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Comparison between Daily and Weekly Undulating Periodized Resistance Training to Increase Muscular Strength for Volleyball Players.

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Abstract

The purpose of this study was to compare the strength gains after 13 weeks of daily undulating periodization (DUP) and weekly undulating periodization (WUP) resistance training program with equated volume and intensity for volleyball players. Eleven volleyball players of Tanta club with minimum 1-year strength training experience participated in current study. All subjects have underwent to both DUP and WUP resistance training program in the same time, using the method of unilateral limb training; one side of the body (i.e. arm and leg) used DUP and the other side used WUP for 4 sessions/ week in non-consecutive days using split routine. One repetition maximum (1RM) was measured during 6 exercises before training program (PRE) and in the 7th week of training (MID) and at the end of the 13-week training (POST). The results have shown statistically significant increase ($p \leq 0.05$) in all exercises at MID and POST compared with PRE, and at POST compared with MID for both DUP and WUP models, statistically significant differences favor WUP ($p \leq 0.05$) at POST for 2 exercises in comparison with the DUP. No statistically significant differences ($p > 0.05$) between DUP and WUP in muscular strength at MID and POST for 4 exercises, however the WUP model shown a higher percentage increase in muscular strength than DUP for these 4 exercises. In conclusion, both DUP and WUP periodized training programs made similar strength gains from baseline to week 6. However, between week 8 and week 13, the WUP model outperformed the DUP model making larger improvements in muscular strength.

Key words: Periodization, daily undulating, weekly undulating, resistance training, muscular strength.

Introduction:

Determining the optimal resistance training program is an on-going process for athletes, athletic coaches, strength coaches, and personal trainers alike. It is important for these professionals to find a training advantage over their competitors. Manipulating training variables in the most effective manner to increase strength can be a daunting task (Kraemer and Ratamess 2004; Rhea and Alderman 2004). Using of periodization is not exclusively for elite athletes. Periodization has been applied successfully in various populations with different levels of physical fitness and training experience and for rehabilitation purposes (Dolezal and Potteiger 1998; Kraemer, Adams et al. 2002).

Periodization is a training scheme where planned variations in training variables (e.g., number of sets and repetitions, exercise order, load, and rest) are manipulated in a manner that increases the ability of a person to achieve specific performance goals (e.g., strength) (Fleck 1999; Stone, O'bryant et al. 1999; Rhea, Ball et al. 2002; Rhea and Alderman 2004). It is based on the overload principle and attempts to maximize the use of physical stress and recovery time by manipulating volume and intensity to facilitate important neuromuscular adaptations and to prevent the onset of overtraining syndrome (Rhea, Ball et al. 2002; Prestes, De Lima et al. 2009). Periodized strength training refers to varying the training program at regular time intervals in an attempt to bring about optimal gains in strength, power, motor performance, and/or muscle hypertrophy (Fleck 1999). There are two main models of periodization have been primary used by athletes and coaches, and examined in the literature (Rhea, Ball et al. 2002; Rhea, Phillips et al. 2003; Fleck and Kraemer 2014). The first is the "classic" or "traditional" or linear, model first created by Russian scientist Leo Matveyev and adapted by Stone and colleagues (Stone, O'Bryant et al. 1981) to add an additional transition period during the training year. Linear periodization (LP) is based on changing exercise volume and intensity across several mesocycles (3-4 months) to organize the training program (Brown and Greenwood 2005). Essentially, this type of exercise strategy starts with high volume and low intensity and then progresses to low-volume and high-intensity training, over a period of several months athletes slowly adapt to the training loads and intensities. This system is logical as long as the athlete recovers and responds appropriately to the training stimulus (Fleck and Kraemer 2014).

The other main model is "nonlinear" or undulating model first proposed by Charles Poliquin (Poliquin 1988) in an effort to improve upon (LP). Poliquin suggested that the alterations of volume and intensity made in the LP model were too gradual and that more frequent changes in the stimulus would enhance strength gains to a greater extent than LP (Poliquin 1988). Undulating periodization (UP) is based on the idea that volume and intensity are altered more frequently (daily, weekly or biweekly) by rotating different protocols to train various components of the neuromuscular system (e.g. strength, power, local muscular endurance) in order to give the neuromuscular system more frequent periods of recovery (Baker, Wilson et al. 1994). Since Poliquin's suggestion to investigate the undulating model, there have been a multitude of studies, which have developed protocols known as Daily Undulating Periodization (DUP) (Rhea, Ball et al. 2002; Rhea, Phillips et al. 2003; Peterson, Dodd et al. 2008; Hoffman, Ratamess et al. 2009; Monteiro, Aoki et al. 2009), and Weekly Undulating Periodization (WUP) (Baker, Wilson et al. 1994; Buford, Rossi et al. 2007), DUP was defined as a sub-type of UP in which variation of training volume and intensity must occur each training session, for example, a DUP model of strength training may have the athlete perform high volume and low intensity (hypertrophy) during Monday's training, medium volume and medium intensity (strength) on Wednesday, and low volume and high intensity (power) training on Friday. On the other hand the WUP which calls for the fluctuation of training variables each week (Buford, Rossi et al. 2007), WUP model would have a strength athlete utilize 6 sets of 10 repetitions at 70% during week one of training followed by 5 sets of 6 repetitions at 80% the second week, and 8 sets of 3 repetitions at 90% the third week (Rhea, Ball et al. 2002).

Several studies have focused on comparing periodized vs. non-periodized programs and showed the superiority of periodized training for increasing strength (Marx, Ratamess et al. 2001; Kraemer, Nindl et al. 2004), fewer investigations comparing specific models of periodization exist in the literature, because varying models of periodization exist, and there is evidence that nonlinear or UP elicits maximal strength and muscular endurance adaptations when compared to LP in competitive athletes or more specifically, strength/ power athletes such as football players (Rhea, Ball et al. 2002; Rhea, Phillips et al. 2003; Peterson, Dodd et al. 2008; Monteiro, Aoki et al. 2009). On the contrary, the majority of studies examining the efficacy of periodized resistance training programs have been conducted on untrained, or novices, or recreationally trained subjects, these studies did not yield any significant findings in favor of the DUP or WUP vs. LP, although no significant differences were found between groups, WUP model shown greater percentage increases in muscular strength than the other protocols (Baker, Wilson et al. 1994; Buford, Rossi et al. 2007; Kok, Hamer et al. 2009), in contrast DUP model shown greater percentage increases in muscular strength than the other protocols (Miranda, Sim et al. 2011; Simão, Spineti et al. 2012) and LP model shown greater percentage increases in muscular strength than the other protocols (Apel, Lacey et al. 2011). Conflicting results in favor of one of periodization models for maximum strength gains among novice trainees may be due to the extreme rate, at which neural adaptations occur in novices, in addition the experimental design of these studies have used multiple groups, and have not included data of a control (untrained) limb or a control group in their analyses. This is an important limitation to these studies because using control data can help account for influences of biological, seasonal and methodological variations, common to a single group pre–post design. However, a no exercise control group cannot control for genetic differences between the two groups, which can affect muscle mass (Ivey, Roth et al. 2000) and muscle function (Kostek, Delmonico et al. 2005) responses to strength training. Another problem is the training group receiving more attention than the control group and other differences resulting from group heterogeneity. Therefore, the authors recommend using the method of unilateral limb training; so one side of the body (i.e. arm and leg) used DUP and the other side used WUP, as a means of isolating the independent effects of strength training and minimizing these threats to internal validity.

The variations of training load in UP prevent overtraining while maximizing the adaptive stimulus (total work). The undulating model provides the added stress and variation necessary to elicit maximal strength and power; this model of periodization may prove particularly beneficial for volleyball players by helping them avoid the plateau effect in strength and power gains (Marques, González-Badillo et al. 2006). In the few studies examining competitive athletes, significant benefits of undulating training model compared with no periodization have been reported in college tennis players (Kraemer, Ratamess et al. 2000; Kraemer, Hakkinen et al. 2003) and football players (Kraemer 1997; Hoffman, Ratamess et al. 2009). However, neither of any studies compared different periodization models in volleyball players. There have been few studies comparing periodized program models with equated volume and intensity (Buford, Rossi et al. 2007), equating volume and intensity helps to insure that differences between groups will come solely from the difference in periodization model. According to one of the authors is a volleyball coach usually use the LP model in strength training, and the previous studies were supported

preference UP on LP in muscular strength gains (Baker, Wilson et al. 1994; Rhea, Ball et al. 2002; Rhea and Alderman 2004; Buford, Rossi et al. 2007; Kok, Hamer et al. 2009), so authors tried to determine which model of UP (daily or weekly) more efficient in increase muscular strength for volleyball players. Knowledge gained through this study could help to make resistance training workouts more effective without having to alter volume or intensity. Thus, volleyball player could improve his workout without adding time or energy.

Finally, to date there does not seem to be any research directly examining the efficacy of DUP vs. WUP with equated volume and intensity to increase muscular strength in volleyball players, using a single group with the method of unilateral limb training, so the aim of this study was to compare the strength gains after 13 weeks of DUP and WUP training load regimen, with equated volume and intensity for volleyball players. Authors hypothesized that both DUP and WUP will produce strength gains; furthermore the WUP will produce greater strength gain than the DUP.

Methods:

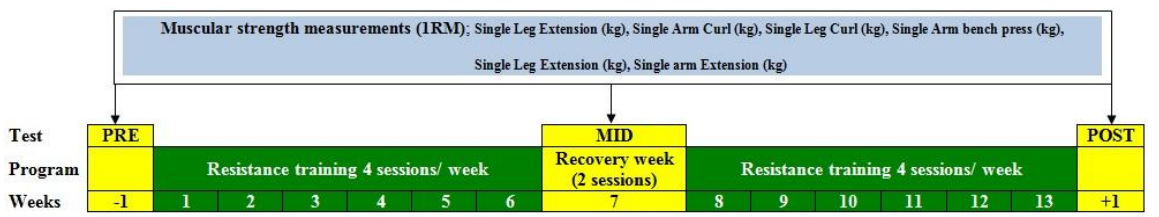
Subjects

Eleven volleyball players of total 16 from Tanta club volunteered to participate in current study. The inclusion criteria for the participation were minimum 1-year experience of strength training, no use of any ergogenic supplements, not participate in any regular resistance training during the study, and If participants missed more than 2 training sessions, they were removed from the study. Subjects' mean (±SD) age, body weight, height and body mass index (BMI) were 24.18 ± 2.23 yr, 84.09 ± 3.18 kg, 187.27 ± 4.82 cm, 23.99 ± 0.81 kg/ m2 respectively. Each subject was provided with an information sheet setting out details of the experiment and completed a medical history questionnaire before providing written informed consent. The study conformed to the Declaration of Helsinki guidelines for human use.

Experimental design

The main objective of the present study was to compare the strength gains between DUP and WUP resistance training program over 13 weeks of training. All subjects have underwent to both daily and weekly undulating resistance program in the same time, using the method of unilateral limb training; one side of the body (i.e. arm and leg) used DUP and the other side used WUP. According to PRE values of 1RM; the UP models were distributed randomized and counterbalanced on both sides of subjects' body, (DUP; 6 dominant side, and 5 non-dominant side), (WUP; 5 dominant side, and 6 non-dominant side), no difference between the two models in strength baseline values ($P > 0.05$). In the present study, all training variables (i.e. intensity, sets, repetitions, and rest time) of both periodization programs were equated except sequence of volume and intensity as recommended by Rhea et al. (Rhea, Ball et al. 2002; Rhea, Phillips et al. 2003). Timing of the study started 1 week after the end of the competitions, subjects were tested for 1RM during seated single leg press, seated single arm curl, laying single leg curl, single arm bench press, seated single leg extension, and seated single arm extension before the beginning of the training program (PRE) and in the 7th week of training (MID) and at the end of the 13-week training program (POST) (Figure 1).

Fig1. Experimental design



One week before the start of experiment, all subjects report to the Tanta club gym 4 times in non-consecutive days. On the 1st visit; all subjects were provided with an information sheet setting out details of the experiment, a medical history questionnaire and written informed consent were completed and signed. They changed into sports clothes (running shoes, shorts and t-shirt), height and body weight were recorded using a portable stadiometer and balance weighing scales respectively. Subjects completed a resistance training session with no or little resistance, where they received instructions on proper exercise techniques, this session familiarized the subjects with the equipments and proper exercise techniques, and to reduce the risk of muscle soreness after the testing. All testing and training sessions were supervised and conducted by the same authors, in addition to 2 certified fitness trainers.

Muscular strength test

The maximum weight that could be lifted for 1RM was used as the measure of muscular strength. Two days after the 1st visit of familiarization session, all subjects

performed 3 trails of 1RM on 3 separate days, with 48 hour between them for 6 exercises previously mentioned to determine the beginning loads (kg) for subjects' resistance training programs, In order to facilitate the recovery and reduce the effect of fatigue, exercises were alternated between the upper and lower body. A high interclass correlation was found between the 2nd and 3rd 1RM trails (R= 0.882). The greatest 1RM determined from the last two trails was used for PRE measurement (baseline). Before the test the subjects performed a warm-up which included 5 min of light treadmill running and 5 min stretching exercises. Thereafter, the subjects performed 10 repetitions at a relatively light load that served as a specific warm-up, followed by a gradual increase in load until 1RM was achieved (Baker, Wilson et al. 1994). The rate of the gradual increase in load was dependent on the participant's self-perceived capacity, and it ranged from 1 to 10 kg for all exercises, with 3 min rest interval between attempts, and the 1RM was achieved within 3-5 attempts. The Authors provided encouragement to all subjects during testing, in an attempt to elicit a maximal effort. All testing sessions used the same test order, equipment, warm-up, and time of the tests (between 5:00 and 8:00 PM).

Resistance training program

Resistance training program was designed based on previous studies published in the literature in terms of periodization and duration (Kraemer, Volek et al. 1997; Bradley-Popovich 2001; Rhea, Ball et al. 2002; Kraemer, Nindl et al. 2004; Hartmann, Bob et al. 2009; Prestes, De Lima et al. 2009; McNamara and Stearne 2010; Apel, Lacey et al. 2011; Fleck and Kraemer 2014). For 13 weeks of periodized resistance training (transition period) , subjects trained 4 sessions/ week in non-consecutive days, with each session lasting approximately 35-75 min according to session outcome. Split routine was used in the resistance training program, training was divided into A (Saturday and Wednesday, days 1 and 3) and B (Monday and Friday, days 2 and 4) in accordance with the recommendations of ACSM (Kraemer, Adams et al. 2002) for advanced athletes to train 4-6 days per week. The exercise order was strictly followed by both models, as presented in (Table 1).

Table 1. Exercises and training session sequences during DUP and WUP programs

Exercise	Training session
Seated single leg press	(A) 1,3
Seated single arm curl	(A) 1,3
Laying single leg curl	(A) 1,3
Single arm bench press	(B) 2,4
Seated single leg extension	(B) 2,4
Seated single arm extension	(B) 2,4

Four weekly sessions, 2 days per week 1and 3 training session A was performed (Saturday and Wednesday) and 2 days per week 2 and 4 training session B was performed (Monday and Friday); DUP = daily undulating periodization; WUP = weekly undulating periodization.

The program variables (e.g., intensity, total volume, rest intervals, repetition velocity, and exercise order) were the same for both the DUP and WUD models. The difference between the two models was the sequence of training volume and intensity. In the DUP model, training intensity was modified in the same week, so that subjects trained with 2 different volumes and intensities in the same microcycle (1 week), during weeks 1, 3, 5, 8, 10, and 12, subjects trained on days 1 and 2 with 3 sets of 12RM and on days 3 and 4 with 3 sets of l0RM, while weeks 2, 4, 6, 9, 11, and 13, subjects trained on days 1 and 2 with 3 sets of 8RM and on days 3 and 4 with 3 sets of 6RM (Table2).

Table 2. Daily and weekly periodized resistance training programs

DUP: Sessions Weeks 1,3,5,8,10,12 **Weeks** 2,4,6,9,11,13	**Sat** 3 x 12RM 3 x 8RM	**Mon** 3 x 12RM 3 x 8RM	**Wed** 3 x 10RM 3 x 6RM	**Fri** 3 x 10RM 3 x 6RM	**Rep. Average** 1296
Week 7 was a recovery week, subjects performed only 2 training sessions in this week (Saturday, training session A, and Monday, training session B), with 2 set of 12RM in each exercise.					
WUP: Weeks 4 sessions/ week	**1,5,10** 3 x 12RM	**2,6,11** 3 x 10RM	**3,8,12** 3 x 8RM	**4,9,13** 3 x 6RM	**Rep. Average** 1296

DUP = daily undulating periodization; WUP = weekly undulating periodization; RM = repetitions maximum; Rep. Average = the average volume for daily and weekly periodization models over the study.

In the WUP model, training intensity was modified each week (microcycle), so the subjects trained with the same volumes and intensity in the microcycle. during weeks 1, 5, and 10, subjects trained with 3 sets of 12RM, in weeks 2, 6, and 11, subjects trained with 3 sets of 10RM, in weeks 3, 8, and 12, subjects trained with 3 sets of 8RM, in weeks 4, 9, and 13, subjects trained with 3 sets of 6RM (Table2). For both DUP and WUP models, a recovery week occurred in the 7th week (Bradley-Popovich 2001; Rhea, Phillips et al. 2003; Prestes, Frollini et al. 2009) in which the subjects performed only 2 training sessions in

this week (Saturday, training session A, and Monday, training session B), with 1 set of 12RM in each exercise.

The MID strength assessment was conducted in the 7th week on Thursday to establish a new load for the exercises in the next weeks, which enabled the subjects' bodies to be progressively overloaded throughout the 13 weeks. To calculate the weight (Kg) of (12, 10, 8, and 6RM) according to 1RM load; Brzycki equation (Brzycki 1995) was used [1RM = W x 36/ (37- R)] where the W= weight (Kg); R= number of repetitions (12 or 10 or 8 or 6 repetitions). The repetition velocity of exercises and rest intervals between sets were according to training load and followed by both models, as presented in (Table 3).

Table 3. Repetitions velocity and rest intervals according to training load

Training load	Rep. Velocity	Rest Intervals (min)
12RM	2 : 1 : 2	3
10RM	2 : 1 : 2	3
8RM	1 : 1 : 1	2
6RM	1 : 1 : 1	2

Rep. velocity = duration of concentric, pause, and eccentric phases of the movement; Rest intervals = rest between sets and exercises.

The training sessions consists of a warm-up period (10 min), an exercise period (20-60 min), and a cool-down period (5 min). The warm-up and cool-down periods included stretching exercises and light treadmill running to reduce the risk of delayed onset muscle soreness (DOMS) and injury. Testing and Training sessions performed on 6 Panatta plate loaded machines, Italy.

Statistical analysis

All data are presented as mean and standard deviations (±SD). The statistical calculations were performed using STATISTICA software version 10 (StatSoft, Tulsa, OK, USA). All variables presented normal distribution and homoscedasticity. The muscular strength was evaluated separately for the 6 exercises, so the repeated-measures analysis of variation (ANOVA) (2 models by 3 time points) was used, and when statistical significance ($P \leq 0.05$) was found, the Tukey HSD post hoc test for comparisons was applied to compare the strength gains between PRE, MID, and POST time points. Test-retest reliability for 1RM was determined using an interclass correlation coefficient (ICC).

Results:

All subjects completed the 13-week study with attendance rate > 97% with only 6 participants absent for 1 training sessions and 5 participants absent for 2 training sessions during the 13 weeks of training programs. There was a statistically significant increase ($p \leq 0.05$) in muscular strength for all exercises were noted at MID and POST compared with PRE evaluation, and at POST compared with MID evaluation for both DUP and WUP models (Table 4).

The study has shown statistically significant differences favor WUP model ($p \leq 0.05$) at the POST evaluation in seated single leg press strength of 47.84%, and in seated single leg extension strength of 39.35% in comparison with the DUP model (40.95% and 23.91%; respectively), whereas there is no statistically significant differences ($p > 0.05$) were found between DUP and WUP in the same exercises at MID evaluation. Although no statistically significant differences ($p > 0.05$) were found between DUP and WUP in muscular strength at MID and POST evaluation for 4 exercises, however the WUP model shown a higher percentage increase in muscular strength than DUP model for these 4 exercises; seated single arm curl (DUP = 24.12%; WUP = 30.30%), laying single leg curl (DUP = 35.60%; WUP = 42.32%), single arm bench press (DUP = 28%; WUP = 37.36%), and seated single arm extension (DUP = 34.76%; WUP = 45.05%)(Table 4) (Fig.2).

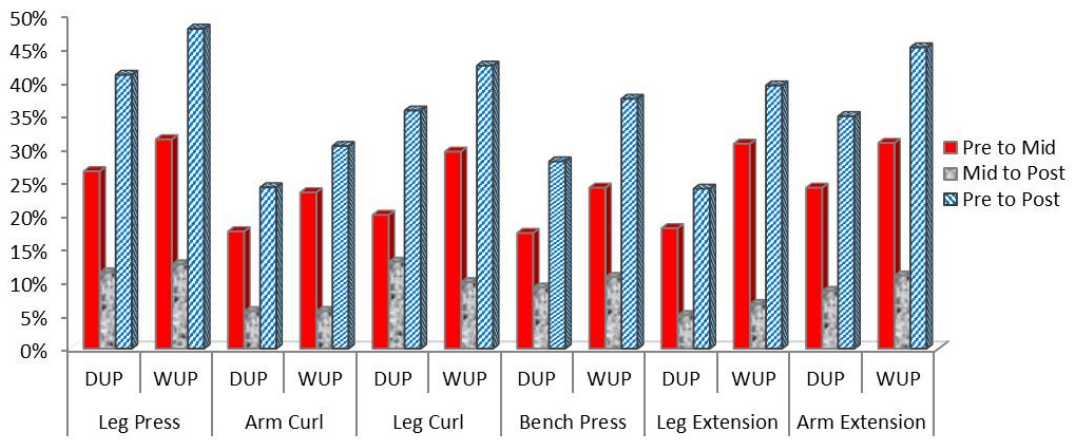
Table 4. Mean and ±SD of muscular strength variables at PRE, MID and POST for the DUP and WUP models

Exercise	PRE	MID	POST
Seated single leg press (kg)			
DUP	39.73 (2.57)	50.27 (2.33)*	56.00 (2.45)*$
WUP	40.09 (1.22)	52.64 (1.91)*	59.27 (1.49)*$#
Seated single arm curl (kg)			
DUP	20.73 (2.05)	24.36 (2.34)*	25.73 (2.57)*$
WUP	21.00 (1.26)	25.91 (2.07)*	27.36 (1.80)*$
Laying single leg curl (kg)			
DUP	22.73 (2.37)	27.27 (2.90)*	30.82 (2.56)*$
WUP	21.91 (2.21)	28.36 (2.84)*	31.18 (2.68)*$

Exercise	PRE	MID	POST
Single arm bench press (kg)			
DUP	37.36 (1.91)	43.82 (2.44)*	47.82 (2.57)*$
WUP	36.27 (2.00)	45.00 (1.95)*	49.82 (2.04)*$
Seated single leg extension (kg)			
DUP	29.27 (2.53)	34.55 (2.62)*	36.27 (2.69)*$
WUP	28.18 (2.09)	36.82 (2.82)*	39.27 (2.65)*$#
Seated single arm extension (kg)			
DUP	17.00 (1.34)	21.09 (1.58)*	22.91 (1.45)*$
WUP	16.55 (1.63)	21.64 (1.96)*	24.00 (2.24)*$

Values were expressed by mean ±SD (n = 11, each model), DUP = daily undulating periodization; WUP = weekly undulating periodization; PRE = baseline evaluation; MID = evaluation in the 7th week of training; POST = evaluation after 13 weeks of training, *statistically significant difference in comparison with PRE, $statistically significant difference in comparison with MID, #statistically significant difference in comparison with DUP ($p \leq 0.05$).

Fig2. Rate of increase in muscular strength for DUP and WUP models



In DUP model, rates of increase in muscular strength ranged between 23.91% in seated single leg extension and 40.95% in seated single leg press at the end of the training program, while in WUP model rates of increase in muscular strength ranged between 30.30% in seated single arm curl and 47.84% in seated single leg press at the end of the training program (Fig.2)

Discussion:

The purpose of this study was to determine whether daily or weekly undulating periodized strength training would elicit greater strength gains over 13 weeks of resistance training using split routines in volleyball players. The independent variable was the sequence of volume and intensity for (DUP vs. WUP) programs, all training variables (i.e. intensity, sets, repetitions, repetitions velocity, and rest time) of both periodization programs were equated between the two models to establish if any difference in training effect were the result of the sequence of volume and intensity used by the different training models (DUP vs. WUP). To our knowledge, The present study was the first study to compare the effectiveness of DUP and WUP on the same subjects using the method of unilateral limb training; so one side of the body (i.e. arm and leg) used DUP and the other side used WUP in the same time to control variables such as genetic differences, nutrition, sleep hours, which can affect muscle mass and muscle function responses to strength training. Also the present study is one of a few to use a 4 sessions/ week training schedule because most studies have used a 3 sessions/ week schedule. The 4 sessions/ week schedule is more similar to that used by athletes (e.g., volleyball players) in their development of strength.

Results showed that both the DUP and WUP programs caused significant increases in muscular strength of all exercises between PRE and MID, between MID and POST, and between PRE and POST evaluation in volleyball players with at least 1 year of strength training experience. Another interesting aspect was the DUP and WUP programs caused a higher muscular strength gains between week 1 and week 7, compared with muscular strength gains between week 8 and week 13 in all exercises. These results indicate that DUP and WUP models may increase maximal strength to a greater extent during the initial training period and result in more consistent strength gains as training progresses. These observations are supported by the results of previous studies (Rhea, Phillips et al. 2003; Kraemer, Nindl et al. 2004; Kraemer and Ratamess 2005; Buford, Rossi et al. 2007; Prestes, Frollini et al. 2009; Apel, Lacey et al. 2011). The initial strength gains (1-7 weeks) due to resistance training are primarily neural adaptations such as: 1) Increased motor unit recruitment, 2) Increased firing frequency, 3) Increased synchronicity of firing and/or 4) decreased co-contraction of the antagonist muscle (Häkkinen, Pakarinen et al. 1992; Behm 1995; Baechle and Earle 2000; Kraemer and Häkkinen 2008), after this period strength gains are also influenced by increases in muscle mass (Gearhart JR, Goss et al. 2001; Brandenburg and Docherty 2002; Deschenes and Kraemer 2002). The greater increases in muscular strength with WUP compared to DUP during the first 6 weeks of training previously shown (Häkkinen, Pakarinen et al. 1992) and in the present study, indicate that WUP may induce quicker neural adaptations than DUP model. Thus we partially support our first hypothesis that both undulating periodized training models (i.e., daily and weekly) will produce strength gains. The most important finding of this study was that there were no significant ($p > 0.05$) differences in strength between the DUP and WUP models between week 1 and week 6, but by week 13, the WUP model was significantly ($p \leq 0.05$) stronger than the DUP model in 2 of 6 exercises (i.e., seated single leg press, seated single leg extension), while no significant between DUP and WUP models in the other 4 exercises. The DUP model increased strength by an average between 23.91% and 40.95% from PRE to POST, whereas the WUD group increased strength by an average between 30.30% and 47.84% from PRE to POST. Thus, WUP strength training program was more successful at increasing muscular strength by week 13 than was DUP strength training program. The week-to-week order of intensity is known to influence muscular strength via neural adaptation (Sale 1988; Kraemer, Adams et al. 2002). This suggests that to elicit strength increases, the choice of training model may become important at some point after week 6, and it may be related to the week-to-week order of intensity. Thus we partially support our second hypothesis that the WUP will produce greater strength gain than the DUP.

Comparing the current study with other periodized strength training studies is not straightforward for many aspects, the most important that all previous studies used more than one group to compare periodization model but in the present study was used one group. More specifically, study of Buford et al. (Buford, Rossi et al. 2007) compared linear periodized strength training with daily and weekly undulating periodized strength training and found no significant ($p > 0.05$) differences between the 3 periodization models in the development of strength. Hoffman et al. (Hoffman, Ratamess et al. 2009) compared non periodized strength training, LP and DUP strength training and found no significant ($p > 0.05$) differences between the 2 periodization models in the development of strength. In contrast, Rhea et al. (Rhea, Ball et al. 2002) found that UP was significantly ($p \leq 0.05$) more effective at developing muscular strength than was LP, whereas the present study found that WUP was more effective than DUP in the development of strength. Another important aspect, studies of Baker et al. (Baker, Wilson et al. 1994), Buford et al. (Buford, Rossi et al. 2007), and the present study all equated the training volume between the groups. It was believed that equating the training volume was the best way to fairly compare the training regimes. However, Rhea et al. (Rhea, Ball et al. 2002) and Hoffman et al. (Hoffman, Ratamess et al. 2009) did not equate training volume, indicating that under real training conditions, the training volume would not be the same between the linear and undulating programs. Which is a more appropriate method of comparison is up to the reader, but all of the studies provide important information. Another important difference among these studies pertains to the undulating periodized program. The studies of Buford et al. (Buford, Rossi et al. 2007), Hoffman et al. (Hoffman, Ratamess et al. 2009), and Rhea et al. (Rhea, Ball et al. 2002) used DUP, with a 3 sessions/ week schedule, meaning that within each week, there were large changes in intensity from session to session (e.g., from Rhea et al.: day1= 3 sets 8RM, day2 = 3 sets 6RM, and day3 = 3 sets 4RM). The current study used DUP, with a 4 sessions/ week schedule and 2 instead of 3 training zones in a week (e.g.,6 weeks using day 1 and 2 = 3 sets 12RM, day3 and 4 = 10RM; and 6 weeks using day 1 and 2 = 3 sets 8RM, day3 and 4 = 6RM). In the current study used WUP, with a 4 sessions/ week schedule, WUP specifies that within a week, the intensity was relatively consistent from workout to workout, but the intensity changed undulated dramatically from week to week and not in a progressively increasing manner. Another important difference among these studies pertains to subjects, the

studies of Buford et al. (Buford, Rossi et al. 2007), Hoffman et al. (Hoffman, Ratamess et al. 2009), and Rhea et al. (Rhea, Ball et al. 2002) have been conducted on untrained, or novices, or recreationally trained subjects, these studies did not yield any significant findings in favor of the DUP or WUP vs. LP, the current study was conducted on volleyball players have experience in strength training more than 1 year. Another interesting comparison is the magnitude of strength gains produced by using whole body routines and split routines. Our training protocol used split routines, whereas, Buford et al. (Buford, Rossi et al. 2007), Hoffman et al. (Hoffman, Ratamess et al. 2009), and Rhea et al. (Rhea, Ball et al. 2002) used whole body routines. Although there is variability in the strength gains, strength coaches and athletes believe that split routines allow individuals to train at a maximal effort level for a given intensity, producing higher muscle strain on a specific session. These routines would facilitate recovery due to the alternation in the muscle group trained. Strength coaches also recognize the importance of recovery microcycles at the end of each mesocycle to accelerate the recovery process and as a result increase training adaptations. Buford et al. (Buford, Rossi et al. 2007), Hoffman et al. (Hoffman, Ratamess et al. 2009), and Rhea et al. (Rhea, Ball et al. 2002) did not use recovery microcycles throughout the 12-week training period, while Rhea et al. (Rhea, Phillips et al. 2003), Prestes et al. (Prestes, Frollini et al. 2009) and the present study had a recovery week (the 7^{th} week). Thus, the effectiveness of recovery microcycles should also be investigated because long training periods (i.e., greater than 12 weeks) may lead to training load accumulation when using both whole body and split training regimens. Thus, the variation in results among these studies is likely related to some combination of total training volume (e.g., days per week), weight training experience, or weekly vs. daily undulating models, or whole body vs. split routines, or all.

Conclusion:

In conclusion, the present study's findings indicate that both DUP and WUP periodized training programs made similar strength gains from baseline to week 6. However, between week 8 and week 13, the WUP model outperformed the DUP model making larger improvements in muscular strength. Also, some variance in the results of this study vs. previous periodized strength training research may have resulted from the increased training frequency (day/ week), and background (i.e., competitive athletes; volleyball players) of the subjects, using only one subject group, using split routine . Therefore, comparison of results across periodized strength training studies must be conducted carefully.

Recommendations:

Volleyball players and coaches can use WUP model combined with split training routines to bring about optimal gains in muscular strength. Re-conduct such a study using different periodization models, different durations of resistance training, different number of sessions per week, another muscle groups for another competitive athletes. Use a single group with the method of unilateral limb training, when comparing between periodization models to isolate the independent effects of strength training. Investigate

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