A Practical Comparison between Traditional Periodization and Daily-Undulated Weight Training Among Collegiate Track and Field Athletes

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by

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ABSTRACT

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Recently, comparisons of "periodized" strength training methods have become a focus of sport science. Daily undulating periodization (DUP), using daily alterations in repetitions, has been developed and touted as a superior method of training. The purpose of this study is to compare traditional periodization (TRA) to DUP in Division I track and field athletes. Thirty-one athletes were assigned to either a TRA or the DUP group training programs based on sex, year, and event. Training lasted 10 weeks. There were 4 testing sessions focusing on strength characteristics. Although, trends favored the TRA group for strength and rate of force development, no significant differences were found between the groups. Significant differences ($p \leq 0.05$) in volume and the amount of improvement per volume load were found to be significantly different ($p \leq 0.05$) between the TRA and DUP groups. These data indicate that TRA is more efficient in producing strength gains than DUP.

DEDICATION

This thesis is dedicated to my parents. They taught me the importance of hard work and education. Without their love and their support for my continued education, I would not be where I am today. I can never express how much gratitude I have for the life they have provided me with, and the love I have for them. From here on, I can only hope that I can continue to make them proud.

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CHAPTER 1

INTRODUCTION

The purpose of this review is to identify key variables and concepts associated with "periodization" and the various forms it has taken throughout the years. Within the literature, there are many definitions of periodization (Graham, 2002; Haff, 2004a; Kirksey & Stone, 1998; Kraemer et al., 2003; Kraemer & Fleck, 2007; Plisk & Stone, 2003; Stone, Stone, & Sands, 2007). When summed, periodization can be briefly stated as a logical method of planning and developing a training program, using cycles and stages specific to the needs of the athlete.

The development of training principles and the concept of periodization can be followed historically. Greeks told a story of Milo from Crotona, a boy that grew up with a bull. As a boy, Milo decided to lift this young bull and carry it on his shoulders (Foster et al., 2001; Silvester, 1992). Milo began to do this regularly and as they both grew older the bull got heavier and heavier, and Milo got stronger and stronger. This training lead Milo to become a six time Olympic champion in his time, and whether this tale is true or not, this example suggests that Greeks understood, in some fashion, training concepts (e.g. overload) associated with building strength and muscle. Arguably, Milo practiced a type of progressive linear training. This idea of training may have become more solidified by the Romans and their adaptation/modification of the Spartan training principles (Atha, 1981). Apparently progress in training principles proceeded primarily through trial and error until the late 1800s and early 1900s (Atha). The topic of defining strength, what intensities to lift with, and methods of developing power were all investigated in the early 1900s (Atha) and continue into the present day. Many of the ideas of strength training that are debated today are the same issues that were discussed in pre-World War II times.

Presently, coaches and sport scientists are still trying to find the best system to develop athletes; however, they do not all agree on which strength training method is the most promising. Frequently, there are discrepancies in the terminology from nation to nation, but inconsistencies exist within the American strength and conditioning community. In the literature, a commonly practiced approach has been referred to as "*Traditional Periodization"* (TRA) and has erroneously been referred to as "*Linear Periodization"* (LP) by some authors (Baker, Wilson, & Carlyon, 1994, Fleck & Kraemer, 1997; Rhea, Ball, Phillips, & Burkett, 2002; Rhea et al., 2003). "*Block Periodization*" is a modern adaptation of the traditional methods (Issurin, 2008).

Another method of training that is gaining popularity is "*Non-linear Periodization"* (NLP), also referred to as "*Undulating Periodization"* (UP) and its modification *"Daily Undulating Periodization"* (DUP) (Baker et al., 1994; Bradley & Haff, 2001; Brown & Greenwood, 2005; Fleck & Kraemer, 1997; Haff, 2004a; Haff, 2004b; Kraemer & Fleck, 2007; Peterson, Dodd, Alvar, Rhea, & Farve, 2008; Rhea & Alderman, 2004; Rhea et al., 2002; Rhea et al., 2003). While some terms are used synonymously with each other in the literature, there are actually differences in each definition. This has confounded the current research on the topic and has lead to some erroneous and misleading statements. With this expanding confusing and at times, contradictory research on periodization and other training methods, it can be easy for strength coaches to become confused and distracted. In order to reduce confusion concerning this issue the following definitions are used.

Operational Definitions

1. **Block Periodization** (BP) – This concept incorporates multiple blocks, or training goals, (usually one block between each competition) that focus on development from general to specific. This method uses the rational of TRA for each block. BP is a modification of the traditional form that used (as a block) over a short-term between competitions.
2. **Development –** A phase that involves improvement and the continuing maturity of the athletic form. This is a common goal of many planned training programs, and has been termed the acquisition phase, pre-season, and preparation.
3. **Daily-undulating Periodization** (DUP) – This is an erroneous term used in the literature as there are no distinct phases or cycles of development emphasizing specific performance or physiological characteristics. Though this is not an appropriate term for this training method, this paper uses DUP to describe this training method. DUP is a type of NLP, this method has been further developed by Kraemer (2007), it is a similar method to UP as well but increases the frequency of variation to a daily occurrence. This training philosophy is still undevelope, and attempts to dictate training volume by using repetitions to control work-load. Periodization is a method that uses the cycling of training characteristics (endurance, strength, power, etc.) in order to build up particular characteristics desired in an athlete. DUP groups several of these characteristics into one week, resulting in a lack of relatively long-term (weeks or months) focus on any one characteristic.

4. **General Adaptation Syndrome** (GAS) **–** Developed by Selye (1956), this principle was originally an attempt to describe the effects of stress over a life-time, but found more relevance in the strength and conditioning environment. GAS has been adopted to describe the constantly changing athletic form.
5. **Hypertrophy** –
    - **a.** Muscle growth. This is a building block for strength and power and is related to the cross-sectional area of the muscle.
    - **b.** Refers to a phase of training dedicated to the building of muscle.
6. **Linear Periodization** (LP) – A commonly used term in current strength and conditioning research to describe a training method that is based on a set and rep scheme that gradually drops volume, by lowering reps, and increases intensity through each mesocycle. This is not true periodization, but for the purposes of this paper, LP is the term used to describe this method of training. This program has (apparently) little to no microcycle variation.
7. **Macrocycle –** Made up of several mesocycles, this period usually last about one year and reaches a peak for a specific competition. The peak of this cycle can be replaced with a maintenance program for sports that have a long season.
8. **Maintenance –** This term is often used with team sports during competition periods and represents the phase that requires continuing optimal performances. With many individual sports, this phase is shortened for specific events, ensuring higher levels of performance.
9. **Mesocycle** – Consists of multiple microcycles and usually has a duration of 2-6 weeks. There are typically two forms of mesocycles: It may concentrate on a

single developmental characteristic (e.g. endurance, strength, power, etc.) or may take the form of a mini-macrocycle (e.g. similar to Block Periodization).

10. **Microcycle** – A short period that usually lasts one week. This cycle dictates the week-to-week variation and can be broken down further into day-to-day variation.
11. **Multi-year plan** – Consists of several macrocycles. This plan was originally developed for Olympic competitions (4-year plan) but can easily be adapted to the duration of an athlete's presence.
12. **Non-linear Periodization** (NLP) –As periodization, by definition, is non-linear, this is yet another misleading term developed from a misunderstanding of the periodization concept. NLP is a training program that fluctuates micro- and/or mesocycles between differing phases (i.e. strength-endurance, functional strength, etc.). Often used synonymously with undulating and daily undulating periodization, this method is very similar to traditional periodized training programs.
13. **Over-reaching** – A state of short-term fatigue that develops through training and/or other stressors. Performance may decrease for a brief period of time.
14. **Over-training Syndrome** (OTS) – A state of chronic fatigue that is detrimental to any athlete. This is an accumulation of stress both from training and outside of training. OTS is a condition that all training plans should try to avoid and has detrimental implications to performance.
15. **Peaking** – A phase similar to the maintenance phase, but peaks athletic performance for single or limited competitions.

16. **Periodization** – A logical process of manipulating variables (i.e. reps, sets, rest, intensity, volume, etc.) in order to plan training over time to best fit an athlete's needs; breaks the training plan into smaller portions of high and low volumes in order to manage fatigue and remove linearity. This method always includes varying phases and cycles that have specific physiological and performance goals. The primary goals of periodization are: 1) fatigue management and reduction of the overtraining potential, 2) peaking at the right time (i.e. climax of the macrocycle) and for sports having defined seasons in which all games are suppose to be won, providing a maintenance program.
17. **Preparedness** – The ability of an athlete to perform well in a competition.
18. **Power** – Work over time. This rate of work may be the most important variable for sports.
19. **Rate of force development** (RFD) – The amount of force produced over a given interval of time.
20. **Repetition** – Number of times a given exercise is performed for a given set.
21. **Repetition Maximum** (RM) – The max amount of weight that can be lifted for any given set and repetition. For instance, a common prescription for an exercise is 3x5 RM, and this means athletes performing the exercise must use the maximum amount of weight they can lift for three sets of five repetitions. This term is often used loosely and has lead to confusion when not applied properly. A true RM leads to failure if another rep is attempted. Due to the difficulty of truly predicting RM values, there is often a range associated with it (3x3-5 RM). This range provides more flexibility in the training program and allows for failure (i.e.

an athlete attempts 3x5, but may only get four repetitions on the last two sets resulting in 1x5, 2x4).

22. **Set** – Number of repetition blocks that will be performed. This combined with a repetition scheme will be denoted (set)x(repetition) (i.e. 3x10, 5x5, 3x3, etc.).
23. **Strength** – The ability to produce force. It is important to understand strength is an ability, because the ability to use strength is what is actually measured.
24. **Temporary Deficit**
    - **a.** This phase is designed to enhance recovery and adaptations. Typically, this phase is used as a transition from peaking to the start of a new program.
    - **b.** This term also refers to the temporary decline in athletic form. Associated with the alarm phase in the GAS principle, this temporary loss in athletic form can develop from training, competitions, and/or other stressors.
25. **Testosterone and Cortisol ratio** (T:C ratio) – A ratio of anabolic and catabolic hormones. This ratio gives an anabolic index related to strength, explosiveness, and body composition. Mathematically: Testosterone / cortisol = T:C ratio.
26. **Traditional Periodization** (TRA) – Basic periodization that breaks macrocycles in to three to four sections; preparatory (General preparation and special preparation), pre-competition, competition, and active rest. This term refers to some of the early work on periodization and is a building block to additional concepts of periodization.
27. **Undulating Periodization** (UP) – Another term developed from the NLP concept. For the purposes of this paper, UP is the term that describes this training

method. UP uses two-week wave-like cycles varying from high volume, low intensity to low volume, high intensity. This method of training typically does not follow criteria set forth by periodization, thus the use of UP is not a sufficient description of this method.

Review of the Literature

Throughout the literature, there are many descriptions of periodization. Periodization is a training method commonly used in sport and has consistently been shown to elicit superior gains in strength and performance compared to non-perioidzed programs (Buford, Rossi, Smith, & Warren, 2007; Cissik, Hendrick, & Barnes, 2008; Herrick & Stone, 1996; Issurin, 2008; Kraemer et al., 2003; Kraemer et al., 2004; Pedemonte, 1982; Plisk & Stone, 2003; Rhea & Alderman, 2004; Rhea et al., 2002; Rhea et al., 2003; Rowbottom, 2000; Schiotz, Potteiger, Huntsinger, & Denmark, 1998; Stone, O'Bryant, & Garhammer, 1981a; Stone et al., 1999). Recently, researchers have been presenting differing "models" of periodization in the attempt to perfect the method. Some misconceptions of periodization have developed and formed confusion and debate over appropriate training models. In order to understand how to implement the method of periodization, there must be an understanding of its development.

General Adaptation Syndrome

Although, the basic concepts of "traditional" periodization (TRA) had been used for many years, the concept, as a training rationale, was standardized in the late 1930s-

1950s (Pedemonte 1982, Plisk & Stone, 2003). Much of the knowledge we have today about training and the underlying basis of periodization is partially based on the work of Hans Selye, specifically his work with the General Adaptation Syndrome (GAS). Selye investigated how organisms responded to repeated stressors both acutely and chronically (illness, training, etc.). Selye indicated that there are distinct phases for stressors somewhat independent of type. These phases are an alarm phase, reaction/resistance development phase, and an exhaustion phase (Brooks, Fahey, & Baldwin, 2005; Brumbach, 1993; Selye, 1956; Stone, O'Bryant, & Garhammer, 1981b; Stone, O'Bryant, Garhammer, & McMillan, 1982; Stone et al., 2007) (See Figure 1.1, pg. 22).

The alarm phase refers to the resulting effects created by any shock to the system or introduction to something unfamiliar. In strength training, initiating a new training program, changing lifts, life stressors of the athlete, or many other variables are types of "shocks" that stimulate an alarm. When implementing a training stimulus that induces an alarm response, it is not uncommon to find a decrease in performance and sometimes fitness (Brooks et al., 2005; Stone et al., 2007). This is an important concept in training, because, according to Selye, if there is no training shock (i.e. stimulus), there will be no alarm response; if there is no alarm response, there is no stimulus for adaption that may ultimately lead to no improvement.

During the reaction/resistance development phase in the GAS an organism adapts to the stresses placed on it (Selye, 1956). In training, muscles hypertrophy, bones become denser, and the heart pumps blood more efficiently; these are just a few of the general adaptations that coaches aim for when training an athlete. Research has shown that benefits from any particular training program are influenced by the level of training experience a person has before the implementation of that program (Bompa, 1994; Poliquin, 1988; Stone et al., 2007; Verkhoshansky, 1977; Verkhoshansky, 1988). This concept is essential when analyzing research because responses to a training stimulus are dependent on the training plan and individual physiologic adaptive capacities (i.e. athletes will respond differently than non-athletes). Accordingly, athletes may adapt to a training program and begin to stagnate in performance (Brumbach, 1993; Cissik et al., 2008; Kraemer & Fleck, 2007; Pedemonte, 1982; Stone, O'Bryant, & Garhammer, 1981a; Stone & Garhammer, 1981). Performance enhancements can be reached by planning additional stimuli or by increasing the stimulus, which could range from introducing different exercises to increasing training volume.

When the stressors are too great to overcome, the exhaustion phase or overtraining can occur (Brooks et al., 2005; Stone et al., 2007). Acute exhaustion can result in fractures, strains, sprains, and lack of energy. Chronic exhaustion can lead to overtraining syndrome (OTS), and depending on the athlete, the signs can be very subtle. Some of the signs of OTS include fatigue, mood swings, abnormal sleeping habits, fluctuations in body composition, amenorrhea, and a decrease in performance (Brooks et al., 2005; Stone et al., 2007; Urhausen & Kindermann, 2002). Overtraining can also take two forms: acute and chronic. Acute overtraining, or overreaching, is not as severe as chronic overtraining, and recovery takes place in a short time frame. Furthermore, there is often a rebound, or super-compensation, increase in performance following recovery (2-5 weeks after the overreaching period) (Stone et al., 2007). Because of the super-compensation of increased performance, overreaching can be used as a training tool (with great caution). Chronic overtraining is much more serious and leads to long-lasting performance decrements. Another aspect of the exhaustion phase is when an athlete plateaus and is no longer stimulated by the same training program, also known as monotonous overtraining (Attetika, 1980; Brumbach, 1993; Rhea et al., 2003; Stone et al., 2007). This phase, typically termed "monotonous training", can lead to slight decrements in performance over time but is not as dire as OTS. Depending on the level of training experience, manipulating volume, intensity, and often-simple variation in exercise selection can push the athlete past the plateau.

It is difficult to ascertain if a stimulus is working properly and how to know when the athletes have had too great of a stimulus. With current research, there is no foolproof method to predict if an athlete will become overtrained, but there have been investigations into methods preventing overtraining while eliciting optimal performance gains (e.g. the training program). Periodization is a method, when carried out appropriately it can reduce the overtraining potential and achieve the desired performance gains.

Fitness-fatigue paradigm

Another underlying basis of periodization is found in the Fitness-fatigue paradigm (Bannister, 1982; Zatsiorsky, 1995). This theory is based on the balance of a negative factor, fatigue, and a positive factor, fitness (Busso, Candau, & Lacour, 1994, Stone et al., 2007). These two factors influence the ability to perform for a competition (similar to GAS). The difference between fitness and fatigue is termed the preparedness, which in turn directly influences the performance potential of an athlete (Stone et al., 2007; Zatsiorski, 1995) (See Figure 1-1).

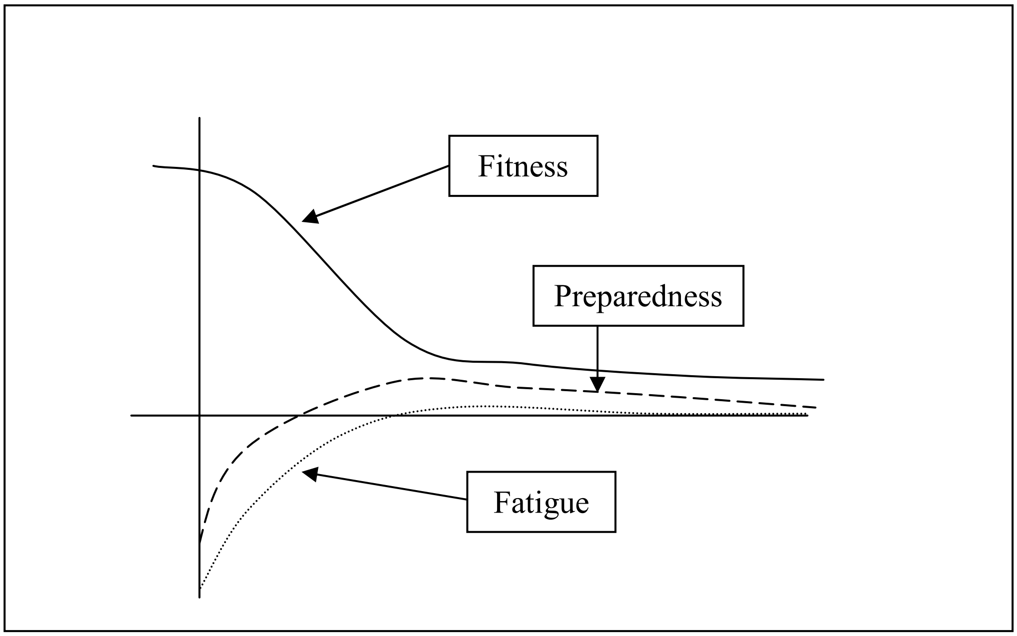


Figure 1-1 Fatigue-Fitness Paradigm

This concept indicates that when the balance between fatigue and fitness are positive, the preparedness of the athlete will increase (Busso et al., 1994). The reverse is also true, the more negative the balance, the lower the preparedness. Figure 1-1 is a very simplified version of the Fitness-fatigue paradigm, only showing one level of fitness. It is important to realize that many athletes train using a multifaceted approach, thus having multiple fitness and fatigue characteristics.

Typically, fitness increases and fatigue, which leads to acute decreases in preparedness, accumulates during training (Busso et al., 1994; Zatsiorski, 1995). Training produces an increase in fitness, but fatigue accumulated during the same training masks the expression of fitness; however fatigue dissipates at a faster rate during a training volume reduction (Zatsiorski, 1995). That indicates that properly structuring periods of recovery after intense training bouts (e.g. a week of lowered volume load after three weeks of increased training volume) can produce gains in preparedness, but only after the fatigue dissipates. The balance between fitness and fatigue are key aspects of periodization. Planning appropriate variation assists in the management of fatigue, and increases the preparedness of an athlete.

Endocrine Responses to Training

Optimizing the response to stressors is a key part of any training program. Part of that response is controlled by the neuroendocrine system. This system controls and regulates the hormonal activity and aids in maintaining homeostasis. Two hormones often discussed in strength and conditioning research are testosterone (T) and cortisol (C). These hormones have shown to be viable markers related to development, strength, power, and OTS (Potteiger, Judge, Cerny, & Potteiger, 1995; Stone et al., 2007; Viru, 1995; Winchester, 2008).

Testosterone. A steroid hormone, T is an androgen primarily secreted by the testes in men, and by the adrenal cortex and the ovaries in women. T is synthesized in the endoplasmic reticulum within these glands (Winchester, 2008). Compared to females, adult males have a higher concentration of T. The production of T is regulated by a negative feedback loop by the secretion of a luteninizing hormone from the anterior pituitary, via cyclic adenosine monophosphate (cAMP), which delays its affect on muscle (Loebel & Kraemer, 1998; Stone et al., 2007). The secretion of androgens may also be related to neural stimulation of the testes (Robaire & Bayly, 1989). Basically, the production of T is stimulated by neural signaling or the presence of particular hormones.

T is important for growth and is highly dependent on genetics (Brooks et al., 2005; Loebel & Kraemer, 1998; Stone et al., 2007; Winchester, 2008). This hormone is responsible for the development of bone and muscle and stimulating metabolism and has been linked to the ability to produce force quickly, strength, power, and even cognitive aspects (Cardinale & Stone, 2006; Consitt, Copeland, & Tremblay, 2002; Kraemer & Ratamess, 2005; Loebel & Kraemer, 1998; Stone et al., 2007; Winchester, 2008). The presence of T assists in the ability to recover and adapt from higher levels of stresses. While stimulating growth, T also inhibits the catabolic effects of C (See Cortisol., pg. 26), thus enhancing the ability of muscle to adapt to a greater extent (Mayer & Rosen, 1975; Stone et al., 2007; Winchester, 2008). This relationship was openly exploited in sports by the use of synthesized androgens (i.e. steroids) until 1976, when the International Olympic Committee banded the use of "artificial" androgen supplementation (e.g. anabolic steroids), and 1983 when T was completely banned. However, even with a ban introduced into professional sports, athletes currently abuse androgen supplementation because of the performance enhancing properties (Kadi, 2008).

T affects tissues through the use of binding sites or androgen receptors (AR). These AR intermittently bind with T to avoid over exposure in brief spikes of T, which can lead to a decreased availability of AR due to a decreased demand for T (Kraemer & Ratamess, 2005; Loebel & Kraemer, 1998; Mayer & Rosen, 1975; Ratamess et al., 2005; Winchester, 2008). With training, acute higher volume sessions tend to spike T concentrations in the blood, but prolonged high volume training lead to decreases in muscle affinity for T. When affinity for T decreases, the catabolic state of the muscle is enhanced. Muscle breakdown may lead to another mechanism for decreased affinity for T. During these training sessions, some evidence suggests that there is a degradation of AR (Hulmi et al., 2008; Kraemer & Ratamess, 2005; Winchester, 2008), which in turn will lead to a diminished uptake of T, thus leaving a higher post-exercise T concentration in the blood. If high volumes are prolonged, AR will become less available, thus muscles will acquire less T lowering the demand to produce T, and will eventually lead to increased muscle breakdown, overtraining, and then possibly OTS. However, there is evidence of an AR-independent pathway (Cabeza et al., 2004; Estrada, Espinosa, Muller, & Jaimovich, 2003; Kadi, 2008). This mechanism and its importance are unclear, but may be associated with intracellular Ca^{++} concentrations and the activation of G-protein-linked receptors that potentially lead to cell growth (Cabeza et al., 2004; Estrada et al., 2003; Kadi, 2008).

Studies investigating resistance training and T have revealed mixed results. Some have shown increases in T concentrations (Hulmi et al., 2008; Potteiger et al., 1995; Winchester, 2008), and others have shown no difference or a decrease (Consitt et al., 2002; Häkkinen, Pakarinen, Alen, Kauhanen, & Komi, 1987; Ostrowiski, Wilson, Weatherby, Murphy, & Lyttle, 1997). One discrepancy between these studies is their subjects that ranged from untrained adolescences to elite weightlifters. Additionally, different types and methods of resistance training were employed with differing volumes of work. Furthermore, muscle cross-sectional area and fiber type vary greatly between trained and untrained individuals (Maughan, Watson, & Weir, 1984; Stone et al. 2007), and type II muscle fibers are affected by T more than type I (Bosco, Tihanyi, & Viru, 1996; Kraemer & Ratamess, 2005; Stone et al., 2007). This may indicate a higher concentration of AR in type II muscle fibers compared to type I that in theory may account for some of the differences between groups. Other reasons for any increase in T post-exercise may be hepatic clearance ability or possibly an alteration in testicular blood flow (Consitt et al., 2002; Loebel & Kraemer, 1998).

While acute exercise induced changes in T are variable, resting adaptations in T concentrations fluctuate only slightly, if at all. Beginning (or novice) lifters have shown to have a small increase in resting T levels after a 10-week strength-power training program (Kraemer et al., 1999). On the other hand, experienced weightlifters show minimal differences within a year of training (Häkkinen et al., 1987; Stone et al., 2007), but they do respond to decreases in volume (tapering) with a temporary increase in T (Busso et al., 1992; Stone et al., 2007). Through normal training, the resting T levels of an athlete should not significantly change. However, if volumes are kept high there may be a noticeable drop in T and a continued elevation of C, putting the athlete in a more catabolic state and lowering preparedness (Stone et al., 2007).

Cortisol. Cortisol is a glucocorticoid and is a steroid hormone primarily produced by the zona reticularis and zona faciculata of the adrenal cortex with very small amounts produced in the testes (Stone et al., 2007). This hormone is regulated by a hypothalamic-pituitary feedback mechanism and is the primary stress hormone (Stone et al., 2007; Viru, 1995; Winchester, 2008). C is responsible for a variety of effects through multiple mechanisms such as gluconeogenisis and immune system suppression. C, catabolic in nature, is an antagonist to T and can compete for the same AR, contributing to muscle wasting (Brooks et al., 2005; Da Silva, 1999; Kraemer & Ratamess, 2005; Stone et al., 2007; Tidball, 2002). C is a stress hormone that tends to rise with increased amounts of stress. It holds a position in metabolism by enhancing gluconeogenesis through the proteolysis of muscle protein and lipolysis of fat to ATP (Kraemer & Ratamess, 2005; Stone et al., 2007; Winchester, 2008). This proteolysis of muscle protein may contribute to the destruction of some AR that may lead to a decreased uptake of androgens (Ratamess et al., 2005).

The immune system plays a key role in muscle development. Inflammatory cells attack the damaged muscles cells and invading macrophages clear scar tissue and other cellular debris away (Da Silva, 1999; Tidball, 2002), but if left unchecked the natural killer cells in the immune system will continue to destroy excess muscle. This is where C plays a major role with the suppression of the immune system. It depresses natural killer cells and histamine production (Da Silva, 1999; Stone et al., 2007; Winchester, 2008), leading to an efficient level of immune response by not allowing excessive muscle proteolysis and, through histamine suppression, less muscle pain. Not only does C affect skeletal muscle and the immune system, it also affects mood state. High concentrations of C tend to elicit depressive behavior, whereas individuals with low to moderate concentrations tend to be more euphoric (Viru, 1992; Winchester, 2008).

Typically, the higher the blood C levels, the more it will reduce the affects of T by the degradation of AR. However, C activates cAMP (Stone et al., 2007), which is associated with the production of T. This association may suggest acute increases in the production of C leads to an increased temporary production of T. This is supported in the research, showing that both T and C rise with brief high volumes of training (Baker, Bemben, Anderson, & Bemben, 2006; Busso et al., 1992; Consitt et al., 2002; Crewther, Cronin, Keogh, & Cook, 2008; Fry et al., 1994; Fry, Kraemer, Stone, Koziris, Thrush, &

Fleck, 2000; Häkkinen et al., 1987; Hulmi et al., 2008; Izquierdo et al., 2006; Izquierdo et al., 2007; Kraemer et al, 1999; Linnamo, Pakarinen, Komi, Kraemer, & Häkkinen, 2005; Mayer & Rosen, 1975; Potteiger et al., 1995), though this association may have independent pathways.

T:C Ratio. T and C play an important role in physical development, especially neuromuscular development (Baker et al., 2006; Cardinale & Stone, 2006; Consitt et al., 2002; Crewther et al., 2008; Fry et al., 1994; Fry et al., 2000; Häkkinen et al., 1987; Kraemer et al., 1999; Kraemer & Ratamess, 2005; Linnamo et al., 2005; Loebel & Kraemer, 1998; Potteiger et al., 1995; Tremblay, Copeland, & Van, 2004; Willardson, 2007). Typically the higher the T:C ratio, the greater the potential that athlete has in developing strength and power characteristics as well as elevating preparedness. Periods of prolonged high volume training can result in negative effects on the neuroendocrine system. During these periods the T:C ratio can decrease, significantly reducing preparedness and increasing the risks of developing OTS (Brooks et al., 2005; Fry et al., 1994; Izquierdo et al., 2006). A temporary elevation of volume (i.e. overreaching) can be beneficial to stimulate tissue growth and endurance capabilities, but continually training at high volumes lead to a more pronounced increase in C, lowering the T:C ratio and may contribute to decreased muscle adaptation. Eventually, prolonged overtraining may mute any beneficial effects of T or C.

The responses of T and C suggest that the neuroendocrine system responds similar to the GAS principle and the Fitness-fatigue paradigm. A training stimulus shocks the system. This leads to increased T (related to fitness) and C (related to fatigue), but if the stimulus is too great, accumulated fatigue causes the T:C ratio (related to preparedness) to decrease and the system becomes exhausted. The neuroendocrine responses to training are an important consideration when developing a training plan because determining rest between sets, total volume, and even exercises can depend on this factor.

Brief History of Periodization

Despite the attention periodization has received in the past couple of decades, it is not a new concept. It is known that the Greeks held the Olympic Games more than two millennia ago, and that those athletes trained for those competitions using a type of periodized program (Atha, 1981). Flavius Philostratus (AD 170-245) kept in-depth writings describing the training methods of the Greek Olympians (Bompa, 2007). Those methods show a similarity to modern concepts of periodization, in that there were distinct cycles of training volume and intensity that were used to prepare for important competitions. Pre-World War I, several researchers had investigated training and the basic concepts of periodization. Researchers such as Mang, Pikala, MacFadden, and Steinhaus, among others, have all investigated various aspects of training, particularly as it relates to strength training (Atha; Bompa).

With the concerns of athlete performance in mind, researchers and coaches alike have focused on obtaining optimal gains while reducing the likelihood of overtraining (i.e. periodization). When considering previous research, much of it has been developed outside of the United States and can be difficult to obtain. Some of the earliest published work in English on periodization began with Matveyev in 1965 from the Soviet Union

(Brumbach, 1993; Kraemer & Fleck, 2007; Pedemonte, 1982; Rowbottom, 2000; Stone, O'Bryant, & Garhammer, 1981a; Stone & Garhammer, 1981). Though he was not the first person to investigate periodization, his concepts and research helped shape the foundations of periodization today. Other researchers outside of the United States who have published work discussing training systems include Nádori, Medvedyev (1989), Verkhoshansky (1977, 1988, 2006), and Bompa (1994). These individuals have all expanded our knowledge of strength training and/or the training process from other countries, yet many coaches and strength trainers within the United States are not familiar with their work. This is a dilemma because some investigators have attempted to develop and dissect periodization trying to perfect and define this notion, but by not having a complete understanding, they are developing misconstrued models of training. Many coaches do not understand the fundamentals of periodization and can be mislead by undeveloped methods that are suggested in research. Some of the earlier investigations discuss the need to structure and plan the training process in order to elicit superior results, which are essential concepts of periodization (Medvedyev, 1989; Stone, O'Bryant, & Garhammer, 1981a; Verkhoshansky, 1977).

Strength-Power Periodization Research

Investigators have continued the examination of periodization, and have further developed two key concepts: cycling training structures and phases/stages of developmental goals (Bompa, 1994; Bompa, 1996; Brumbach, 1993; Graham, 2002; Haff, 2004a; Issurin, 2008; Kraemer & Fleck, 2007; Plisk & Stone, 2003; Rowbottom, 2000; Schiotz et al., 1998; Stone, O'Bryant, & Garhammer, 1981h; Stone et al., 2007).

The training process cycles through three different phases; preparation (general and specific), competition, and transition (Kirksey & Stone, 1998; Pedemonte, 1982; Plisk & Stone, 2003; Stone et al., 1999a; Stone et al., 2007) (See Figure 1-2). All of the phases are designed to manipulate volume and intensity factors in order to elicit optimal performance gains from the athlete(s) for which it is designed. Because much of the knowledge of periodization came from Olympic sports, it is important to understand that throughout the literature, the phases have taken on several names with the same basic meaning. Preparation is synonymous with pre-season and development. Competition can be interchanged with in-season, peaking, maintenance, and even Olympic Games, though there can be slight differences in their meaning (e.g. maintenance is usually used to maintain optimal performance throughout an entire season of a sport instead of peaking for certain competitions).

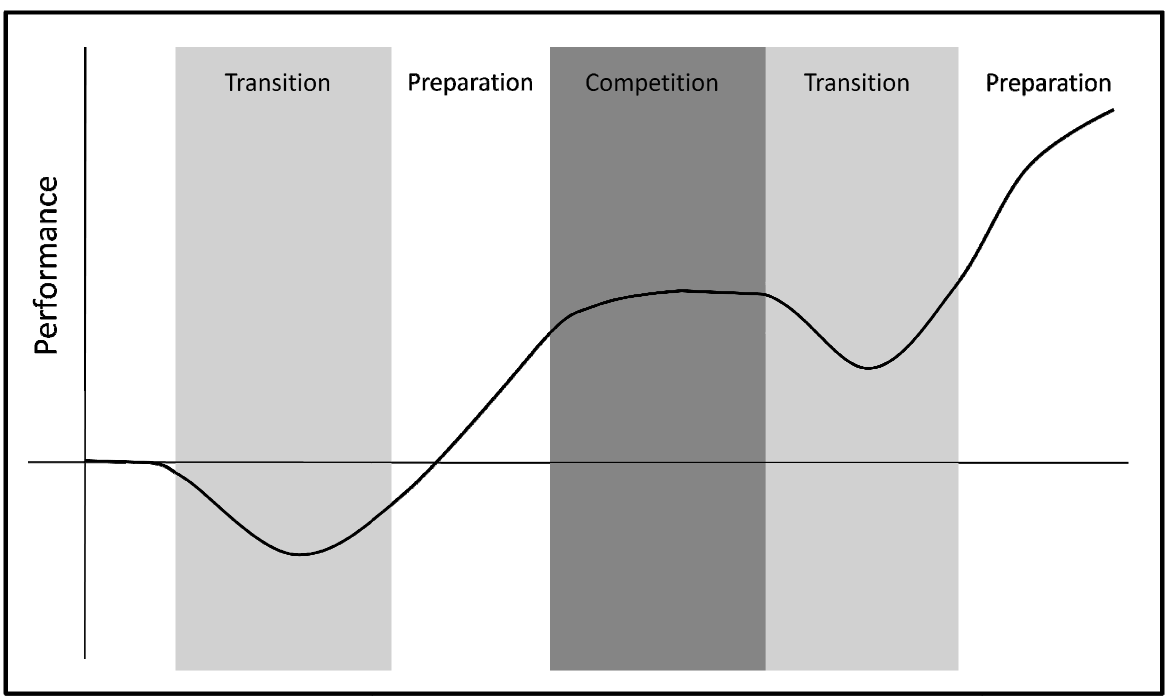


Figure 1-2 Phases of Training

The transition phase consists of active rest and a possible temporary loss of sport specific performance. Active rest corresponds to post-competition training reduction that includes relaxation (a complete absence of training) and/or low volume, low intensity training. The transition phase typically follows a strength-endurance concentrated load or a competition phase, and because of the accumulated fatigue athlete preparedness will be decreased (Stone et al. 2007, Verkhoshansky 1977). For example, a concentrated load increases both fitness and fatigue, but in order to increase performance/preparedness, the accumulated fatigue must diminish.

Development of athlete performance abilities and capacities is the universal goal of all athletic training programs. Relating to GAS, the performance during the preparation phase corresponds to the reaction phase. When breaking down a macrocycle in a traditionally periodized training program, there will be periods of low and high performance, and usually, with regards to seasonal sports, athletes should perform better during the seasonal/peaking mesocycles than during the off-season mesocycles. One reason for this is the sequential structure of the training plan and the ability to manage preparedness through the modulation of fitness and fatigue.

Coaches use the preparation phase as a chance to develop their athletes, often using increased workloads. This phase of training typically consists of high volume and low to moderate intensity exercises in order to stimulate various endurance, strength-endurance, or muscle hypertrophy factors depending upon the needs of the sport (Behm, Reardon, Fitzgerald, & Drinkwater, 2002; Bompa, 1994; Brooks et al., 2005; Medvedyev, 1989; Plisk & Stone, 2003; Poliquin, 1988; Stone et al., 2007; Stone &

Garhammer, 1981). Hypertrophy is a cornerstone for strength/power training programs because additional muscle mass will help an athlete better cope with in-season stresses as well as increasing the potential of strength/power development by increasing contractile elements (Medvedyev, 1989; Poliquin, 1988; Stone et al., 2007; Stone & Garhammer, 1981; Verkhoshansky, 1977). Due to this increase in workload, endurance and strength-endurance characteristics can be enhanced. However, there can be an acute but temporary decrease in sport-specific performance because of the increased amounts of fatigue.

Narrowing the scope more, we should find that within a preparation phase, there can be even more fluctuations (See Figure 1-3). Micro-fluctuations within a mesocycle are formed through the manipulation of microcycles. Even closer examinations shows that there are more micro-fluctuations within each microcycle that are attributed to daily variance, as well as fluctuations within the day. (See Cycling and Stages., pg. 50 for an expanded discussion of cycle variation.) These variations in workload help in reducing to total amount of accumulated fatigue and aid in the development of performance.

A maintenance phase (a variation of the competition phase) is more appropriate during extended seasons. In many team sports (i.e. American football, soccer, basketball, etc.) there is a long in-season period that can make it difficult for a strength coach to design an appropriate training program. This is a fine balance between the fitness and fatigue because if the athletes are stimulated too much, preparedness will decrease as a result of accumulated fatigue that could increase the risk of reduced competitive performance. On the reverse side, if the athletes are not stimulated enough, fitness will decline and a state of involution will occur resulting in a decrease in preparedness and ultimately performance capacities. At this point, it is imperative to develop well thought-out microcycles that optimize performance through the balance of fitness and fatigue. The transition (active rest) phase is needed in order to advance performance and encourage development. This is a period of rest and recovery in order for the body to adapt to the stresses of an upcoming training session, mesocycle, or sport season. This period of recovery may lead to lowered performances and diminished athletic performance. Typically, with an increase in volume or after a concentrated load, there is a decrease in performance.

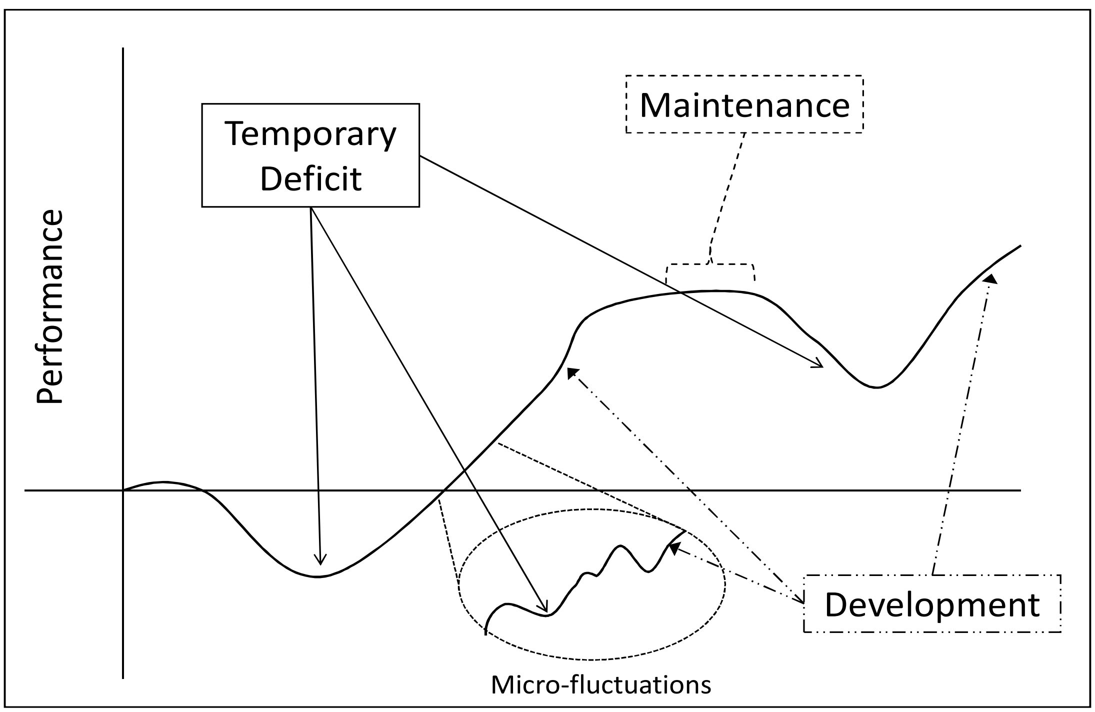


Figure 1-3 Development of an Athlete Over Time

This type of temporary deficit is similar to the alarm phase, and may also be present in a more minute scale down to day-to-day performances, but the fatigue induced suppression of performance can be managed by altering workloads. At the end of a phase of training, performance is usually decreased, but following this brief decrease in performance there is a delayed training effect that elevates performance higher (supercompensation) than it was before the stimulus of the training phase (Brooks et al., 2005; Stone et al., 2007; Verkhoshansky, 1977).

Recent Developments. Many investigators have pursued the best avenue to implement periodization and there have been two basic tracks that have developed: traditional periodization (TRA) and "linear" periodization (LP) (See Figure 1-4). The TRA side of thinking more closely resembles the original concept, whereas LP tends to neglect key concepts developed in the early stages of periodization. TRA has evolved into Block Periodization (BP), which is a concept that calls for multiple periodized blocks to be sequenced across a season (macrocycle).

There have been several investigations into periodization and multiple papers compared periodization methods to non-periodized methods (Herrick & Stone, 1996; Kraemer et al., 2003; Kraemer et al., 2004; Kraemer et al., 2000; Rhea & Alderman, 2004; Rhea et al., 2002; Rhea et al., 2003; Schiotz et al., 1998; Stowers et al., 1983; Willoughby, 1993). Current research has attempted to manipulate TRA in order to develop other methods (i.e. UP, DUP, LP, etc) within the guidelines of periodization.

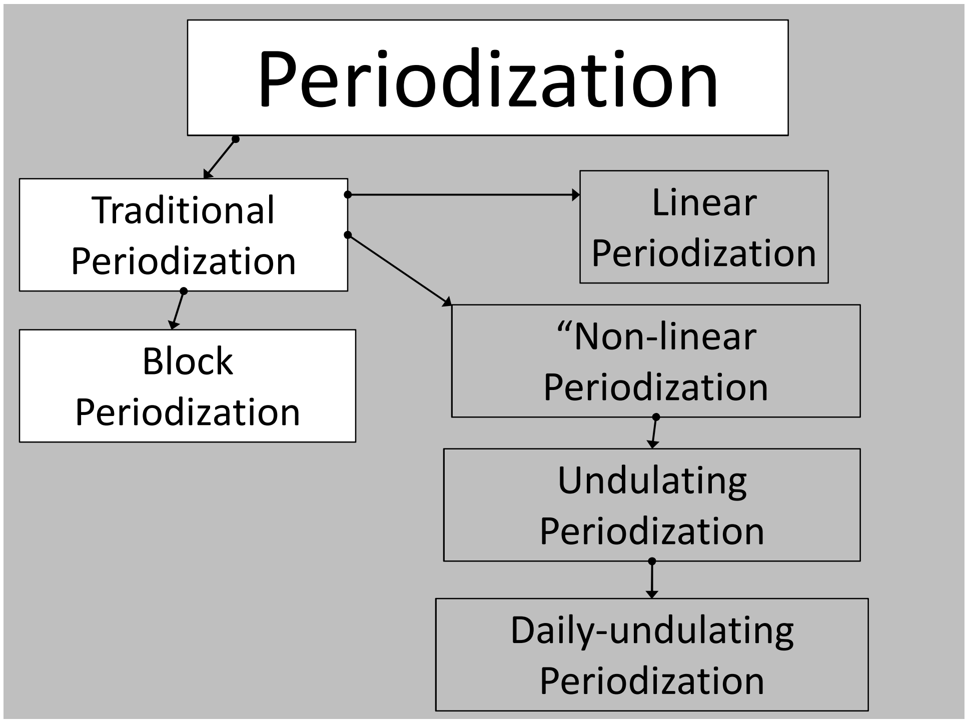


Figure 1-4 Development of Training Methods

The usage of the term LP has become more prevalent in current research (Hoffman et al., 2009; Peterson et al., 2008; Prestes, De Frollini, Donatto, & Conte, 2009; Rhea et al., 2002; Rhea et al., 2003), and this term has some of its roots with Baker et al. (1994). An over-simplified version of periodization, it increases intensity, and decreases volume sharply (Baker et al., 1994) with each mesocycle in a block, while neglecting microcycle fluctuations. By definition, the current version of LP repeatedly being used is not a form of periodization. It often uses repetitions, while training to failure, to establish training volume (Baker et al., 1994; Hoffman et al., 2009; Kraemer et al., 2003; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003; Stone et al., 2007) and lacks the essential microcycle variations that are key in managing fatigue. In addition, researchers use total repetitions to erroneously estimate the volume changes in the program. This is a misrepresentation of TRA that integrates training factors and alters training focus. Many researchers have used the terms TRA and LP incorrectly when they have attempted to compare it to other training models. This discrepancy has confounded the research and has caused some misconceptions.

The study done by Baker and colleagues (1994) compared non-periodized, UP, and LP training models (12-weeks in duration) on previously trained individuals and found there were no significant differences between the groups (Baker et al., 1994; Kraemer & Fleck, 2007; Stone et al., 2007). This study equated volume and intensity by using a set and repetition scheme, which is a substandard method. In addition, this investigation established the LP model by incorrectly referencing Stone, O'Bryant, and Garhammer (1981). Baker et al (1994) were unclear in their training protocols, trained three days a week, used additional exercises, and failed to incorporate week-to-week or day-to-day variation. Additionally, this study suggests that no repetitions were missed even though exercises were performed to repetition maximum (RM).

Another investigation compared LP to reverse LP using a 12-week program, and found LP to be superior in eliciting strength gains, but reverse LP showed to elicit better endurance gains (Prestes et al., 2009). This investigation simply indicates that increasing the workload of training better simulates sport-specific tasks of endurance activities.

One study claiming to use periodization methods, actually implemented, what seemed to be, a strength-endurance phase of a DUP style (Kraemer et al., 2003). In this study Kraemer et al. (2003) indicate that this method of periodization (DUP) provides more variation but only compared it to a training program that used 2-3 sets of 8-10RM each day. The first error in this investigation is the classification of a daily variation model of training (DUP) as periodization. This study was established on the notion that traditional training programs provide “limited variation” over long-term periods (Kraemer et al.). It is unclear if this is a reference toward TRA models of training, but in comparing the DUP model to a linear program with no variation simply contrasts the differences between using variation and using relatively little variation. In this study, it was found that using variation produced greater strength gains (Kraemer et al.).

Rhea et al. (2002, 2003) have conducted two investigations comparing LP to DUP, and in both of the studies, they attempted to equated volume and intensity using total repetitions. They claim that DUP is more effective in the development of strength (Rhea et al., 2002), but there were no significant differences between LP and DUP in muscular endurance (Rhea et al., 2003). However, both of Rhea’s investigations used RMs for the training sets, and most practical training models rarely use RMs because; one, the use of RM values essentially creates a constant relative maximum reducing variation (i.e. no heavy or light days), and two, the constant training to failure makes fatigue management increasingly difficult and raises the potential for OTS (Campos et al., 2002) and the detrimental effects on strength and power development (Izquierdo et al., 2006). Additionally, instead of referencing the original source, Rhea et al. based their strength development model from the paper by Baker (Baker et al., 1994; Rhea et al., 2002), who developed his misinterpreted model after Stone, O’Bryant, and Garhammer (1981a).

Undulation training that resembled DUP was examined in another study using firefighters. Peterson et al. (2008) compared undulating training to a “standard training” control group, which appeared to have some similarities to the LP used in Rhea’s studies (Rhea et al., 2002; Rhea et al., 2003). Peterson et al.’s (2008) research indicates that

DUP "…may offer greater transference to performance for firefighter-specific job tasks." One issue with this 9-week study is the lack of information about the control group. The study presents the DUP training protocols, but leaves the reader to assume the nature of protocols for the control group. Without clearly defined protocols, it makes replication and interpretation of this study difficult.

An additional investigation compared LP, or what was called "traditional periodized linear training," to DUP and found no significant differences in most variables (Hoffman et al., 2009). However, they did find a significant increase in medicine ball throws in only the LP group, which may indicate more explosiveness. Additionally, calculations of the effect size (ES = 1.43 vs 0.74) based on means and standard deviations and the percent gain (20.9% vs 11.1%) indicate that the LP group actually produced superior gains in the squat compared to the DUP group.

Buford (2007) compared three differing models of periodization (LP, DUP, and a weekly-UP) for nine weeks and found that there was no difference between the groups in the early phase of training. One issue presented by this study is the lack of sharp changes in what appeared to be volume load. The LP group only had a difference of two repetitions between phases (i.e. 3x8, 3x6, 3x4), while the DUP and weekly-UP groups had instances of a four repetition difference (i.e. 3x8 to 3x6 to 3x4, then back to 3x8, 3x6, 3x4…) (Buford et al., 2007). This can potentially become a problem because physiologically the loading changes in the LP group are very similar from one phase to the other, while the weekly-UP change from 3x4 back to 3x8, which may influence more pronounced physiologic changes. Another dilemma of this study is the percent differences (%diff) found from the first and last trials were not the same (Buford et al., 2007). When analyzed using effect sizes (Cohen's *d*), both the LP and weekly-UP groups performed markedly better than the DUP group in both the bench press and leg press (See Table 1-1).

Table 1-1 *Differences Between Groups*

Exercise	Program	Start*			End*			Effect Size	%diff
Bench Press	LP	131.11	±	52.1	162.8	±	58.4	0.57	24.2
	DUP	154.5	±	74.2	181.5	±	70.5	0.37	17.5
	Weekly-UP	145.0	±	40.9	180.6	±	43.3	0.84	24.5
Leg Press	LP	370.0	±	116.3	685.6	±	165.2	2.21	85.3
	DUP	399.5	±	139.8	715.0	±	160.8	2.09	79.0
	Weekly-UP	255.56	±	89.32	710.0	±	153.0	2.83	99.7

*Data taken from Buford et al. (2007) A comparison of periodization models during nine weeks with equated volume and intensity for strength. *Journal of Strength and Conditioning Research.* 21, 1245-1250

Common Problems in the Literature. When considering the recent investigations into differing training models, there seems to be some confusion. Equating volume and intensity, misconceptions of training ideas, and using RM target repetition ranges (an example would be lifting 3x3-5 RM rather than lifting 3x3 or 3x5 at a given load or percent of 1RM) seem to be the common error made when investigators have developed their models of training.

Periodization is a method that uses the manipulation of volume, intensity, and other variables to accomplish specific goals. This is an important idea because the goals of any particular program dictate how the variables are manipulated. Fatigue is related to volume, and consistently high volumes can create excessive fatigue causing overtraining that could eventually develop into OTS. Periodization is a way to manage volume, allowing for fluctuations between high and low volumes of work. The variation of volume is accomplished at the mirco-, meso-, and macrocycle level of the periodized plan. Some researchers who have attempted to equate volume and intensity (Baker et al., 1994; Rhea et al., 2002; Rhea et al., 2003) have neglected fundamental aspects of training program variations. Often set and repetition schemes are used incorrectly to denote volume and intensity. This method of depicting volume assumes that everyone in the same group lifts approximately the same weight for the same exercise through the course of the give set and repetition scheme. Because of the constant fluctuations in strength and performance throughout a training cycle, this method does not illustrate any micro-fluctuations resulting from fatigue or planned variations. However, set and repetition schemes have been investigated numerous times and certain schemes can be associated with particular training goals (i.e. high repetitions to hypertrophy, medium repetitions to strength, low repetitions and fast movements to power, etc.). In addition, the programs found in these studies used RMs, thus trained to failure (Baker et al., 1994; Rhea et al., 2002; Rhea et al., 2003). When training to failure, it is impossible to equate total repetitions as the actual amount of repetitions completed varies between individuals

A major problem with recent trends in the literature is basic terminology. The term LP has been compared and contrasted, yet many programs developed using this method lack microcycle variations. Thus, the lack of variation used in the LP is a different concept compared to periodization. Even though he cites Stone, O'Bryant, and Garhammer (1981a), Rhea's development of the LP training program is more of a blend from that paper and Poliquin's (1988) depiction of periodization. The paper by Stone et al. (1981a) illustrates ranges for the stages of development; 3-5 sets and 8-20 repetitions for hypertrophy, 3-5 sets of 2-6 repetitions for basic strength, and 3-5 sets of 2-3 repetitions for power (Stone et al., 1981a). When examined closely, Stone et al. (1981a) do not indicate ranges for the lifting sessions but rather ranges for the microcycles. This is an important distinction because instead of performing 3x5 or 5x5 in a session as Stone suggests, there is a range, and with this range comes the RM zone tactic (Kraemer & Fleck, 2007) (See Table 1-2).

Table 1-2 *Example Set x Repetition Scheme for a 4-Week Mesocycle with a Focus on Strength*

Suggested by Stone (1981a)				RM zone training			
	Sets	Repetitions	Total Repetitions		Sets	Repetitions	Total Repetitions
Week 1	5	5	25	Week 1	3	2 to 6	3 to 18
Week 2	3	5	15	Week 2	3	2 to 6	3 to 18
Week 3	3	3	9	Week 3	3	2 to 6	3 to 18
Week 4	3	2	6	Week 4	3	2 to 6	3 to 18
Mesocycle total repetitions =			55	Mesocycle total repetitions =			12 to 72

The RM zone strategy has had limited research. One study suggests RM training may improve local muscular endurance (Rhea & Alderman, 2004); however, other researchers indicate this strategy may not be as useful for developing strength and power (Izquierdo et al., 2006). In this example RM zone training may have a greater potential for producing volume (See Table 1-2), and that may be a factor that can lead to greater muscular endurance (Behm et al., 2002; Izquierdo et al., 2006). Herein lies the challenge of focusing training on muscular endurance; train too little, and there will be little gain in fitness; train too much and there will be a high risk of increasing fatigue and becoming overtrained (Stone, Chandler, Conley, Kramer, & Stone, 1996; Urhausen & Kindermann, 2002; Willardson, 2007). One proposed solution to this problem is to disregard the RM zone approach and develop microcycle volume variations.

When focusing on strength development, studies have shown improvements in both training to failure (Rhea & Alderman, 2004) and not training to failure (Behm et al., 2002; Izquierdo et al., 2006). However, these studies show that the training to failure group are more fatigued and overworked, which in turn produces smaller gains compared to the not training to failure groups (Izquierdo et al., 2006; Stone et al., 1996; Stowers et al., 1983). This is an important aspect, because fatigue accumulation becomes too great if high intensities are encountered too often or proper recovery is not installed into a training program, which can lead to decreases in performance and possibly overtraining.

Using RMs has been compared to using percentages of a 1-RM (%1-RM) in order to prescribe training intensities (Crewther et al., 2008; Izquierdo et al., 2006; Shimano et al., 2006). Regarding the variance in strength throughout the day and the capabilities of different muscle masses, %1-RM can be an inefficient way to prescribe intensity (Poliquin, 1988; Shimano et al., 2006; Tan, 1999). It has been suggested that training to RM may be more beneficial than using %1-RM because of the potential to recruit more motor neurons (Kraemer & Fleck, 2007; Tan, 1999). However, the superiority of RM training because of recruiting additional motor units is debatable (Stone et al. 1996) because it does not appear to produce superior strength or power gains when compared to non-failure (non RM) training (Izquierdo et al., 2006; Peterson et al. 2005; Stone et al. 1996). Furthermore, training to failure should not become a consistent training protocol because of the high risks for overtraining and overuse injuries (Hoffman et al., 2009; Izquierdo et al., 2006; Stone et al., 1996; Tan, 1999; Willardson, 2007), and the use of light days that recruit fewer motor units may aid in the maintenance of fatigue (Plisk & Stone, 2003) . One possible solution to this situation is the use of relative intensities. Using periodization, the idea of relative intensity can become simple to integrate into a training plan.

Assigning relative intensities is a method of determining training loads that minimize the risk of overworking the athlete, especially advanced athletes. In order to implement relative intensities, a training plan must be developed that depicts heavy and light weeks and has an assigned set and repetition scheme. After the basic development, intensity percentages can be assigned for each week (See Figure 1-5, pg. 46). For example, the first phase of training emphasizes strength-endurance and increasing lean body mass. If the program calls for four weeks of 3x10, one of those four weeks should be more intense (heaviest load) than the rest. This type of loading (increasing intensity and/or volume load for 3 weeks, then often followed by a lighter or unloading week) is the typical pattern used to enhance maximum strength or strength-endurance (Plisk & Stone, 2003; Stone et al., 1981a; Stone et al., 1982; Stowers et al., 1983).

In this example, the third week will be the most intense and highest volume load week of the phase, so for that week an average relative intensity range is given: 90%-95% (See Figure 1-3). Each week can be further broken down into heavy and light days. Heavy and light days are created by adjusting the load, not by changing the repetitions and the loading. Thus alterations in intensity (load) result in changes in volume of work (volume load) (Plisk & Stone 2003; Stone et al. 2007). For elite lifters, this process can be broken down even further to the multiple training sessions in a day. This ensures the desired training affect while giving room for the athlete to adjust in case there are external stressors adding to fatigue. This method also negates the problems that %1-RMs had by not being relative to the lifters current strength levels. However, there is a need to accurately project a reasonable assessment of how much load an athlete would be able to handle 2-3 weeks in advance. Experience with several hundred athletes indicates that this method of planning training loads worked quiet efficiently and requires only a few weeks for the athletes to become accustom to this method (personal communiqué, M.H. Stone and K.C. Pierce).

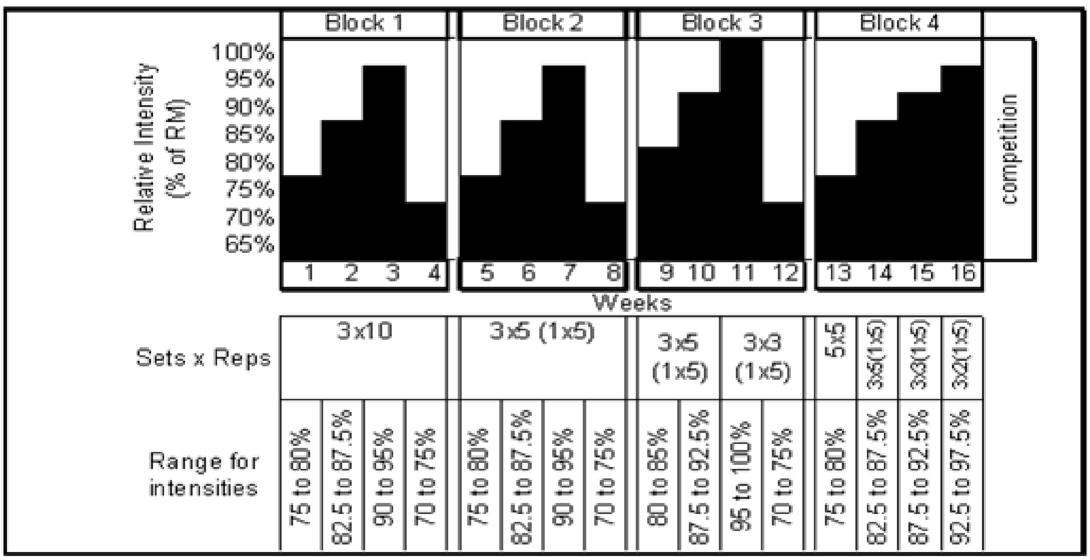


Figure 1-5 An Example of a Basic Periodized Training Plan

In the example shown in Figure 1-5, the fourth week in each block is the unloading week. This unloading week, along with heavy and light training days, is a crucial microcycle that aids in the avoidance of excessive fatigue. A week of lower intensity and volume assists in fatigue management; however, the loading must be kept at a level that does not allow for involution to occur. Other strategies that can be implemented in the prescription of volume load include clusters and potentiation complexes (Stone et al., 2007). It is also important to note that not all exercises need to follow the same set x repetition scheme. Assistance exercises have lower metabolic costs, use less muscle mass, and have decreased biomechanical efficiencies, thus these exercises may not need as much variation.

Other shortcomings of current research include the lack of appropriate sample pools and the length of the studies. Several investigations use non-athletes and/or small sample sizes (N<10) (Buford et al., 2007; Campos et al., 2002; Peterson et al., 2008; Prestes et al., 2009; Rhea et al., 2002; Rhea et al., 2003; Willoughby, 1993). While it is realized that subjects, particularly well trained subjects or athletes in training may not be readily available, small samples still may limit interpretation of results and generalizability. Many of the earlier investigations into periodization of training involved large sample sizes and lasted six months or longer, while using advanced athletes (Attetika, 1980; Medvedyev, 1989; Stone et al., 1981a). These issues rely heavily on subject convenience and availability and were often descriptive in nature.

Within the United States, there is often a resistance from coaches to allow their athletes to participate in research studies. With this resistance, many investigators have used an average healthy population or moderately to well-trained non-athletes. While research on training non-athletes is warranted, it has often been applied to the athletic population. It has been noted that strength/power athletes, endurance athletes, and untrained individuals all respond differently when physically stressed (Fry et al., 1994; Skurvydas, Dudoniene, Kalvenas, & Zuoza, 2002; Tan, 1999). Differences between non-athletes and athletes can include genetic abilities, physiological adaptations, and training history. Increased muscle cross-sectional area, heightened neurological signaling, and increased hormone sensitivity have all been associated with prolonged strength-power training. Due to these differences, it is imperative that investigations with the goal of advancing athletic training be focused on an athletic population.

Furthermore, athletes rarely use specific aspects of training (e.g. strength, endurance, power, etc.) in complete isolation. On the other hand, a common mistake in training athletes is emphasizing all training characteristics simultaneously, which may initially yield improvements but will lead to excessive fatigue that can result in stagnation or low performance improvement over a relatively short term (e.g. months) (Issurin, 2008). However, training athletes requires a multifaceted approach, and this can be accomplished through properly planning variation. The use of a periodized approach assists in emphasizing the correct characteristics at the appropriate time.

The majority of current studies are less than 15 weeks in duration (Bradley & Haff, 2001; Buford et al., 2007; Campos et al., 2002; Harris, Stone, O'Bryant, Proulx, & Johnson, 2000; Herrick & Stone, 1996; Hoffman et al., 2009; Izquierdo et al., 2006; Kraemer et al., 2003; Peterson et al., 2008; Potteiger et al., 1995; Rhea et al., 2002; Rhea et al., 2003; Schiotz et al., 1998; Willoughby, 1993). With a limited length, it is difficult to ascertain the long-term effects of any given training program. Without extended research, any differences (or lack of differences) between groups may be a temporary result rather than a continual affect the program will elicit. This criticism (short-term study) is a major limitation of our current level of research on strength-power periodization effects, but was a strength of previous observational studies (Plisk & Stone 2003).

Large sample sizes will increase the validity of any study, but often obtaining data from large groups can be difficult, especially when dealing with athletes. Because athletics have such a large range (e.g. team sports vs. individual sports), it can be a challenging to acquire an entire team to participate in a study. This becomes even more challenging when attempting to manipulate training for a study using this population. With just cause, coaches often want the best training for their athletes, and they are frequently adverse to the suggestion of using an unsubstantiated method of training. With these obstacles, it is easy to understand why there is limited research on upper-level athletes and athletes in general.

Periodization Rational

Each training program should be designed to fit the individual needs of the athlete or sport. Periodization is not a concept that centers on more than one set and repetition scheme. It is a logical and systematic way of planning and organizing a training program to produce optimal performance gains while avoiding the accumulation of excessive fatigue. If used correctly, periodization will allow for better control of training variables (Bompa, 1996; Rhea & Alderman, 2004; Rowbottom, 2000; Stone et al., 1999a; Stone, Pierce, Sands, & Stone, 2006; Stone et al., 2007). Many strategies have a similar pattern of workload manipulation. Lowering training volume while raising intensity is a basic periodization concept and may have contributed to how the term “linear” periodization (LP) has found its way into the scientific terminology (Baker et al., 1994; Bradley & Haff, 2001; Rhea et al., 2002; Rhea et al., 2003). Models of LP have been developed (See Table 1-3) and when examining them at the mesocycle level, they do seem to progress in a linear fashion, but an analysis of the microcycles and placing multiple mesocycles together (forming a macrocycle) turns what seemed to be a linear pattern into a wavelike design. Poliquin (1988) states, “A common mistake seen in strength training programs for football is linear intensification…” (See Table 1-3), or simply continually increasing the weight while lowering the set and repetition scheme.

Due to the lack of recovery, a “linear” model of periodization could increase accumulated fatigue that may elevate the risks of overtraining. Varying volume and intensity has been shown to produce optimal performance gains (Herrick & Stone, 1996; Poliquin, 1988; Stone & Garhammer, 1981). Aspects of periodization that proponents of LP have failed to recognize and incorporate into their research are the variations that are contained in the meso- and microcycles. Table 1-3 represents a gross over-simplification of the TRA model, which has mutated into the LP model. When considering the example TRA plan in (pg. 50), the set and repetition scheme may be similar, but there is considerably more week-to-week variation with volume and intensity than compared to LP. Day-to-day variation (heavy and light days) also occur but are not shown. This example illustrates how a TRA training program cycles stages and varies both volume and intensity, leading to elevated fitness and/or performance. A more appropriate term than LP for this model would be “block” periodization as presented by Issurin (2008).

Table 1-3 *Standard Linear Intensification of Training in Strength Development*

Weeks	1-4	5-8	9-12	13-16
Repetitions	10	5	3	2
Sets	5	3	3	3
Intensity	75%	85%	90%	95%
Volume (total repetitions)	50	15	9	6

Adapted from: Poliquin, (1988). “Five steps to increase the effectiveness of your strength training program.” *NSCA Journal.* 10, 34-39

Cycling and Stages. It has been suggested that the development of multi-year plans are necessary in order to direct the training program more efficiently (Bompa, 1994; Haff, 2004a; Stone et al., 2007; Verkhoshansky, 1977). Beginning with the annual training plan and working down to the individual microcycles, each stage should cycle through preparation, transition, and/or competition phases as mentioned previously (See Strength-Power Periodization Research, pg. 30). Macro- and mesocycles undergo three phases: preparation, competition/peaking, and a transitional period (Bompa, 1994; Bompa, 1996; Brooks et al., 2005; Brown & Greenwood, 2005; Haff, 2004a; Kirksey & Stone, 1998; Plisk & Stone, 2003; Rowbottom, 2000; Stone et al., 1999a; Stone et al., 2007; Verkhoshansky, 1977). These phases move from less specific to more specific in the prescription of exercises and metabolic demands. For example, if the primary goal of the sport were power, it would be logical to train strength-endurance, strength, and then power (See Figure 1-6).

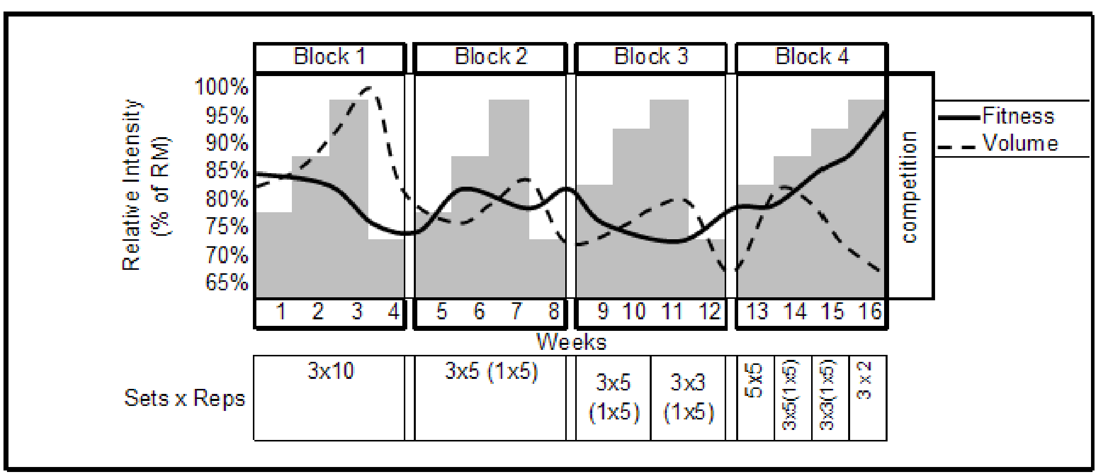


Figure 1-6 An Example of a Basic Weight Training Periodization Plan

The basic pattern found in TRA is an attempt to follow a physiological bio-cycle. These bio-cycles are meant to provide an optimal environment in which an athlete can develop (Brooks et al., 2005). Viru (1995) discusses the half time of the training effect and recommends 24-28 day training cycles with four to six subdivisions, each four to seven days long. Other authors have suggested a similar pattern, splitting the training program into a one-month training cycle with about four subdivisions lasting about a one week long (Medvedyev, 1989; Plisk & Stone, 2003; Stone et al., 2007). With this in mind, the structure of the program should be straightforward and the next step would be determining which cycle would develop which factor.

Depending on the goals of the program, the development of the athlete typically ranges from strength-endurance to power (Fleck & Kraemer, 1997; Graham, 2002; Medvedyev, 1989; Plisk & Stone, 2003; Stone et al., 2007; Verkhoshansky, 1977; Verkhoshansky, 2006). It is important to develop these characteristics in a specified order, because the development of one should augment the development of another (Verkhoshansky, 1977). As noted before for strength/power athletes, initially developing strength-endurance will aid with the development of other variables. In most sports, power is the key to success, and this is a rationale behind cycling stages in order to produce the greatest power gains. While there are arguments as to the best method of training for power, it is commonly accepted that volumes should be lower during a phase devoted to power development (Kraemer & Fleck, 2007; Linnamo, Häkkinen, & Komi, 1998; Plisk & Stone, 2003; Stone et al., 2007; Wilson, Newton, Murphy, & Humphries, 1993).

Non-linear Periodization

Recently researchers have tried to further the development of the method of periodization (See Figure 1-7). These attempts have lead to a various array of concepts, among them are NLP, reverse LP, and UP (Bradley & Haff, 2001; Hoffman et al., 2009; Kraemer & Fleck, 2007; Peterson et al., 2008; Poliquin, 1988; Rhea et al., 2002; Rhea et al., 2003). It is vital to understand that many of these concepts use the guise of periodization, when in fact they violate the major tenants of a true periodizated method. Considering that the origins of these "Non-linear" models of training have their roots in a misconception of periodization, the development of these models is skewed.

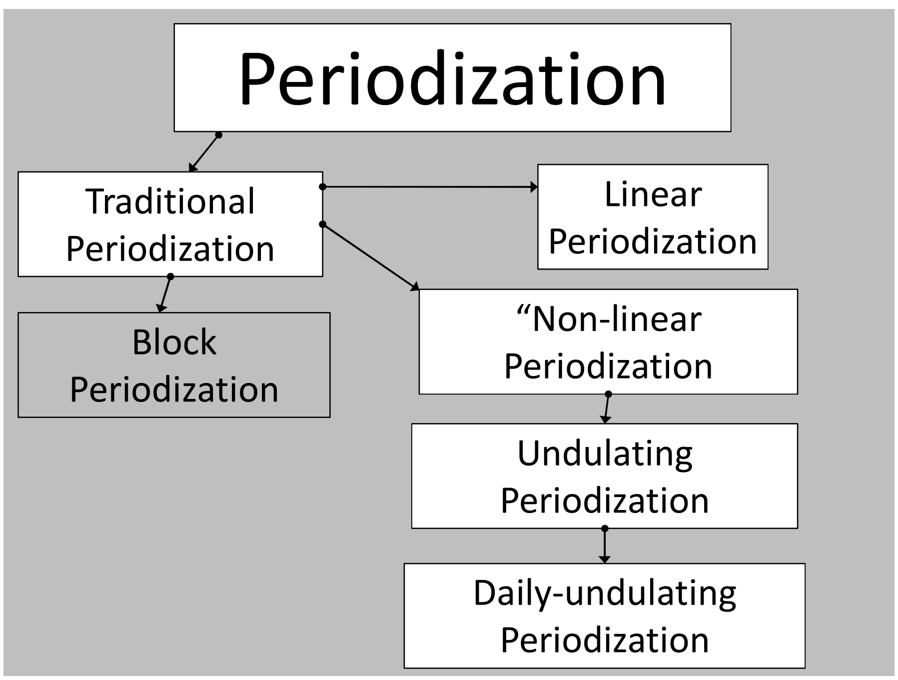
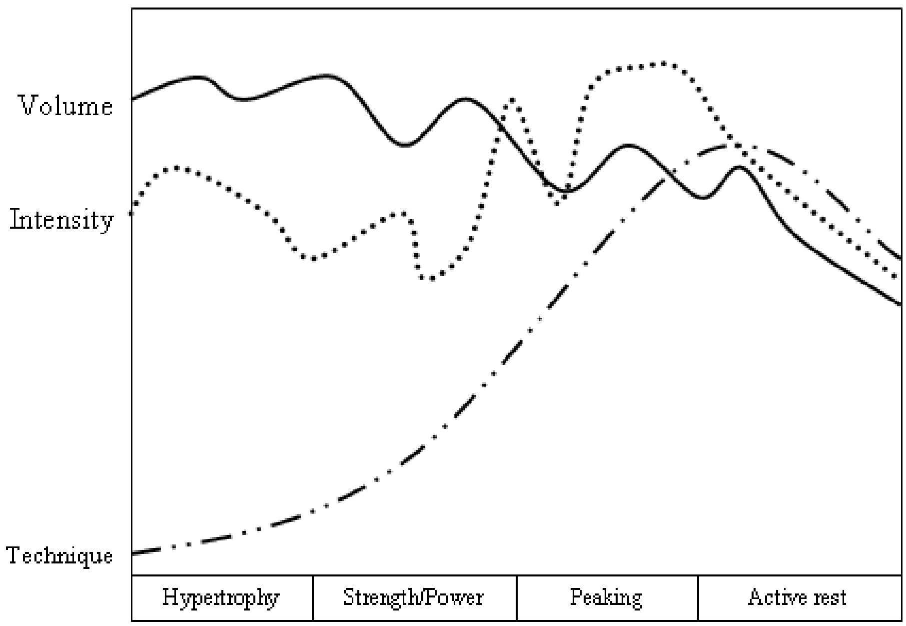


Figure 1-7 Development of Training Methods (Non-Traditional)

The development of DUP (and also LP, NLP, & UP) has been attributed to a paper (Poliquin, 1988) aimed to improve football coaching methods (Bradley & Haff, 2001; Kraemer & Fleck, 2007; Poliquin, 1988; Rhea et al., 2002; Rhea et al., 2003). From this, the term NLP was coined in order to classify the UP and DUP models. With the constant term swapping, it can be difficult to ascertain which program is unique and which are simply another version of the original. An example of what is termed NLP is shown in Figure 1-8.



Adapted from Fleck, S., Kraemer, W. (1997) *Designing resistance training programs*, pg. 104

Figure 1-8 Example on a "Non-linear" Training Program

As represented in Figure 1-7, much of what is being examined today is a misconstrued version of periodization (LP). Because notions of NLP, UP, and daily-undulating periodization (DUP) all stem from LP, they all lack essential components presented in the original concept of periodization. However, many of these newly developed theories actually coincide with the original concept of periodization (TRA) by calling for variation in intensity and volume bi-weekly, weekly, and/or daily. Thus, on a basic level, each program calls for microcycle variation, but the fundamental difference between TRA and the NLP models is the manner in which the programs manipulate the variables of volume and intensity.

Daily-Undulation. Based on the present available literature, programs using the NLP/DUP method tend to adjust volume and intensity solely using repetitions and load, whereas the TRA training method uses repetitions, intensities, training focus, and various exercises to adjust volume. It is known that, especially among advanced and elite athletes, variation in volume, intensity factors, exercise selection, and focus are important training variables that are associated with superior adaptation to training (Plisk & Stone, 2003; Stone et al., 2007). Thus, one possible alteration in training method is to increase the degree of variation. This is a major part of the rationale behind the DUP (Kraemer & Fleck, 2007). A common prescription for a DUP training program is shown in Table 1-4. With this example, Mondays are considered moderate in intensity with 3-4x8-10 RM; Wednesdays are the heavy day using 4-5x3-5 RM; Fridays are the light days with 3-4x12-15 RM. Also, DUP training programs decrease the rest intervals between sets; approximately three minutes for the heavy day, one to two minutes for the moderate day, and only one minute for the "light" day (Kraemer, 2007). One issue with this particular program would be the "light" Fridays. In essence, the weight lifted is lighter than that on the other two days, but there are major physiological implications when performing multiple sets of 12-15 RM with only one minute of rest.

Table 1-4 *Example of a Daily-Undulating Workout Plan*

	Monday	Wednesday	Friday
RM zone	8-10	3-5	12-15
Sets	3-4	4-5	3-4

Adapted from: Fleck, S., Kraemer, W. (1997). *Designing resistance training programs* and Kraemer, W., Fleck, S. (2007). *Optimizing strength training: designing nonlinear periodization workouts*

Evidence indicates that the volume of work accomplish in a session is a primary factor in post-exercise recovery from strength training (Behm et al., 2002; Meirelles & Gomes, 2004; Stone et al., 2007). Volume is typically estimated by volume load (Stone et al. 2007). Considering the typical loading schemes for DUP training, it appears that there are actually no heavy and light days within a microcycle (week). Indeed, a DUP light day (multiple sets of 12 -15 RM) would actually become a heavy day due to the volume load. Lack of day-to-day variation increases accumulative fatigue and can eventually reduced performance. Additionally, the use of RM values necessitates constant training to failure (as previously mentioned). This results in a relative maximum intensity for every training session, again increasing accumulative fatigue and reducing training adaptation.

This type of training plan also disregards the potential natural bio-cycles as mentioned earlier (See Cycling and Stages., pg. 50). Appropriate planning may take advantage of these bio-cycles, or circadian patterns, to produce optimal training environments. A disregard of these cycles may limit any training program and the development of an athlete.

Summary

Periodization refers to a logical, systematic process of manipulating training variables (i.e. repetitions, sets, rest, intensity, volume, etc.) in order fit an athlete's needs by breaking the training plan into smaller portions of high and low volumes in order to manage fatigue and remove linearity. This method always includes varying phases and cycles that have specific physiological and performance goals. The primary goals of periodization are: 1) fatigue management and reduction of the overtraining potential, 2) peaking at the right time, and 3) providing a maintenance program for sports that have a defined season in which all games are suppose to be won. Recently a number of "alternative" or new forms of periodization have been developed; these new methods including DUP attempt to maximize variation by altering the repetition scheme on a daily basis. To date there have been few studies that have compared a more traditional approach to periodized strength training and DUP, especially among athletes during normal training. Additionally, many of the comparison studies also disregard other training factors by conducting strength training in isolation. The purpose of this study is to compare traditional (TRA) methods of periodized training with DUP among NCAA D-1 track and field athletes during a fall preparation phase of training.

CHAPTER 2

A PRACTICAL COMPARISON BETWEEN TRADITIONAL PERIODIZATION AND DAILY-UNDULATED WEIGHT TRAINING AMONG COLLEGIATE TRACK AND FIELD ATHLETES

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Abstract

Recently, a comparison of "periodized" strength training methods has been a focus of sport science. Daily undulating periodization (DUP), using daily alterations in repetitions, has been developed and touted as a superior method of training. The purpose of this study is to compare a traditional form of periodization (TRA) to DUP in Division I track and field athletes. Thirty-one athletes were assigned to either a TRA or the DUP group training programs based on sex, year, and event. Training lasted 10 weeks. There were 4 testing sessions focusing on strength characteristics. Although, trends favored the TRA group for strength and rate of force development, no statistically significant differences were found between the groups. Significant differences in volume and the amount of improvement per volume load were found to be significantly different ($p \leq 0.05$) between the TRA and DUP groups. These data indicate that TRA is more efficient in producing strength gains than DUP.

Keywords: strength, volume load, intensity, T:C ratio

A practical comparison between traditional periodization and daily-undulated weight training among collegiate track and field athletes

INTRODUCTION

Several different methods (models) of strength-power training have been developed recently, each model is purported to represent a form of periodization and each is purported to make advances over more traditional forms of periodization (TRA). TRA has been suggested to be linear in nature [1] and thus results in too little variation for optimum performance adaptation. Daily undulating periodization (DUP) is one of these newer methods that use a form of variation in which repetitions are altered each training session. The greater variation in training offered by the DUP has been suggested to produce superior results [22].

To date few comparison studies have examined differences between DUP and other methods of training and all studies have taken place over a short-term (weeks). These few studies do not indicate any clear cut superiority of one training method over another [4,16,20,21,27,29,30]. However, these studies have some shortcomings that potentially reduce the ability to clearly differentiate between training methods and thus their applicability to well-train and athlete populations. For example, many studies did not use very well trained subjects or athletes. Some of the studies attempted to equalize volume and intensity, usually by equalizing repetitions, a method that is fraught with problems and furthermore tends to obviate the necessary alterations in training variables (i.e. volume and intensity). Nor did any of the studies attempt to track alterations in work done (by volume load) or efficiency of the training programs. .

The purpose of this study was to compare DUP versus a more traditional method of strength-power training (TRA) in NCAA Division-1 track and field athletes over a 10-week fall semester preparation-phase training program. Comparisons were made on maximum strength, rate of force development, and differences in the volume of training load.

METHODS

Experimental approach to the Problem

This study was part of an ongoing athlete research and monitoring program approved by the IRB. The coach of the team approved of all training programs prior to implementation and was encouraged to be present during testing and each lifting sessions. Basically, this study entailed dividing a group of track and field athletes into two groups, each performing a different method of strength-power training. The two groups were traditional periodized training (TRA) and daily undulating training (DUP). Comparisons were made on body mass and composition, maximum isometric strength, isometric rate of force development, and the training variables volume load and training intensity (average bar load). The total amount of tests performed were 4; 3 over a 10 week period, with one the following week.

When comparing differing training methods, it is essential to follow as closely as possible the guidelines of that method. Both training programs were developed after an exhaustive literature review and were reviewed by multiple strength coaches. Repetition maximums (RM) were used only with the DUP group in specific exercises based on previous research [16,20, 29,30] and the text by Kraemer and Fleck [22]. Training volumes were not equated as the present study dealt with practical "real life" training programs. Furthermore, it is probable that by equating work, one or both programs would not be using optimal training schemes (loading, number of sets and repetitions, etc.). This detail has often been overlooked. By equating volume and/or intensities [5,29,30,40], some of the fundamental differences between programs can be missed. As each group contained approximately equal number of athletes by event and sex, the only differences were the volumes and intensities represented by the strength training programs.

Subjects

Thirty-two collegiate level track athletes, 18-22 years of age, initially participated in this study (males = 23, females = 9). All athletes were orally informed of the requirements for the study and all risks involved, then were instructed to read and sign IRB approved informed consent documents prior to initiation of the study. Athletes were grouped into one of three categories; sprinters (S), jumpers (including pole-vaulters)(J), or throwers (THW). No athletes who performed primarily endurance activities (i.e. cross country) were used in the study. Subjects were divided equally between groups based on event, sex, and year (freshmen or returner). All subjects were healthy and approved for practice by the athletic training staff before inclusion. If an injury occurred, the athletic training staff examined the athlete before continued participation. Exclusion criteria included missing three training session for any reason, missing a testing sessions, or a perceived continual lack of effort (i.e. lifting below the prescribed training intensities for multiple sessions). After the conclusion of the study, 6 athletes had been excluded; 1

DUP male THW, 2 DUP male J, 1 TRA male S, 1 DUP female S, and 1 TRA female S. Initial demographic data is shown in Table 2-1.

Table 2-1 Initial physical characteristics of the athletes

Initial Data

	Height (cm)	age
TRA (n=14)	176.9 ± 11.3	19.9 ± 1.2
DUP (n=12)	177.2 ± 5.6	19.4 ± 0.8
TRA males (n=10)	181.1 ± 10.3	20.1 ± 1.3
DUP males (n=9)	178.5 ± 4.7	19.3 ± 0.7
TRA females (n=4)	166.4 ± 6.1	19.5 ± 0.9
DUP females (n=3)	173.1 ± 7.0	19.9 ± 1.3

Procedures

This experiment was performed under real life circumstances. Coaches had control of sport practices, and athlete lifestyles (such as nutrition, sleep, etc.) were not controlled. All data were collected through a previously instated athlete monitoring program. At each session coaches recorded the loads lifted and repetitions completed for each set. Volume load is (VL) an easily calculated estimate of work performed [35]. Volume loads for strength training were calculated from these data. In order to track volume for non-strength-training practices, all athletes were surveyed prior to each lifting session. VL is calculated by sets x repetitions x load. The practice data were checked with the coaches for accuracy. Additionally, the survey included questions concerning any additional exercise performed outside of normal training (strength training and practices). These data were used to estimate the volume of non-strength training work performed. All event groups lifted at their previously designated times; all THW lifted at

7:30 am while all S and J lifted at 5pm. In addition, all S and J lifted after their practices due to time constraints.

<u>Testing</u>

Testing times corresponded closely with lifting times; THW trained and tested in the morning, and S and J trained and tested in the afternoon. All testing occurred at the beginning of the week, on weeks 1(T1), 4 (T2), 8 (T3), and 11 (T4). All testing dates corresponded to the start of a new block for the TRA group. Each athlete was familiarized with the training protocols on multiple occasions several weeks prior to the T1 and the beginning of the program.

Testing consisted of hydration status, blood draws for resting T:C ratio, body composition, and isometric mid-thigh pulls. This testing session took the place of the training session for that day and no other activity was permitted. Testing was conducted on the Monday of each testing week. All athletes were asked to fast for 12 hours before testing took place on day one to achieve optimal conditions for blood analysis, but were permitted to bring something to eat following the blood collection.

Hydration status of the athletes was measured using a refractometer, which measures urinary specific gravity (USG). Specific gravity is a measure of the amount of particles in fluid, pure water having a specific gravity of 1.000. If athletes were dehydrated (USG $\geq$1.02), they were required to drink at least eight ounces of water and retest hydration before they were tested. Hydration status of the athlete is important and has implications for performance and cognitive abilities [41] and could affect test results. Hydration status was also measured on a random basis throughout the study to insure the athletes were maintaining a hydrated status.

After hydration, each athlete was directed to an area designated for blood collection. Blood was collected by certified personnel form an antecubital vain using 21Gx 1-1/2" multiple sample needles and 8.5ml (16 x 100mm) clot activator blood collection tubes. All samples collected were stored on ice until blood clotting took place. After clotting, samples were centrifuged to separate the serum, and the serum was then pipetted into smaller centrifuge tubes and frozen in a -80ºF freezer. Samples were analyzed in one data set at the end of the study. Testosterone (T) and Cortisol (C) were measure by ELISA (DRG International, Mountainside) intra assay CV was 3.8 % for T and 4.5 % for C.

$$T{:}C \text{ ratio} = T/C \times 100$$

Subject height was measured using a stadiometer and recorded to the nearest 0.1 cm. Body mass was determined using an electronic scale and was measured to the nearest 0.1 kg. Body composition was assessed at each time point with the use of plethysmography procedures (BodPOD, Concord, CA).

Each athlete then went through a standard warm-up protocol and performed the isometric mid-thigh pull (isopull). Each individual was placed in the "power" position. In this position, the athlete's back is perpendicular to the ground and is in a partial squat stance with a knee angle of 120-130º (see Figure 2-0-1). The isopull was performed on a rack encompassing a force plate. Measurements recorded by the force plate were analyzed for peak force (PF), rate of force development (RFD) from 0-200ms, and force at 50ms, 90ms, and 250ms. Force measures generally correspond with striking (i.e. 50 ms: kicking a ball, punching, etc.), foot contact time in a sprint (90 ms), and a vertical jump (250 ms), respectively [(23)]. Athlete bar height was recorded before all testing took place and individual bar height was used for every testing session. For each test, the athletes performed at least four pulls (50% effort, 75% effort, and two at maximal effort) on a fixed bar with 1-2 minutes of rest between. If the athlete failed to perform the test correctly or had a difference of more than 250 N between pulls, the athlete repeated the attempt. Isometric mid-thigh pull testing was chosen as the strength measure because its administration is relative rapid (approximately 10 min per athlete), it has a high reliability (ICCα PF = 0.99 and ICCαRFD = 0.96), and the isometric mid-thigh pull shows strong relationships to typical dynamic measures of 1RM squat, snatch and power clean [(14,26,34)].

Monitoring Injuries

Injury surveillance was supervised by the ETSU Sport Medicine Department. All injuries were evaluated and recorded by NATA certified athletic trainers. Athlete training time was modified depending upon the severity of injury.

Figure 2-0-1: Isometric Mid-thigh Pull (Isopull)

Training Programs

In the development of the TRA program, several strength coaches provided feedback, and multiple sources [3,19,28,33] were referenced. The development of the TRA program was constricted within the limitations of scheduling the athletic department weight-room and practice times. The athletes trained 3 days a week for 10 weeks, and each training session was completed within one hour. The TRA program is shown in Table 2-2.

Table 2-2

Sets and Repetitions for the Traditional Group

B1	Strength-endurance	**Week 1**	3x10
		Week 2	3x10
		Week 3	3x10
B2	Strength	**Week 4**	3x5 (1x5)
		Week 5	3x5 (1x5)
		Week 6	3x3 (1x5)
		Week 7	3x2 (1x5)
B3	Power	**Week 8**	5x5
		Week 9	3x3 (1x5)
		Week 10	1x3 (3x5)

Three blocks were set up within the 10 weeks of training. Block 1 (B1) consisted of strength-endurance for 3 weeks; block 2 (B2) focused on strength development for 4 weeks; and block 3 (B3) concentrated on the development of power using the remaining 3 weeks. Table 2-2 shows the set and repetitions for the target sets (warm-up sets are not shown, but were recorded and used in data analyses). Exercises were carefully chosen to best fit the overall needs of the athletes (See Table 2-3). Additionally, heavy and light days were incorporated into the weekly TRA training structure. For example Monday was always a heavier day than Friday. This was accomplished by decreasing the loads by approximately 15%. This alteration in loading was carried out to aid in managing fatigue and to provide a variety of contraction velocities.

Table 2-3

Exercises for the Traditional Periodization Group

Block 1	Block 2	Block 3
Monday	**Monday**	**Monday**
Squats	Squats*	1/4 Squats*
Behind neck press	Push Press*	Weighted Jumps (0-20% of Body mass)
Bench Press	Incline Bench Press*	Push Jerk*
		Incline DB BP*
Wednesday	**Wednesday**	**Wednesday**
Power snatch (3x10 light)	Power Snatch (light)	Power Snatch (light)
CGSS	CGSS	Mid-thigh pulls
Mid-thigh pulls	Mid-thigh pulls*	SLDL
SLDL	SLDL	
DB Row	DB Rows	
Friday	**Friday**	**Friday**
Squats	Squats*	1/4 Squats
Behind neck press	Push Press*	Weighted Jumps (0-20% of Body mass)
Bench Press	Incline Bench Press*	Push Jerk
		Incline DB BP*

*down-sets were performed after each exercise

When attempting to develop a DUP program (Table 2-4 and Table 2-5), much of the literature seemed vague in the description. From multiple sources [5,16,20,22,27,29,30], it was ascertained that each day in the DUP group would more or less be congruent to a phase/block of the TRA program. With this in mind, each of the three days of lifting in the DUP group corresponded to the three distinct blocks setup in the TRA group, and each day having a similar focus (i.e. strength-endurance, strength, power). The next challenge of developing a DUP program was condensing each block into one day of work. Not all blocks in the TRA program followed the same set x repetition scheme each week. The RM range scheme, which has been used in many DUP comparison studies

[5,16,20,27,29,30] and discussed in the literature [22], was employed to negate the differing weeks within the TRA blocks. This method (RM training) was also applied to the selection of exercises for each day of the DUP training program. However, not all DUP exercises were performed to RM (failure values) – power oriented exercises such as pulling movements were performed for the required repetitions with a load requiring a reasonable effort (as deemed so by the coach) but not to failure, and weighted jumps were performed only for the required sets and repetitions at the listed percent of RM.

Table 2-4

Weekly DUP weight training plan

Monday	Strength-endurance	3x8-12 RM
Wednesday	Strength	3x5-7 RM
Friday	Power	3x3-5 RM

An important note regarding the differences between the training protocols is that volume and intensity were not equated, because the manipulation of these variables is a key difference between the training programs. In the present study, the TRA method calls for heavy and light days within the week; however, the DUP protocol manipulates repetitions through the week (Table 2-4).

Table 2-5

Exercises for the Daily-undulating Periodization Group

Monday	Wednesday	Friday
Squats	Squats	1/4 Squats
Mid-thigh pulls	CGSS	Mid-thigh pulls
Behind Neck Press	Push Press	Weighted Jumps (30% Bdm)
Bench Press	Incline BP	Push Jerk
DB Rows	DB Row	SLDL

Knowledgeable training staff (coaches) aided in monitoring and coaching the exercises for all athletes. Each coach was assigned three to four athletes and alternated between the TRA and DUP groups every two weeks to negate coaching affects. The lead investigator oversaw all training and ensured adherence to the training protocol.

Statistical Analyses

All data were analyzed with SPSS (version 14.0 & 16.0; SPSS, Inc. Chicago, IL.). Multiple 2 x 4 repeated measure analysis of variance (ANOVA) were used to determine if significant differences existed between the training interventions and the measurement times for all tested variables. A 2 x 10 ANOVA was used in the analysis of the volume load for each of the 10 weeks of training. Follow-up one-way ANOVAs were then performed in order to determine where significant differences existed. In order to compare across event groups, allometric scaling of force (strength) was used to normalize affects of body size. Any allometrically scaled variable is followed with a lowercase a (example, IPFa).

$$\textit{Allometric scaling} = \textit{isometric force}/(\textit{body mass (kg)}^{\wedge 2/3})$$

Effect sizes (ES) were calculated. Only ES above 0.5 were reported. Due to a small sample size, THW were compared to both S and J between the groups. There were no statistical differences noted between sexes. Thus, data, when appropriate are presented as complete groups (DUP vs TRA) and group by event.

RESULTS

No statistical differences were noted between groups except for volume load that was about 35% greater over the 10 weeks for the DUP compared to the TRA. However, trends were evident and are noted where appropriate.

Body mass and composition did not change in either group statistically. Body mass tended to increase over time (See Table 2-6). The effect sizes for fat mass and body mass were trivial for both groups.

Table 2-6: Changes in Body Composition over Time

	Fat mass (kg)			
	Test 1	*Test 2*	*Test 3*	*Test 4*
TRA	18.0 ± 15.5	18.8 ± 15.4	17.6 ± 14.9	17.2 ± 14.2
DUP	14.5 ± 8.5	14.6 ± 7.7	14.1 ± 8.1	14.7 ± 8.6
	Body mass (kg)*			
TRA	86.1 ± 30.9	87.4 ± 31.1	87.7 ± 31.0	87.0 ± 30.4
DUP	80.7 ± 18.1	82.2 ± 18.6	82.9 ± 18.2	83.7 ± 19.1

*Significant time effect for body mass (T1 – T4) $p \leq 0.05$

Both instantaneous and maximum forces improved over time ($p \leq 0.05$). Table 2-7 shows IPF and IPFa for the TRA and DUP at each test session.

Table 2-7: Average IPFa & IPF scores

	TRA					
	IPFa			IPF		
T1	236.469	±	49.0534	4609.54	±	1636.622
T2	239.217	±	45.0635	4698.905	±	1561.23
T3	248.925	±	38.1223	4904.296	±	1544.038
T4	271.459	±	47.073	5304.737	±	1709.497
	DUP					
	IPFa			IPF		
T1	215.203	±	41.4535	4032.083	±	1083.739
T2	225.937	±	37.639	4277.32	±	1057.61
T3	240.587	±	34.8621	4595.472	±	839.0647
T4	241.734	±	42.9384	4625.076	±	1144.269

Although there were no statistical differences for force between groups, the TRA group showed a slight improvement for all forces. The TRA ES was 0.73 (14.7 %) for IPFa and 0.41 for IPF (15.1%). The DUP ES was 0.63 (12.1%) for IPFa and 0.52 (14.7%). The ES for the TRA RFD was 0.06 and the ES DUP was -0.22. Figure 2-0-2 shows changes for allometrically scaled instantaneous forces and maximum strength from T1 to T4. Figure 2-0-3 shows the allometrically scaled force gains (T1 vs T4) by event. Although no significant differences were noted, the trend of alterations favors the TRA group. This trend is apparent for each of the force variables.

Figure 2-0-2: Alterations in IPFa T1 vs T4 for TRA and DUP

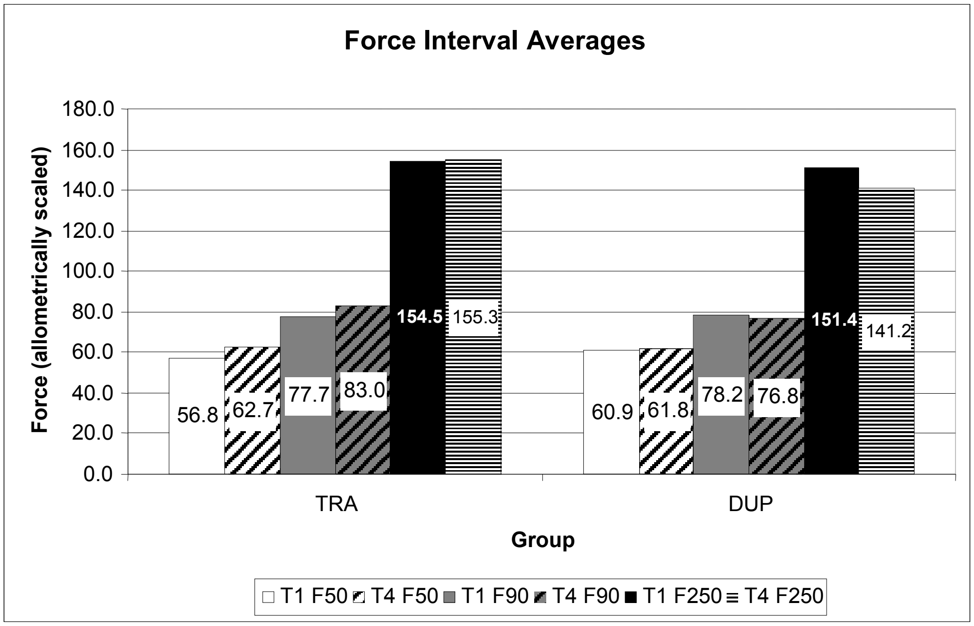


Figure 2-0-3: Alterations in Allometrically Scaled Force Characteristics by Event (T1 vs T4)

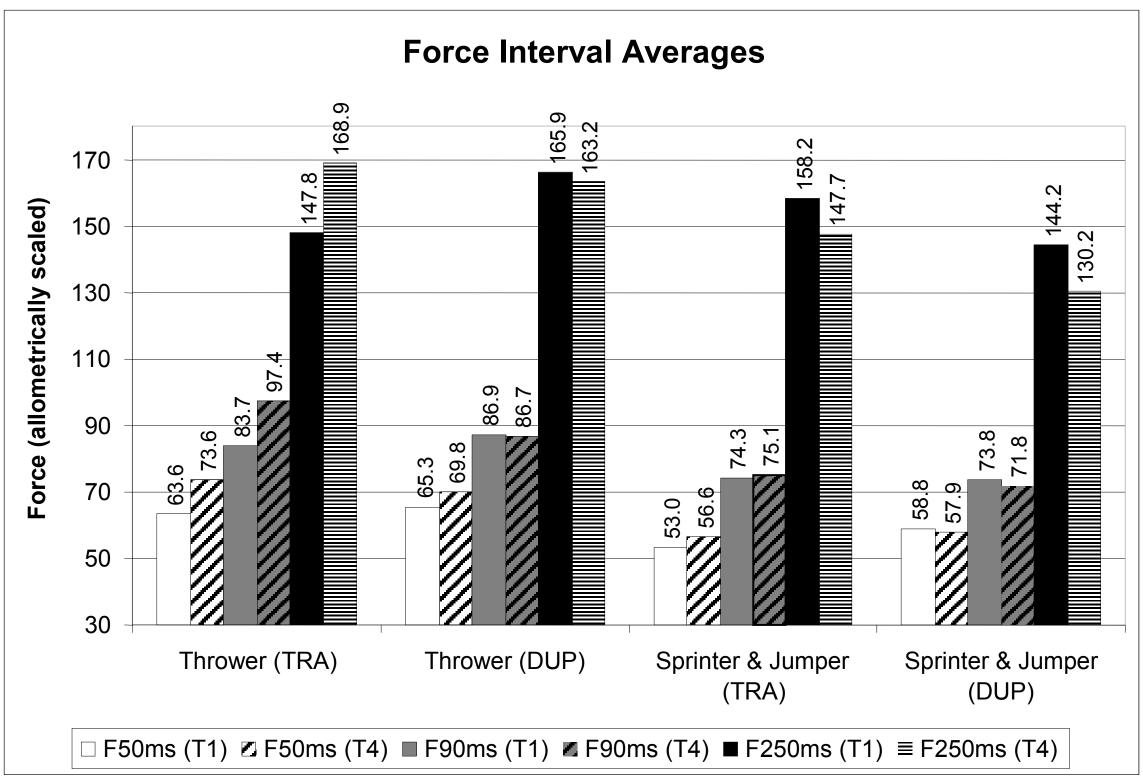
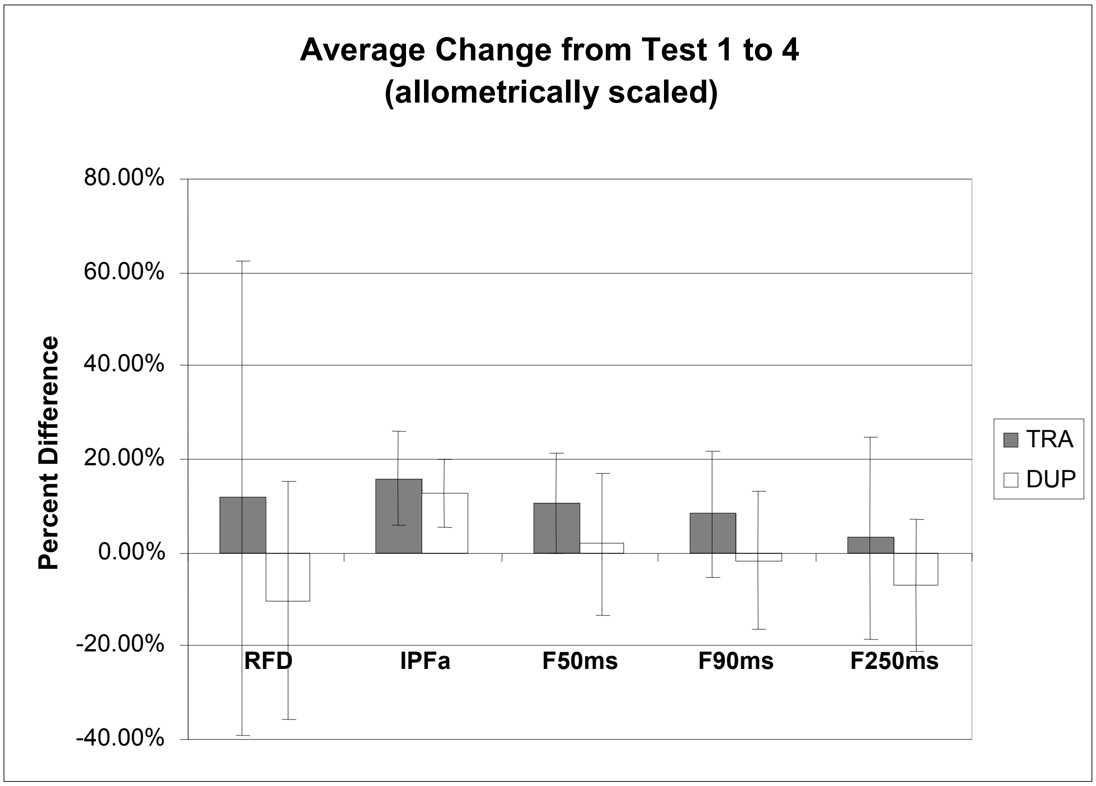


Figure 2-0-4 shows the net percent gain (T1 vs T4)

Figure 2-0-4: Net Percent Differences (T1 vs T4)



<u>Volume Load</u>

Data revealed a markedly ($p \leq 0.05$) higher number of repetitions (52%) for the DUP group (Table 2-8) and VL was different in each of the last 6 weeks of training in the DUP group (Table 2-9). The total work (estimated by volume load) was approximately 35% higher for the DUP compared to the TRA.

Table 2-8: Comparison of Repetitions Accomplished by the Traditional and Daily Undulating Group

Week	Traditional Group			Daily Undulating Group			P	η^2
	Mean	±	SD	Mean	±	SD		
1	264.3	±	79.5	240.8	±	40.7	0.360	0.03
2	404.5	±	46.0	476.8	±	63.4	**0.002**	0.32
3	418.7	±	35.7	440.3	±	37.4	0.138	0.09
4	174.7	±	31.6	227.0	±	27.9	**<0.001**	0.45
5	214.7	±	62.8	315.7	±	102.4	**0.004**	0.29
6	196.9	±	35.6	450.3	±	97.3	**<0.001**	0.78
7	173.3	±	42.7	390.4	±	102.0	**<0.001**	0.69
8	215.1	±	30.6	238.5	±	48.2	0.137	0.09
9	169.9	±	28.9	447.5	±	102.4	**<0.001**	0.80
10	255.5	±	35.2	460.6	±	70.7	**<0.001**	0.80
Total	2487.5	±	234.8	3687.9	±	377.4	**<0.001**	0.80

Table 2-9: Comparison of Volume Load Accomplished by the Traditional and Daily Undulating Group

Week	Traditional Group			Daily Undulating Group			P	η^2
	Mean	±	SD	Mean	±	SD		
1	14072.8	±	6054.3	14703.9	±	4002.6	0.76	0.004
2	21584.4	±	7826.4	26410.7	±	5830.5	0.09	0.112
3	21172.8	±	6169.0	26127.4	±	7021.3	0.06	0.132
4	11710.5	±	5354.0	16319.3	±	4349.6	**0.02**	0.189
5	13569.9	±	5956.8	20234.5	±	7438.5	**0.02**	0.211
6	12596.1	±	3993.6	29527.1	±	10401.1	**<0.001**	0.575
7	10893.6	±	3716.3	25733.1	±	9689.6	**<0.001**	0.545
8	13308.6	±	3524.1	20499.5	±	7161.3	**0.002**	0.318
9	11246.8	±	3564.7	31325.1	±	12378.2	**<0.001**	0.590
10	15575.6	±	6095.9	30326.9	±	10042.1	**<0.001**	0.471
Total	145731.0	±	44612.5	241207.5	±	67657.2	**<0.001**	0.437

This difference in volume of repetitions and VL produces a marked difference in the efficiency between the DUP and TRA protocols. The trends shown in VL (Figure 2-0-5) and VLa (Figure 2-0-6) illustrate these differences.

Figure 2-0-5: Volume Load Each Week for 10 Weeks (T1 – T4)

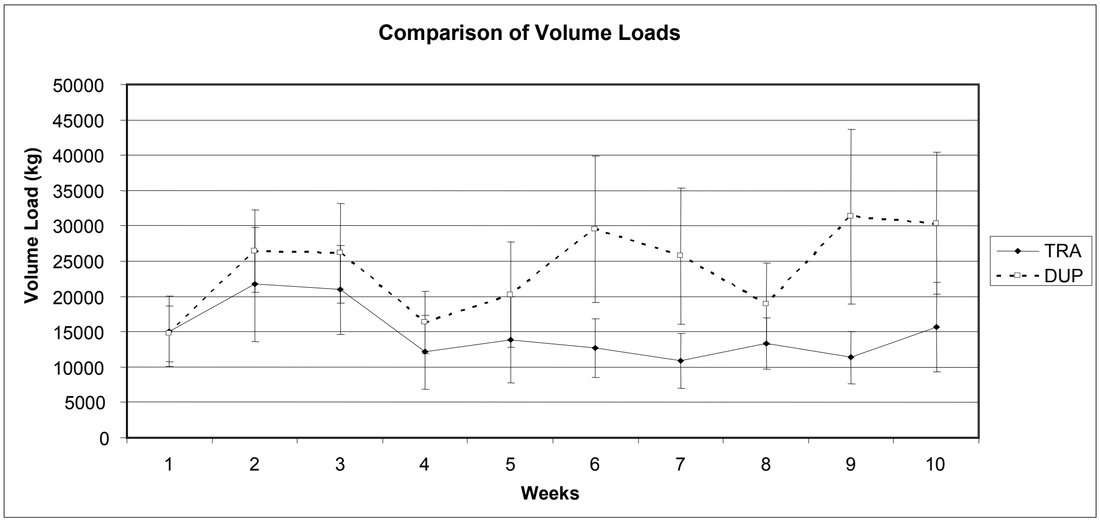
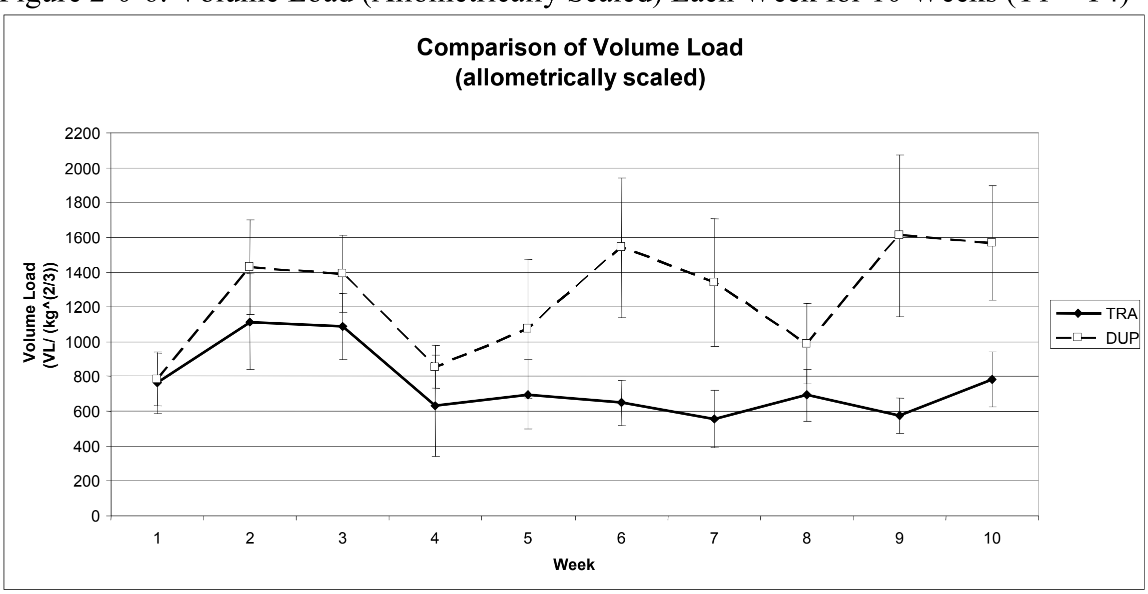


Figure 2-0-6: Volume Load (Allometrically Scaled) Each Week for 10 Weeks (T1 – T4)



As a result of the differences in volume of work (VL), the efficiency in gain scores are markedly different, Figure 2-0-7 **Program Efficiencies** indicates that the TRA was more efficient than the DUP ($p \leq 0.05$). The differences in gain efficiency were also evident by event (Figure 2-0-8 **Program and Group Efficiencies**).

$$Efficiency = (\Delta IPFa_{T1\text{-}T4} / VLa_{total})$$

Figure 2-0-7 Program Efficiencies

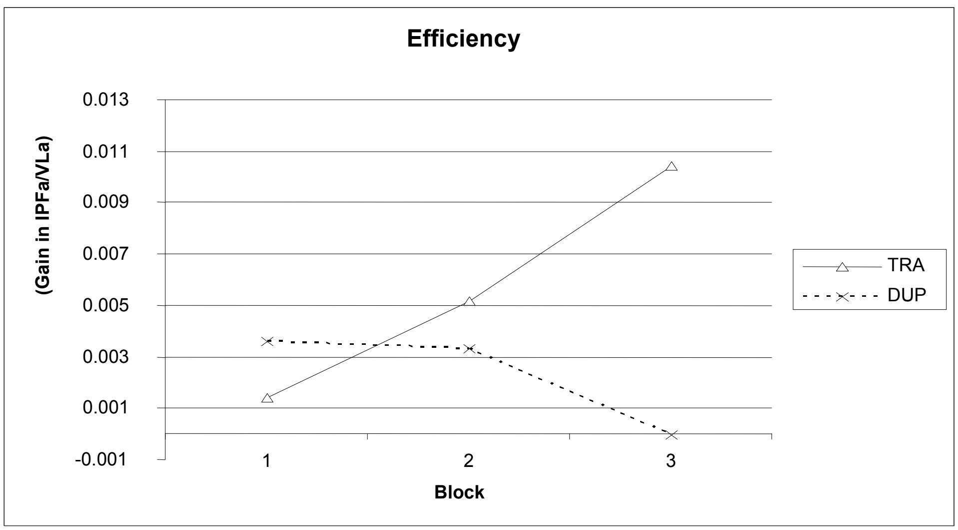
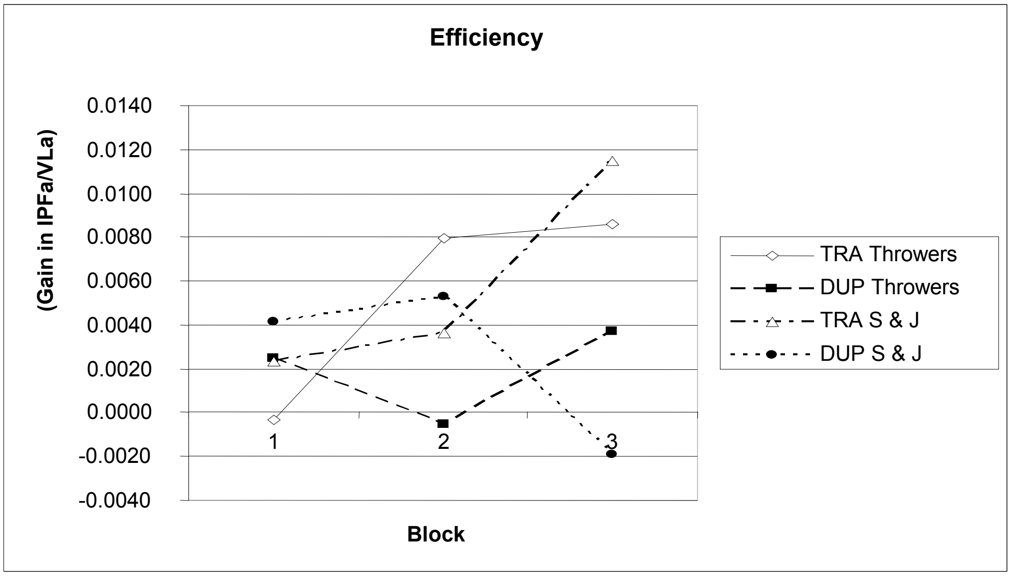


Figure 2-0-8 Program and Group Efficiencies



Testosterone and Cortisol

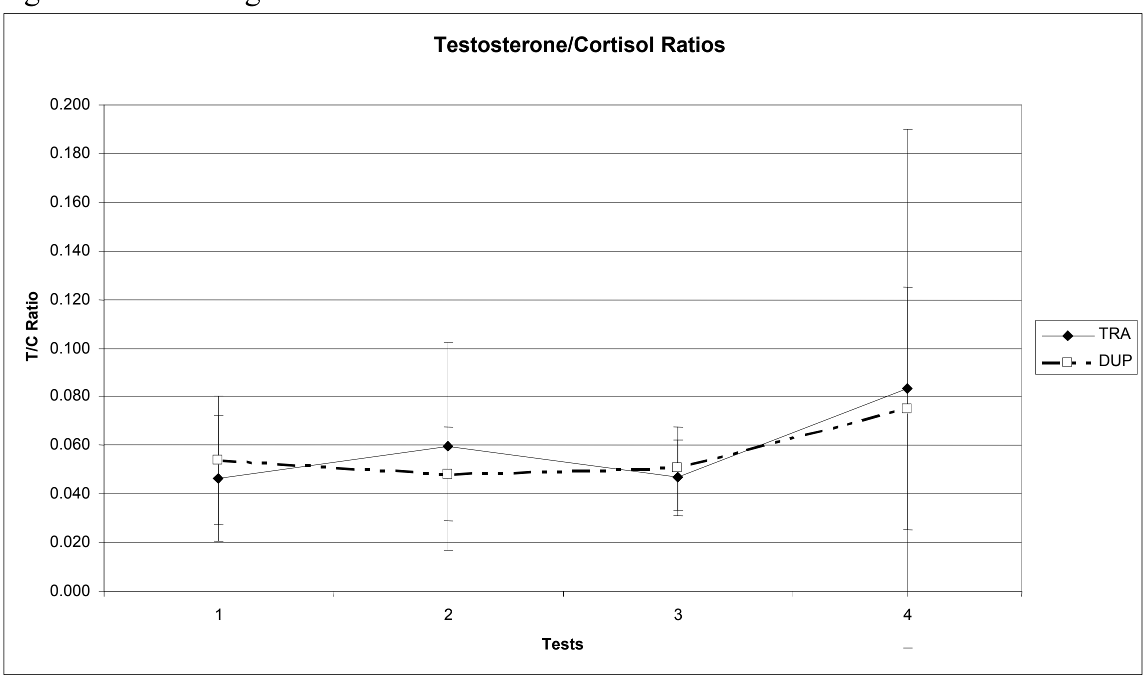
Due to the differing hormonal attributes between sexes and the limited number of females, all females were excluded from T and C data analyses. The concentrations for T and C are shown in Table 2-10; and the T:C ratios are illustrated in Figure 2-0-9 **Average T:C Ratios**).

Table 2-10 Average Testosterone and Cortisol Values

	Testosterone						Cortisol					
	TRA			DUP			TRA			DUP		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD
T1	18.4	±	6.1	20.9	±	7.6	428.1	±	102.1	410.6	±	70.4
T2	19.9	±	6.7	20.5	±	10.1	404.3	±	149.9	425.7	±	73.7
T3	19.2	±	7.3	23.5	±	7.0	428.6	±	142.5	474.9	±	70.2
T4	18.3	±	6.6	22.5	±	6.9	345.4	±	183.4	383.6	±	177.2

No significant differences were found between groups when analyzing resting T and C blood concentrations. In addition, resting T and C concentrations did not significantly change from T1 through T4. Alterations in the T:C ratio are shown in Figure 2-9, Initial T:C ratios correlated strongly with IPF (r = 0.64) and IPFa (r = 0.62). Additionally, initial T:C ratios correlated well with the change from T1 to T4 for both IPF (r =0 .69) and IPFa (r =0 .61) with the TRA group, but not in the DUP group (IPF, r =0 .21; IPFa r =0 .20). The T:C ratio at T4 had a high correlation with the change in both IPF (r = 0.79) and IPFa (r = 0.77) from T1 to T4 for the combined groups. This correlation was higher in the TRA group (IPF, r = 0.86; IPFa r =0 .84) compared to the DUP group (IPF, r =0 .66; IPFa r = 0.60). Interestingly, the DUP group had very high correlations between their C levels at T3 and their change from T1 to T4 in both F50ms (r = 0.83) and F90ms (r = 0.82).

Figure 2-0-9 Average T:C Ratios



Based on sports medicine department room records, the TRA training protocol produced injuries among 40% of the athletes, and 100% of the athletes who performed the DUP training protocol reported an injury. Severity of injuries ranged from minor cuts and abrasions to torn muscles; however, no injuries were reported acutely during lifting sessions. Two athletes in the DUP had to be removed from the study as a result of injury; none were removed from the TRA. It should be noted that it is impossible to determine the exact cause of the injuries (i.e. practice versus weight-room or a combination).

DISCUSSION

The primary finding of this study was that the TRA produce substantially greater gains in IPF and RFD considering the differences in volume of training (e.g. the TRA was much more efficient).

A basis for the DUP is that more variety would stimulate greater gains in strength and related characteristics. For example, Kraemer et al. [20] compared DUP to a training program that used a linear program of 2-3 sets of 8-10RM each day. This study was established based on the idea that traditional training programs provide "limited variation" over long-term periods [20]. In this study, it was found that using variation produced greater strength gains [20]. However, previous investigations of more traditional forms of periodized strength training versus DUP have resulted in equivocal results.

Rhea [29,30] has headed two investigations comparing linear periodization to DUP. However, it is unclear exactly what is meant by linear periodization as this term and, the mechanics of achieving linearity or underlying mechanisms are not clearly defined in either study. In both of these studies, attempts were made to equate volume by manipulating the set and repetition schemes. Although Rhea et al. concluded that DUP was more effective in the development of strength [29], there were no statistical differences between LP and DUP for muscular endurance [30].

Peterson et al. [27] compared undulation training, (DUP) using firefighters, and a "standard training" control group that appeared to have some similarities to the LP used in Rhea's studies [29,30]. Peterson et al.'s [27] research indicates that DUP "…may offer greater transference to performance for firefighter-specific job tasks" [27]. One issue with this 9-week study is the lack of information about the control group. The study presents the DUP training protocols but leaves the reader to assume the nature of protocols for the control group. Without clearly defined protocols, it makes replication of the study much more difficult.

Using freshmen American football players, Hoffman et al. compared LP to DUP and found no significant differences in most variables [16]. However, they did find a significant increase in medicine ball throws in only the LP group, which may indicate improved explosiveness. Additionally, calculations (not presented by the authors) of the effect size (ES = 1.43 vs 0.74) based on the presented means and standard deviations and the percent gain (20.9% vs 11.1%) indicate that the LP group actually produced superior gains in the squat compared to the DUP group.

Buford et al. [5] compared three differing models of periodization, LP, DUP, and a weekly-Undulating method (WUP), for nine weeks and found that there was no difference between the groups on any strength measure (bench press and leg press). One issue presented by this study is the lack of sharp changes in loading in the LP group. The LP group only had a difference of two repetitions between phases, while the DUP and WUP had instances of a four repetition difference [5]. However, when analyzed by effect sizes (not presented by the authors) and using percent differences, both the LP and WUP performed markedly better than the DUP in both strength measures (the bench press and leg press).

These studies present several major problems. First is exactly what is meant by linear periodization. Considering the basic definitions of periodization [12,13,28,31,32,35] linear periodization is a misnomer as a primary purpose of periodization is the removal of linearity. Traditional periodization protocols, including short-term block periodization protocols [17], are characterized by containing specific phases or stages that emphasize a particular fitness variable (e.g. strength, endurance, power, etc.). In the present study, the TRA emphasized strength-endurance (wks 1-3), basic strength development (weeks 4-6), and power development (wks 7-10).

Several studies attempted to equated volume using repetitions [5,29,30]. However, this method (using repetitions) is likely the least accurate and reliable method of attempting to quantify training volume (work) [35]. Equated work is believed to be necessary in order to study the effects of intensity, technique, or other attributes independently [8,9,25], and some evidence indicates that higher volume of work produce greater gains in strength and power [9] (Cronin et al. 2004). However, it is likely that equated work may obviate the strengths of the methods being studied as this may reduce necessary volume and intensity manipulation or produce training protocols that are not optimum. Assuming VL is a reasonable estimate of work differences [25], the present study supports this last point. The TRA made statistically equal gains with considerably less work (35% less VL) and fewer repetitions (52%). Thus, total work may not be the most important factor in producing performance gains but rather appropriate variable manipulation. During the first 3 weeks training session time was approximately equal (about 50 min/session) and this remained constant over the 10 weeks for the DUP; however, during weeks 4-7 the mean time for the TRA decreased to about 40 min and decreased to about 35 min during weeks 8-10. As training time is a valuable asset for coaches and athletes, the extra time spent in the weight-room for the DUP group also represents a degree of inefficiency. Additionally, it should be noted that tests days occurred on Monday, which was the highest volume day for the DUP, so the actual differences between groups during a typical program could be even greater. Furthermore, speculation would suggest that the extra volume of work handled by the DUP may have contributed to the larger injury rate as a result of less efficient fatigue management.

Furthermore, these studies do not appear to manipulate volume and intensity in a manner adequate to produce true heavy and light days of training in either group. Evidence indicates that heavy stimulus (i.e. heavy/intense training day) followed by adequate recovery time resulting from a light day can produce greater gains than programs using les marked variation [10,35]. The DUP group uses RM values that necessitate frequently training to failure. In the author's experiences most practical training models rarely use RMs because; one, the use of RM values essentially creates a constant relative maximum effort reducing variation (i.e. no heavy or light days), and two, the constant training to failure makes fatigue management increasingly difficult and raises the potential for OTS [7] and strength and power development can be reduced [18]. The heavy and light days used in the TRA contributed to the lower VL, greater gain efficiency in maximum strength and RFD performance.

Of these studies comparing more traditional methods to DUP, only Hoffman et al. [16] used athletes. Trained athletes often respond differently than untrained, semi-trained, or well-trained individuals. Part of the reason for this is that athletes are not typically performing resistance training in isolation. Typically, athletes perform additional forms of training outside of the weight-room. The present study addresses this problem by using USA D-1 collegiate track and field athletes during a fall preparation period of training. Outside practice and any conditioning was a constant factor (based on surveys) for these athletes, thus the strength-training methods (TRA vs DUP) represented major volume and intensity alterations among the athletes.

None of these studies measured hormone concentrations. The T:C ratio is related to fatigue management, overtraining potential, and a number of physiological variables that can impact on performance [35] . For example, if the T:C ratio is increased lean body mass tends to be elevated and fat mass tends to be lower, maximum strength and explosiveness are also elevated with increased T:C ratios [2,11,24,35]. Furthermore, there is evidence that among athletes alterations in the VL can alter the T:C ratio and that even minor alterations may be meaningful in terms of accumulative fatigue and performance [6,15,35]. In the present study, although no statistically significant alterations occurred across time, there are two interesting aspects to consider. Initially the T:C ratios were higher in the DUP group, this pattern was inverted at T4. Secondly the correlations between the hormone concentrations, the T:C ratios, and performance values were consistently higher in the TRA. These relationships may indicate a better level of fatigue management in the TRA compared to the DUP.

Practical aspects

Strength coaches are often faced with a dilemma as to what resistance training method produces superior results. Periodized strength-power training appears to offer superior results compared to linear programs [28,35]. However, in recent years a number of strength training "periodized models" have been created each purported to produce superior results. This study investigated the effects on maximum strength and RFD of two of these methods, TRA and DUP. The authors of the present study would suggest that TRA is the superior method, even over a short-term (10 wks). This is based on:

1. Differences in training effects are difficult to detect among athletes (Hopkins et al. 2009). For example, the difference between 1st and 4th at the last 6 Olympics, in most sports has been less than 1.5%. Furthermore, Mujka indicates that in many sports the difference between 1st and 8th place in the finals of the world championships and Olympics is often $\leq 0.4\%$ and can be strongly influenced by the type of training program and taper just prior to competition. Thus, small alterations in effect among athletes often have great meaning. Although statistical significance was not achieved, the results of this study suggest trends favoring the TRA. For example, the net gains in all forces and in RFD changes favor the TRA (Figure 2-0-4). In many cases, the DUP actually lost performance, which the authors attribute to accumulative fatigue. From a practical standpoint these data are supported by the fitness-fatigue paradigm (Stone et al. 2007).

2. The difference in the injury rate was quite large and may have resulted from superior fatigue management in the TRA group.

3. The efficiency of the TRA was markedly greater. Thus, less work was necessary to accomplish gains in similar performance. Furthermore, the additional training time necessitated by the DUP protocol (particularly on Monday) can interfere with scheduling in the weight room and practice.

This data indicates that more traditional methods of periodized strength power training, structurally similar to the phase potentiation methods described by Stone et al. (35), the conjugated successive methods of Verkhoshanky (37-39), and the block periodization described by Issurrin (17) appear to produce superior effects over a short-term.

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CHAPTER 3

DISCUSSION

Results

The primary finding of this study was that the TRA produced greater gains in IPF, F50, F90, F250, and RFD considering the differences in volume of training. Due to high deviations, statistical significance was difficult to achieve. While there was no significant difference found in the strength measures between the groups, VL was significantly lower in the TRA group. This finding indicates that the TRA method produced the same, if not better, results using less overall volume.

When analyzing trends, strength improvement seems to favor the TRA group. Seemingly, all means for the strength measure differences from T1 and T4 were higher in the TRA group. Some measures even illustrated a decline in strength in the DUP group.

The data collected in this study indicate that more traditional methods of periodized strength power training (structurally similar to the phase potentiation methods described by Stone et al.(2007), the conjugated successive methods of Verkhoshanky (1977, 1988, 2006) and the block periodization described by Issurrin (2008)) appear to produce superior effects over a short-term.

The T:C ratio is related to fatigue management, overtraining potential, and a number of physiological variables that can impact performance (Stone, 2007). For example, if the T:C ratio is increased lean body mass tends to be elevated and fat mass tends to be lower, maximum strength and explosiveness are also elevated with increased T:C ratios (Baker et al., 2006; Fry et al., 1994; Loebel & Kraemer, 1998; Stone et al., 2007). Evidence suggests that athletes who experience alterations in the VL also have alterations in the T:C ratio and that even minor alterations may be meaningful in terms of accumulative fatigue and performance (Busso et al., 1992; Häkkinen et al., 1987, Stone et al., 2007). In the present study, although no statistically significant alterations occurred across time, there are two interesting aspects to consider. Initially the T:C ratios were higher in the DUP group, this pattern was inverted at T4. Secondly the correlations between the hormone concentrations, the T:C ratios, and performance values were consistently higher in the TRA. These relationships may indicate a better level of fatigue management in the TRA compared to the DUP.

Discussion of Methods

The development of the strength training programs was supported in the literature for both TRA (Bompa, 1996; Garhammer, 1986; Kirksey & Stone, 1998; Plisk & Stone, 2003; Rowbottom, 2000; Stone et al., 1981a; Stone et al., 1982; Stone et al., 2006; Stone et al., 2007) and DUP (Buford et al., 2007; Kraemer et al., 2003; Kraemer et al., 2004; Kraemer & Fleck, 2007; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003). In the development of both programs, several strength coaches also provided feedback to increase the validity of their development. However, the development of the programs was constricted within the limitations of scheduling the athletic department weight-room and the incorporation of practice times.

When attempting to develop a DUP program, much of the literature was vague in the description. From multiple sources (Buford et al., 2007; Hoffman et al., 2009; Kraemer et al., 2003; Kraemer & Fleck, 2007; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003), it was ascertained that each day in the DUP group would more or less be congruent to a phase/block of the TRA program. Then, each block was related to one of the days in the DUP. The RM range scheme used in the DUP program development also corresponded with many of the current comparison studies (Buford et al., 2007; Hoffman et al., 2009; Kraemer et al., 2003; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003). This method (RM training) was also applied to the selection of exercises for each day of the DUP training program.

Isometric strength measures are becoming more and more prevalent. This type of strength measure correlates with dynamic movements and has been validated by previous research (Kraska, 2008; McGuigan & Winchester, 2008; McGuigan, Winchester, & Erickson, 2006; Nuzzo, McBride, Cormie, & McCaulley, 2008; Stone et al., 2003; Stone et al., 2004). Using isopulls has been used to track athlete progress and monitor fatigue (unpublished data).

When analyzing the literature for athletic development, an issue that arises with many comparison studies is that they do not use athletes as their population (Buford et al., 2007; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003), but that was a strength of this study. Often it can be difficult to obtain permission from coaches to manipulate training at any point in the season. This issue can limit interpretation of results and generalizability. This difficulty has turned investigators to the average healthy population or moderately to well-trained non-athletes. However, this type of research should not be generalized to the athletic population. It has been noted that strength/power athletes, endurance athletes, and untrained individuals all respond differently when physically stressed (Fry et al., 1994; Skurvydas et al., 2002; Tan, 1999). Differences between non-athletes and athletes can range from genetics to physiology to training history. Increased muscle cross-sectional area, heightened neurological signaling, and increased hormone sensitivity have all been associated with prolonged training.

Because of the practical nature of this study, it was vital to obtain an appropriate sample pool, and the use of D-I collegiate athletes during their usual training period was a great benefit to this study. However, the coaches had complete control over practices, which could prove to be a drawback. Not being able to integrate the strength-training program with the practices equally influenced both groups and may have blurred overall results.

The duration of this study was determined by time constraints. Due to NCAA restrictions, athletes could not start training with a coach at the beginning of the semester. Other time obstacles included major holidays and final exams. These constraints limited the study to 10 weeks.

Further Investigations

Strength coaches are often faced with a dilemma as to what resistance training method produces superior results. Periodized strength-power training appears to offer these superior results compared to linear programs (Plisk & Stone 2003, Stone et al. 2007). However, in recent years a number of strength training "periodized models" have been created each purported to produce superior results. Many of these studies have attempted to equate volumes and intensities (Buford et al., 2007; Hoffman et al., 2009; Peterson et al., 2008; Rhea et al., 2002; Rhea et al., 2003). Through this, the true differences in programs are negated, and actual volume fluctuations are masked. Further investigations should track all volume in the weight room and at practice to ensure adequate descriptions of workloads. In addition, attempts to equate volume and intensity should be avoided. This only leads to muddled versions of training programs. Only through the adherence to specific guidelines will differences in training programs be discovered. Moreover, clearly defining training methods in research will reduce the amount of uncertainty in future replications.

While it may be difficult, lengths of studies also need to be extended. Short-term studies are needed but only show acute changes in performance variables. The Fitness-fatigue paradigm suggests that with fitness builds fatigue, but fatigue duration is three times shorter than that of fitness (Zatsiorsky, 1995). That suggests that actual changes in fitness might be masked by fatigue and only through an extension of the training periods will actual fatigue management be revealed. Conversely, extending the length of a training study may reveal the lack of fatigue management particular programs offer, which will manifest in progressively smaller gains or even a loss of performance. In order to achieve a more detailed depiction of how any program affects athletes in the long-term, research studies need to be extended to six months or longer.

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APPENDICES

APPENDIX A

Before Workout Questionnaire

Athlete Name: ____________________ Date: _______________

(If athlete answers NO move to next question.)

1. Did you perform any workouts after your previous lifting session? YES NO

   What did you do? ____

   ____

   ____

2. Did you practice yesterday? YES NO

   How far and how many sprints did you perform? ____________________________

   ____

   How far did you jog? ____

   What else did you do during practice? ___________________________________

   ____

3. Did you practice today? YES NO

   How far and how many sprints did you perform? ____________________________

   ____

   How far did you jog? ____

   What else did you do during practice? ___________________________________

   ____

4. Were there any other team activities that required physical exertion? YES NO

   What was it and how many? ____

   ____

5. Did you perform any workouts (abs, jogging, etc.) on your own time? YES NO

   What did you do and how much (distance, sets & reps, etc.)? _________________

   ____

   ____

APPENDIX B

IRB approval

ETSU

East Tennessee State University
Office for the Protection of Human Research Subjects • Box 70565 • Johnson City, Tennessee 37614-1707 • (423) 439-6053
Fax: (423) 439-6060

January 23, 2009

Keith B. Painter
Box 13037

Dear Mr. Painter,

Thank you for recently forwarding information regarding "A practical comparison between traditional and non-linear periodized weight training".

I have reviewed the information submitted, which includes the completed Form 129 summarizing the case study and its purpose.

The determination is that this case study is not human subjects research. As such, it does not fall under the purview of the ETSU IRB and does not require IRB approval.

Thank you for your commitment to excellence.

Sincerely,

Dale Schmitt
Co-Chair, ETSU IRB

Accredited Since December 2005

VITA

KEITH BALLARD PAINTER

Education:	East Tennessee State University, Johnson City, TN Master of Arts in Kinesiology and Sport Studies Concentration in Exercise Physiology and Performance, August, 2009
	Truman State University, Kirksville, MO Bachelor of Science in Exercise Science May, 2007
Professional Experience:	East Tennessee State University, Johnson City TN Sports Performance Enhancement Consortium (SPEC) Laboratory Supervisor 2008-2009 East Tennessee State University, Johnson City, TN
	Community Support Coach 2006-2007 Learning Opportunities Inc., Kirksville MO
	Internship: Strength and Conditioning Camp Coordinator 2006 Ottumwa Family YMCA, Ottumwa IA
	Resident care technician 2005-2006 Preferred Family Health Care, Kirksville MO
Professional Certifications:	American Red Cross Adult First Aid CPR/AED Re-Certified: May 2009 American Red Cross Disease Transmission Prevention
Professional Memberships:	National Strength and Conditioning Association Member Since: January 2009 USA Weightlifting Member Since: January 2007

Abstracts

G.G. Haff, R. Ruben, M. Molinari, **K. Painter**, M.W. Ramsey, M.E. Stone, and M.H. Stone. THE RELATIONSHIP BETWEEN THE ECCENTRIC UTILIZATION RATIO, REACTIVE STRENGTH, AND PRE-STRETCH AUGMENTATION AND SELECTED DYNAMIC AND ISOMETRIC MUSCLE ACTIONS. NSCA National Conference, July 2009

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