ± 37.5</td>
<td>188.3 ± 37.5</td>
<td>*&lt;.001</td>
<td>0.554</td>
</tr>
<tr>
<td>Wilks</td>
<td>287.5 ± 49.3</td>
<td>319.99 ± 45.6</td>
<td>298.3 ± 45.8</td>
<td>331.58 ± 38.7</td>
<td>*&lt;.001</td>
<td>0.750</td>
</tr>
<tr>
<td>Kilocalories</td>
<td>2704.4 ± 542.0</td>
<td>2734.9 ± 509.4</td>
<td>2701.1 ± 606.0</td>
<td>2693.1 ± 522.4</td>
<td>0.760</td>
<td>0.600</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>285.5 ± 66.8</td>
<td>299.2 ± 63.7</td>
<td>285.1 ± 82.0</td>
<td>298.0 ± 74.7</td>
<td>*0.028</td>
<td>0.940</td>
</tr>
<tr>
<td>Protein</td>
<td>145.6 ± 20.6</td>
<td>149.6 ± 23.2</td>
<td>170.2 ± 34.9</td>
<td>167.9 ± 30.8</td>
<td>0.703</td>
<td>0.171</td>
</tr>
<tr>
<td>Fat</td>
<td>109 ± 31.2</td>
<td>104.3 ± 24.8</td>
<td>97.7 ± 29.6</td>
<td>92.3 ± 25.3</td>
<td>*0.031</td>
<td>0.891</td>
</tr>
</tbody>
</table>

* = indicates statistical significance
CHAPTER 5:  
DISCUSSION

The aim of the present study was to investigate the efficacy of Tiered Daily Undulating Periodization for producing strength improvements in the back squat, bench press, and deadlift as compared to a traditional model of Daily Undulating Periodization. To the researcher’s knowledge, TDUP is a novel form of periodization that has yet to be examined in the literature. Similar studies have investigated other forms of DUP such as flexible DUP (McNamara, & Stearn, 2010; Colquhoun, 2017, and compared different protocols of DUP (Zourdos, 2016), but this was the first study to apply a tiered structure of training to the undulating periodization model in males training the powerlifting movements.

Significant increases in strength were observed over time as measured by back squat one rep max, bench press one rep max, deadlift one rep max, powerlifting total, and Wilk’s score following 8 weeks of resistance training. However, there were no significant differences between the TDUP and DUP groups in any of the strength variables measured. Additionally, there were no interaction effects observed between groups for any of the variables. The similarity in strength gains between groups could be explained by the similar magnitude of work, volume, and intensity that was performed. While the distribution of workload was different, both groups completed the same number of sets and repetitions by the end of the week with the exception of their plus set which determined their working weight for the following week. The intensity of the exercise was also similar between groups throughout a given week albeit distributed in slightly
different fashions. Additionally, it is possible that the subjects of this study had not previously been exposed to a well-designed, periodized, resistance training program that focused on powerlifting movements. While each subject did meet the criteria for being well trained, the magnitude of the average strength gains observed in this study lead to the conclusion that similar strength improvements would not have been made had the subjects been training on their own. Therefore, the equality in workload and the favorable response to a well-designed resistance training program may explain the similarity in strength improvements that were observed between groups.

Despite the absence of statistical differences between TDUP and DUP, there were slight differences in strength adaptations that may be of practical significance. The traditional model of DUP resulted in a 3.6 kilogram (7.9 lbs) greater increase in back squat 1RM as compared to tiered DUP (DUP BS 1RM Δ = 22.8 kg; TDUP BS 1RM Δ = 19.2 kg). However, TDUP produced a 2.3 kilogram (5.1 lbs) greater increase in deadlift 1RM compared to traditional DUP (DUP DL 1RM Δ = 16.4 kg; TDUP DL 1RM Δ = 18.7 kg). Strength adaptations in the bench press (DUP BP 1RM Δ = 10.7 kg; TDUP BP 1RM Δ = 10.2), powerlifting total (DUP total Δ = 50.0 kg; TDUP total Δ = 49.4 kg), and Wilk’s score (DUP Wilk’s Δ = 32.5; TDUP Wilk’s Δ = 33.3) were essentially identical between groups from a practical standpoint. These differences may have potentially important implications for athletes and coaches when designing individualized resistance training programs in terms of maximizing strength gains in the back squat or deadlift.

Several studies have investigated modifications to daily undulating periodization and their efficacy in producing strength adaptations in trained males. The results of the present study are similar to those obtained by Colquhoun and colleagues (2017). Investigators exposed 32
resistance trained males to either a traditional or flexible daily undulating periodization protocol. Subjects completed the back squat and bench press three times per week and the deadlift twice per week with various accessory exercises being performed on each day as well. The working weight was auto-regulated using plus sets in a very similar fashion to the protocol used in the present study. Both groups completed the same workload and used the same repetition schemes throughout the week. However, those assigned to the flexible DUP group were given the option to choose which repetition scheme to complete on a given day while the traditional group was forced to complete their workouts in a preset order (Workout 1 = Hypertrophy, Workout 2 = Power, Workout 3 = Strength). The results of this study showed no significant difference between flexible and traditional DUP with respect to bench press 1RM, back squat 1RM, deadlift 1RM, powerlifting total, and Wilk’s score.

Zourdos (2016) investigated a novel form of daily undulating periodization for its effect on improving 1RM strength in the powerlifting movements. Eighteen male powerlifters were split into either an HSP protocol (Hypertrophy, Strength, Power) or an HPS (Hypertrophy, Power Strength) protocol which signified the order of the workouts they would complete each week. Subjects completed 8 weeks of resistance training with results showing that both protocols produced significant increases in squat 1RM, deadlift 1RM, powerlifting total, and Wilk’s score over time. Bench press strength significantly increased in the HPS group but not in the HSP group. The results of the present study, Zourdos (2016), and Colquhoun (2017), seem to demonstrate that daily undulating periodization can be modified in several ways while producing similar augmentation to maximal strength.

One key element of the present study that differed from previous studies was the use of different exercise order in each workout completed by the TDUP group compared to the strict
order used in the traditional DUP group. Given that a powerlifting competition is completed in the specific order of squat, bench press, and deadlift many practitioners have confined themselves to completing their workouts in this order in an attempt to preserve the principle of specificity. However, the results of the current study seem to suggest that the exercises can be ordered according to personal preference while still delivering similar increases in strength.

Another method that was employed in this study was the use of autoregulation for the progression of working weight from week to week. Autoregulation has been used successfully in practice by athletes and coaches to improve strength and performance. The results obtained in the present study are similar to those of other studies that have shown autoregulation to be an effective tool when designing resistance training programs (Mann et al., 2010; Colquhoun, 2017; Zourdos, 2016). One important aspect of autoregulation is the use of rating of perceived exertion (RPE) to determine the training load for a given training bout. For example, rather than prescribing a specific weight to be used for an exercise, a coach may instead indicate an RPE value that an athlete should experience when completing their working sets. As an athlete progresses through a typical training session, it is plausible to assume that the onset of fatigue may affect the perceived effort that the athlete experiences. This means that, excluding the first exercise of the day, an athlete could experience a skewed sense of RPE which could result in lighter loads being used when using an autoregulatory program. This could manifest in compounded reductions in volume and intensity over time and may eventually restrict maximal strength adaptions. This represents a possible improvement that the tiered daily undulating periodization model may offer over the traditional protocol. By performing one high intensity exercise per day with each subsequent exercise decreasing in intensity, the athlete may avoid the deleterious effects that fatigue may have on the use of RPE and autoregulation.
One last noteworthy observation of this study were the attrition rates displayed by each training group. The traditional DUP group started with 24 subjects but ended with only 12 which represented a 50% dropout rate. In comparison, the TDUP group also began with 24 subjects but ended with 16, a 33% dropout rate. Based on these findings it is possible that the traditional model of daily undulating periodization may present as less sustainable or less satisfying as compared to the tiered approach. However, the overall attrition rate of 42% presents a troubling finding with respect to both forms of daily undulating periodization. A comprehensive resistance training program should be both effective in delivering results as well as enjoyable and sustainable for the athlete. While the current study demonstrates the effectiveness of daily undulating periodization for increasing maximal strength, it may also present DUP as an unsustainable protocol for long term training. Although it was not empirically measured, participants seemed to complain of aches and pains near the end of the intervention with many remarking of the welcomed break from heavy training that would accompany the end of the study. This is important to keep in mind for athletes and coaches when structuring a long term training plan.

**Practical Applications**

No significant differences were observed between traditional and tiered DUP with respect to maximal strength or body composition. However, traditional DUP did result in a 3.6 kilogram greater increase in back squat 1RM while the tiered approach resulted in a 2.3 kilogram greater increase in deadlift 1RM. This could potentially guide the program design of an athlete who may require greater strength in either one of those exercises relative to the other. Furthermore, the use of varied exercise order in the TDUP group did not seem to negatively impact maximal strength gains compared to the strict back squat, bench press, and deadlift order that is usually employed.
with powerlifting training. This may suggest that exercise order can be designed according to
personal preference while preserving strength adaptations. Lastly, the use of a tiered DUP structure
may increase adherence to the training program compared to the traditional approach. However, it
should be noted both versions of daily undulating periodization studied might only be appropriate
for short periods of time and may not be a sustainable for long term training programs.


Appendix A: IRB Approval Letter

Andres Vargas
Educational and Psychological Studies
Tampa, FL 33612

RE: Full Board Approval for Initial Review
IRB#: Pro00025964
Title: Tiered Daily Undulating Periodization vs. Traditional Daily Undulating Periodization for Improving Powerlifting Performance in Trained Males

Study Approval Period: 5/2/2016 to 5/2/2017

Dear Mr. Vargas:

On 5/2/2016, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents contained within, including those outlined below.

**Approved Item(s):**
**Protocol Document(s):**
Study Protocol - Version 2 (Clean Copy Version) 5-3-16

**Consent/Assent Document(s)***
Informed Consent Version #2 - Clean Version (5-3-16).pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

The Board determined all future reviews of this study qualify for expedited review under category 9 (Continuing review of research, not conducted under an investigational new drug
application or investigational device exemption where categories two (2) through eight (8) do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified).

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval via an amendment. Additionally, all unanticipated problems must be reported to the USF IRB within five (5) calendar days.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

E. Verena Jorgensen, M.D., Chairperson
USF Institutional Review Board