Comparison Between Different Off-Season Resistance Training Programs in Division III American College Football Players

Jay R. Hoffman,[1] Nicholas A. Ratamess,[1] Marc Klatt,[1] Avery D. Faigenbaum,[1] Ryan E. Ross,[1] Nicholas M. Tranchina,[1] Robert C. McCurley,[1] Jie Kang,[1] and William J. Kraemer[2]

[1]*Department of Health and Exercise Science, The College of New Jersey, Ewing, New Jersey; and* [2]*Human Performance Laboratory, Department of Kinesiology, The University of Connecticut, Storrs, Connecticut*

Abstract

Hoffman, JR, Ratamess, NA, Klatt, M, Faigenbaum, AD, Ross, RE, Tranchina, NM, McCurley, RC, Kang, J, and Kraemer, WJ. Comparison between different off-season resistance training programs in Division III American college football players. *J Strength Cond Res* 23(1): 11–19, 2009—The purpose of this study was to examine the efficacy of periodization and to compare different periodization models in resistance trained American football players. Fifty-one experienced resistance trained American football players of an NCAA Division III football team (after 10 weeks of active rest) were randomly assigned to 1 of 3 groups that differed only in the manipulation of the intensity and volume of training during a 15-week off-season resistance training program. Group 1 participated in a nonperiodized (NP) training program, group 2 participated in a traditional periodized linear (PL) training program, and group 3 participated in a planned nonlinear periodized (PNL) training program. Strength and power testing occurred before training (PRE), after 7 weeks of training (MID), and at the end of the training program (POST). Significant increases in maximal (1-repetition maximum [1RM]) squat, 1RM bench press, and vertical jump were observed from PRE to MID for all groups; these increases were still significantly greater at POST; however, no MID to POST changes were seen. Significant PRE to POST improvements in the medicine ball throw (MBT) were seen for PL group only. The results do not provide a clear indication as to the most effective training program for strength and power enhancements in already trained football players. Interestingly, recovery of training-related performances was achieved after only 7 weeks of training, yet further gains were not observed. These data indicate that longer periods of training may be needed after a long-term active recovery period and that active recovery may need to be dramatically shortened to better optimize strength and power in previously trained football players.

Key Words American football, athletes, power, strength training

Address correspondence to Jay R. Hoffman, hoffmanj@tcnj.edu.

23(1)/11–19

Journal of Strength and Conditioning Research

Introduction

During the past 50 years, a number of studies have examined the influence that differences in intensity and volume of training have on strength improvements. Early studies suggested that an optimal training load (i.e., intensity of training) should be used to maximize strength gains (4,23). Subsequent studies have indicated that when training intensity and volume are manipulated within a training cycle, strength performance can be enhanced to a significantly greater extent than when these training variables are maintained consistent during the training period (10,16,18,20,28–30,33). The steplike alteration of training intensity increases and volume decreases is commonly referred to as the traditional model of periodization (2,11,25,26). It is also referred to as linear periodization, in which each phase of the training program emphasizes a specific training goal (i.e., hypertrophy, strength, or power). However, for some training programs, the goal may be to simultaneously emphasize both power and hypertrophy development. As a result, alterations in daily program emphasis would provide the ability for athletes to train for both at the same time. This periodized training model is often referred to as nonlinear or an undulating training model (7,16).

Studies examining nonlinear periodized training programs have demonstrated that daily program manipulation is more beneficial in eliciting strength gains than nonperiodized training (16,18,20,26). However, comparisons between traditional linear and nonlinear periodization models are quite limited. Rhea and colleagues (26) have reported that a nonlinear periodized resistance training program was more effective in stimulating strength gains than linear periodization after 12 weeks of training. In contrast, Baker et al. (2)

were unable to see any significant differences in strength gains between these 2 periodization models after 9 weeks of training. In support of these results, a recent study by Buford and colleagues (5) has compared 3 different periodization models (linear and 2 types of nonlinear programs) and does not report any significant differences in strength performance between the groups. Interestingly, the subjects in these studies were all novice or recreational lifters. The majority of research examining the efficacy of periodized resistance training programs has not been conducted on competitive athletes or, more specifically, strength/power athletes such as American football players. In the few studies examining competitive athletes, significant benefits of a nonlinear training model compared with no periodization have been reported in college tennis players (18) and football players (16). However, neither of these studies compared different periodization models. In addition, there does not seem to be any research examining the efficacy of the traditional linear periodization model vs. nonlinear or no periodization in football players. Despite limited evidence supporting the use of a periodization model for training strength/power athletes, it seems that such training has garnered widespread acceptance, as suggested by several recent reviews and discussions (1,19,24,31). This is surprising, considering that the call for more research on the effectiveness of periodization was published nearly a decade ago (7). In addition, a common characteristic of conditioning programs in Division III collegiate athletes is a relatively long active rest period between the conclusion of the season and the onset of the off-season training program. Few data are available comparing training programs after this longer period of activity in a previously trained group of strength/power athletes. Within this context, the purpose of this study was to examine the training adaptations that can be achieved under these circumstances in American football players using periodized and nonperiodized approaches to program design in athletes returning to high-intensity training.

Methods

Experimental Approach to the Problem

The subjects were randomly divided into 3 experimental groups. All subjects were experienced resistance trained athletes participating in a 15-week off-season conditioning program. The first group trained using a nonperiodized training routine (e.g., no manipulation performed of training intensity during the 15-week period), group 2 participated in a linear periodized training program in which changes in exercise intensity occurred every few weeks in a linear manner with the resistance increasing and the volume decreasing, and group 3 performed a planned nonlinear periodized training program in which planned changes in exercise intensity differed from workout to workout. All subjects were tested for strength (1-repetition maximum [1RM] lifts in the bench press and squat exercises), lower-body power (vertical jump test), and upper-body power (medicine ball throw [MBT]) at the beginning of the training program, after 7 weeks of training, and at the end of the 15-week training program.

Subjects

Fifty-one experienced resistance trained American football players of an NCAA Division III football team were randomly assigned to 1 of 3 groups that differed only in the manipulation of the intensity and volume of training during a 15-week spring semester off-season resistance training program. Group 1 (mean ± *SD*: age: 19.9 ± 1.3 years; height: 180.9 ± 5.2 cm, body mass: 99.5 ± 18.3 kg) participated in a nonperiodized (NP) training program, group 2 (mean ± *SD*: age: 19.5 ± 1.1 years; height: 182.0 ± 7.1 cm, body mass: 96.5 ± 16.5 kg) participated in a linear periodized (PL) training program, and group 3 (mean ± *SD*: age: 19.6 ± 0.9 years; height: 180.9 ± 4.9 cm, body mass: 105.1 ± 21.9 kg) were assigned to a planned nonlinear periodized (PNL) training program. The subjects gave their informed consent as part of their sport requirements, in accordance with the institution's policies of institutional review board for use of human subjects in research.

Resistance Training Programs

The off-season resistance training program for each group can be seen in Table 1. The exercises selected for the resistance training program were the same for all 3 groups. They differed only in the intensity (repetition maximum [RM]) used per workout. Any exercise that was added and/or removed during a new phase of training was done so for all 3 groups, regardless of the training program. Subjects were provided an RM zone to perform at a recommended intensity of their 1RM for each exercise. For instance, if a subject was required to perform 6–8RM for the bench press exercise, he needed to select a resistance that he could perform for at least 6 repetitions but not for more than 8. The intensity recommended for each workout was equivalent to the range of repetitions required (11). Subjects were also instructed to increase the resistance if they performed the maximum number of repetitions required for 2 consecutive exercise sessions. Subjects recorded all workouts in a logbook. The logbook was collected by one of the investigators after each workout, and feedback was provided with regard to changes in exercise loading. All exercise sessions were supervised by members of the investigative team who were certified strength and conditioning specialists.

All 3 training programs followed a 4-day split routine, in which days 1 and 3 focused on exercises training the chest, shoulders, and triceps, and days 2 and 4 focused on exercises training the legs, back, and biceps. The eighth week of training coincided with the school's spring break, and study investigators instructed all subjects to use this as an active rest period and to not participate in any resistance-type exercise. The NP group used the same exercise intensity throughout the 15-week training program. No manipulation of training intensity was performed, and training volume differed only

Table 1. Linear periodized resistance training program.

No periodization				Linear periodization				Nonlinear periodization			
Phase I (4 wk)											
Monday/Thursday		Tuesday/Friday		Monday/Thursday		Tuesday/Friday		Monday/Thursday		Tuesday/Friday	
Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps
Bench press	4 × 6–8	Squat	4 × 6–8	Bench press	4 × 9–12	Squat	4 × 9–12	Bench press	4 3–5 9–12	Squat	4 9–12 3–5
Incline bench press	3 × 6–8	Dead lift	4 × 6–8	Incline bench press	3 × 9–12	Dead lift	4 × 9–12	Incline bench press	3 3–5 9–12	Dead lift	4 9–12 3–5
Incline fly's	3 × 6–8	Leg curls	3 × 6–8	Incline fly's	3 × 9–12	Leg curls	3 × 9–12	Incline fly's	3 3–5 9–12	Leg curls	3 9–12 3–5
High pulls	4 × 3–4	Standing calf raises	3 × 6–8	High pulls	4 × 5–6	Standing calf raises	3 × 9–12	High pulls	4 1–2 5–6	Standing calf raises	3 9–12 3–5
Seated shoulder press	4 × 6–8	Lat pull-down	4 × 6–8	Seated shoulder Press	4 × 9–12	Lat pull-down	4 × 9–12	Seated shoulder press	4 3–5 9–12	Lat pull-down	4 9–12 3–5
Power DB shrugs	3 × 6–8	Seated row	4 × 6–8	Power DB shrugs	3 × 9–12	Seated row	4 × 9–12	Power DB shrugs	3 3–5 9–12	Seated row	4 9–12 3–5
Lateral raises	3 × 6–8	Biceps curl	3 × 6–8	Lateral raises	3 × 9–12	Biceps curl	3 × 9–12	Lateral raises	3 3–5 9–12	Biceps curl	3 9–12 3–5
Triceps push-down	3 × 6–8	Hammer curl	3 × 6–8	Triceps push-down	3 × 9–12	Hammer curl	3 × 9–12	Triceps push-down	3 3–5 9–12	Hammer curl	3 9–12 3–5
Triceps DB extensions	3 × 6–8			Triceps DB extensions	3 × 9–12			Triceps DB extensions	3 3–5 9–12	–	–
Phase II (6 wk)											
Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps
Power clean	4 × 3–4	Squat	4 × 6–8	Power clean	4 × 3–4	Squat	4 × 6–8	Power clean	4 1–2 5–6	Squat	4 9–12 3–5
Bench press	4 × 6–8	Dead lift/SL dead lift	4 × 6–8	Bench press	4 × 6–8	Dead lift/SL dead lift	4 × 6–8	Bench press	4 3–5 9–12	Dead lift/SL dead lift	4 9–12 3–5
Incline bench press/DB	3 × 6–8	Leg curls	3 × 6–8	Incline bench press/DB	3 × 6–8	Leg curls	3 × 6–8	Incline bench press/DB	3 3–5 9–12	Leg curls	3 9–12 3–5
Incline fly's	3 × 6–8	Standing calf raises	3 × 6–8	Incline fly's	3 × 6–8	Standing calf raises	3 × 6–8	Incline fly's	3 3–5 9–12	Standing calf raises	3 9–12 3–5

(*Continued on next page*)

Push press/DB	4 × 3–4	Lat pull-down	4 × 6–8	Push press/DB	4 × 3–4	Lat pull-down	4 × 6–8	Push press/DB	4 1–2 5–6	Lat pull-down	4 9–12 3–5
High pulls (snatch grip)	3 × 3–4	Seated row	4 × 6–8	High pulls (snatch grip)	3 × 3–4	Seated row	4 × 6–8	High pulls (snatch grip)	3 1–2 5–6	Seated row	4 9–12 3–5
Front raise DB	3 × 6–8	Biceps curl	3 × 6–8	Front raise DB	3 × 6–8	Biceps curl	3 × 6–8	Front raise DB	3 3–5 9–12	Biceps curl	3 9–12 3–5
Triceps push-down	3 × 6–8	Hammer curl	3 × 6–8	Triceps push-down	3 × 6–8	Hammer curl	3 × 6–8	Triceps push-down	3 3–5 9–12	Hammer curl	3 9–12 3–5
Triceps DB extensions	3 × 6–8			Triceps DB extensions	3 × 6–8			Triceps DB extensions	3 3–5		
					Phase III (4 wk)						
Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps	Exercise	Sets/reps
Power clean/hang clean	5 × 3–4	Squat	5 × 6–8	Power clean/hang clean	5 × 1 –2	Squat	5 × 3–5	Power clean/hang clean	5 1–2 5–6	Squat	5 9–12 3–5
Bench press	5 × 6–8	Power/hang snatch	4 × 4–6	Bench press	5 × 3–5	Power Snatch/hang snatch	4 × 1–2	Bench press	5 3–5 9–12	Power snatch/hang snatch	4 5–6 1–2
Incline bench press/DB	4 × 6–8	Dead lift/SL dead lift	4 × 6–8	Incline bench press/DB	4 × 3–5	Dead lift/SL dead lift	4 × 3–5	Incline bench press/DB	3 3–5 9–12	Dead lift/SL dead lift	4 9–12 3–5
Push press	5 × 3–4	Leg curl	3 × 6–8	Push press	5 × 1–2	Leg curl	3 × 3–5	Push press	4 1–2 5–6	Leg curl	3 9–12 3–5
High pulls (snatch grip)	4 × 3–4	Standing calf raises	3 × 6–8	High pulls (snatch grip)	4 × 1–2	Standing calf raises	3 × 3–5	High pulls (snatch grip)	4 1–2 5–6	Standing calf raises	3 9–12 3–5
Triceps DB extensions	3 × 6–8	Lat pull-down	4 × 6–8	Triceps DB extensions	3 × 3–5	Lat pull-down	4 × 3–5	Triceps DB extensions	3 3–5 9–12	Lat pull-down	4 9–12 3–5
		Seated row	4 × 6–8			Seated row	4 × 3–5		3 3–5 9–12	Seated row	3 9–12 3–5
		Biceps curl	3 × 6–8			Biceps curl	3 × 3–5		3 3–5 9–12	Biceps curl	3 9–12 3–5

DB = dumbbell; SL = stiffed leg.

with the addition or subtraction of exercises that occurred during specific points of the training cycle (in conjunction with any change of exercise for the other training programs). The intensity used throughout the training program for NP was equivalent to that seen during the strength phase of PL (6–8 RM in the traditional power exercises and 3–4 RM in the Olympic movement exercises). Subjects were instructed to rest for 2–3 minutes between each set.

The PL group followed a traditional linear periodized training program (11), in which the training cycle was divided into several mesocycles. Each mesocycle differed in the intensity and volume of training. Subjects performed a 4-week preparatory/hypertrophy phase (subjects were instructed to rest for 1 minute between sets), a 6-week strength phase (subjects were instructed to rest 2–3 minutes between sets), and a 4-week power phase (subjects were instructed to rest 3 minutes between sets). The PNL group followed a nonlinear periodized training program in which the intensity and volume of exercise differed from workout to workout. Workouts would alternate from a power workout (3–5 RM in the power exercises and 1–2 RM in Olympic movement exercises, with a 3-minute rest between each set) to a hypertrophy workout (9–12 RM in the power exercises and 5–6 RM in the Olympic movement exercises, with a 1-minute rest between sets). During the last 5 weeks of training, all subjects participated in a 3-d·wk^{-1} speed and agility training program.

Performance Assessments

All subjects participated in strength and power assessments that were performed before the training program (PRE), after 7 weeks of training (MID), and at the end of the 15-week resistance training program (POST). Again, a 1-week break was taken after the seventh week of training for 1 week, and then training continued on from weeks 9 to 15. Because previous studies have shown that maximal strength assessment can potentiate anaerobic power performance during similar testing protocols (15), all subjects were required to perform maximal strength testing before the power assessments.

Strength Measures. During each testing session, subjects performed a 1-repetition maximum (1RM) strength test on the bench press and squat exercises to measure upper- and lower-body strength, respectively. The 1RM tests were conducted as previously described (12). Each subject performed a warm-up set using a resistance that was approximately 40–60% of his perceived maximum, and then he performed 3–4 subsequent attempts to determine the 1RM. A 3- to 5-minute rest period was provided between each lift. No bouncing was permitted, because this would have artificially inflated strength results. Bench press testing was performed in the standard supine position: the subject lowered an Olympic weightlifting bar to midchest and then pressed the weight until his arms were fully extended. The squat exercise required the subject to rest an Olympic weightlifting bar across the trapezius at a self-chosen location. The squat was performed to the parallel position, which was achieved when the greater trochanter of the femur was lowered to the same level as the knee. The subject then lifted the weight until his knees were extended. Previous studies have demonstrated good test-retest reliability ($r > 0.97$) for these strength measures in our laboratories (13,14).

Anaerobic Power Measures. Vertical jump testing performed on a force plate and a seated MBT were used to assess lower- and upper-body power, respectively. Before vertical jump testing, all subjects performed a 5-minute warm-up on a cycle ergometer. In addition, a movement-specific warm-up was then performed. Each subject was instructed to perform 5 vertical jumps at approximately 50% of their maximal effort, followed by an additional 5 jumps at approximately 75% of their maximal effort. After the warm-up, subjects then performed 5 maximal-effort vertical jumps with a countermovement. Subjects completed the 5 jumps consecutively.

During the countermovement jump testing, each subject began by standing erect on an AccuPower portable force plate (Advanced Medical Technology Inc., Watertown, Mass) with his hands on his hips. Before jumping, each subject was instructed to maximize the height of each jump while minimizing the contact time with the force plate between jumps. On a verbal signal, the subject lowered himself to a self-selected depth and immediately performed the required number of vertical jumps landing back on the force plate. For each jump, the subject's displacement of the center of mass was recorded for subsequent calculation of power data. The computer recorded force and displacement data, and a software package (AccuPower, Frappier Acceleration, Fargo, ND) was used to calculate power. Samples were collected at 200 Hz. The system was calibrated before each test. The highest power output of the 5 trials for each jump was recorded. High test-retest reliabilities ($r > 0.90$) have been previously reported with this testing apparatus (32).

The seated MBT was used to assess upper-body power (3). A 3-kg medicine ball was used for this test. Each subject was seated on a chair with a 90° angle at the tibiofemoral and acetabular-femoral joints. The subject would sit upright in the chair with both hands grasping the ball. The ball was maintained at chest level. Subjects were instructed to release the ball at a 45° angle. The subjects were allowed 2 practice throws. Once a subject felt comfortable with the technique, he was allowed 3 throws. Chalk was placed on the ball before each throw to provide measurement accuracy (e.g., determining where the ball landed). The throw with the greatest distance was recorded to the nearest centimeter.

Questionnaire

To provide a subjective measure of the subjects' perceptions of the 3 different training protocols at the conclusion of the study (during the posttesting period at week 15), subjects were asked to rate 4 statements using the following 5-point rating scale: 1 = strongly disagree, 2 = disagree, 3 = no strong feeling either way, 4 = agree, and 5 = strongly agree. The first statement was, "I was able to maintain the prescribed intensity/volume of my workouts throughout the study," and the second statement was, "I feel stronger and more powerful than I did at the start of the study." The third statement was, "I felt that I had sufficient recovery between each workout session," and the final statement was, "I felt that the program I was on provided me the best opportunity to increase my strength and power."

Statistical Analyses

Statistical evaluation of the data was accomplished by a repeated-measures analysis of variance. In the event of a significant *F* ratio, least significant difference post hoc tests were used for pairwise comparisons. A criterion alpha level of $p \leq 0.05$ was used to determine statistical significance. All data are reported as mean ± *SD*.

Results

Body mass, strength, and power changes can be observed in Table 2. No significant changes in body mass were seen from PRE in any group demonstrating the already high level of training-induced muscle mass that was already present in these athletes. All groups significantly increased both 1RM squat and 1RM bench press from PRE to MID. Results were still significantly greater than PRE at POST, but significant strength improvements were not seen from MID to POST in any group for either strength measure, again indicating a recovery phenomenon from the active rest period without any further tissue or neurological enhancements during the final 7-week training period.

Vertical jump significantly improved for all 3 groups between PRE and MID. However, no other changes were noted, and no between-group differences were observed. No between- or within-group changes were observed in vertical jump power. Upper-body power as assessed by the MBT revealed significant PRE to POST improvement for only PL. No between-group differences were noted.

The subjective assessment of the training programs can be observed in Table 3. No significant differences were noted between the groups in any of the subjective measures assessed. All 3 groups indicated that they felt stronger and more powerful than at the beginning of the study, and each group indicated that their specific training program provided the best opportunity for them to increase their strength and power. In addition, all groups remarked that they were able to maintain the prescribed intensity and volume of training, and that recovery between each training session was sufficient.

Discussion

The results of this study indicate that the greatest gains in strength and vertical jump height during a 15-week off-season strength and conditioning program in college football players occurred within the first 7 weeks of training, and the

Table 2. Body mass, strength, and power changes during 15 weeks of training.

Variable	Group	PRE	MID	POST
Body mass (kg)	NP	99.5 ± 18.3	101.4 ± 18.8	101.4 ± 19.0
	PL	96.5 ± 16.5	97.8 ± 16.2	95.8 ± 15.4
	PNL	105.1 ± 21.9	106.3 ± 22.3	106.1 ± 21.7
1RM squat (kg)	NP	161.8 ± 16.6	182.3 ± 21.5*	194.8 ± 24.5*
	PL	149.5 ± 25.0	172.9 ± 23.4*	180.5 ± 17.6*
	PNL	164.2 ± 23.2	182.2 ± 25.4*	182.5 ± 25.6*
1RM bench press (kg)	NP	125.9 ± 12.2	134.8 ± 11.5*	136.8 ± 9.5*
	PL	118.5 ± 18.3	125.5 ± 17.6*	127.7 ± 20.7*
	PNL	124.0 ± 25.0	131.3 ± 26.7*	134.3 ± 27.1*
Vertical jump height (cm)	NP	61.0 ± 8.0	63.5 ± 7.4*	63.7 ± 8.6
	PL	63.6 ± 7.1	65.1 ± 7.8*	64.0 ± 8.0
	PNL	59.1 ± 11.2	61.0 ± 10.8*	59.8 ± 11.6
Vertical jump power (W)	NP	6497 ± 734	6779 ± 742	6478 ± 541
	PL	6462 ± 863	6576 ± 573	6554 ± 736
	PNL	6845 ± 1279	6761 ± 999	6237 ± 793
Medicine ball throw (cm)	NP	566 ± 53	564 ± 54	577 ± 45
	PL	537 ± 49	545 ± 42	570 ± 45*
	PNL	556 ± 73	580 ± 59	576 ± 53

All data are reported as mean ± *SD*.

PRE = before training; MID = after 7 weeks of training; POST = after training; NP = nonperiodized; PL = linear periodization; PNL = nonlinear periodization; 1RM = 1-repetition maximum.

*Significantly different from PRE.

Table 3. Subjective assessment of training program.

Statement	Group	POST
I was able to maintain the prescribed intensity/volume of my workouts throughout the study.	NP	4.1 ± 0.6
	PL	3.7 ± 1.0
	PNL	3.9 ± 0.5
I feel stronger and more powerful than I did at the start of the study.	NP	4.0 ± 0.9
	PL	4.4 ± 0.7
	PNL	4.2 ± 0.7
I felt that I had sufficient recovery between each workout session.	NP	3.0 ± 1.0
	PL	3.3 ± 1.2
	PNL	3.9 ± 0.6
I felt that the program I was on provided me the best opportunity to increase my strength and power.	NP	3.6 ± 1.0
	PL	3.6 ± 1.0
	PNL	3.8 ± 1.1

All data are reported as mean ± *SD*.
POST = after training; NP = nonperiodized; PL = linear periodization; PNL = nonlinear periodization.

magnitude of strength improvement did not differ between the training programs. These results likely reflect the rapid strength gains made by the subjects returning from an extended detraining or active recovery period. After the end of the regular season, all returning players (e.g., subjects) were recommended to participate in an active rest period. No formal strength and conditioning program was employed, but the subjects were encouraged to remain physically active. This phase of the yearly training cycle is designed to allow the athlete to recover from the competitive season (11), but it also provides time for the collegiate athlete (especially at the Division III level) to focus on his or her studies and to prepare for final exams. The active rest period in this study was approximately 10 weeks (it also coincided with the semester break). Although resistance training may have occurred during this period, it was not monitored, and, from anecdotal experience, it was not performed at the intensity or consistency generally seen during official team training sessions. Previous studies have demonstrated significant strength losses occurring from similar detraining periods (8). The significant strength improvements noted in the initial stage of the off-season training program likely reflect the rapid return to previous strength levels as a result of neural adaptation (6), which would have given an advantage to the groups where high force and power exposure were the greatest owing to the need for maximal recruitment of motor units. The concept of a rapid strength return after a detraining period in resistance trained subjects has been termed "muscle memory," and this was first demonstrated in women by Staron and colleagues (27). The results observed during the initial 7 weeks of training in this study seem to support this concept even in highly trained men.

As the training program progressed, additional changes in strength may have provided a greater reflection on the effectiveness of the different training paradigms being examined. However, with another microcycle of active rest (the week of spring break) and only 7 additional weeks of training, the ability to stimulate physiological adaptations may be limited, considering the resistance training experience of these athletes. Previous research has indicated that short-term strength improvements in experienced, resistance trained athletes may be more a function of neurological change vs. change in lean tissue mass (9). A greater duration of training seems necessary to impact changes in lean tissue mass to generate greater strength improvements in these athletes (9).

Performance in upper- and lower-body power measures differed between the groups. Significant improvements in vertical jump height were seen between PRE and MID in all 3 groups. However, no additional improvements were seen in any group from MID to POST. Furthermore, vertical jump height at POST was not significantly different than PRE for any group, suggesting that lower-body power performance was reduced at that time point. The final 7 weeks of training also coincided with a 5-week plyometric, speed, and agility program that was performed during spring football. Spring football at the level of this college (Division III) is performed without any physical contact, and with a finite amount of practice times permitted. As a result, the 4-d·wk^{-1} off-season resistance training program was maintained throughout the 15 weeks. It is possible that the cumulative training stresses of resistance, plyometric, speed, and agility training resulted in a potential overtraining syndrome that minimized performance gains, especially in the lower body. Moore and Fry (21) have reported that the combination of off-season training and spring football practices in American college football players can result in nonfunctional overreaching, in which short-term performance decrements are seen.

A significant PRE to POST MBT improvement was seen in PL only. It is likely that the greater intensity of training used by PL in the latter stages of the training program provided a greater stimulus for power development than the nonlinear style of training used by PNL or NP. Although PNL incorporated power training from the beginning of the training program, the single session of power training for the lower body per week may not have been sufficient to provide an adequate training stimulus. The training program for NP did not provide any higher-intensity training typically seen during power cycles. Previous research has demonstrated that power performance may even decline if force outputs during training are not sufficient (22).

Research on the efficacy of periodization models has primarily investigated previously untrained or recreationally trained individuals. These studies (10,26,28–30,33) have established that manipulation of training intensity and volume provides a greater advantage for strength and performance gains than training programs that do not use any variation strategies. However, these results have been extrapolated to be efficacious for competitive strength/power athletes even though there are only 2 studies known to have actually examined periodization strategies in competitive athletes. One study investigated collegiate women's tennis players with no prior resistance training experience (18), and the other study examined collegiate football players (16). Both studies indicated that nonlinear periodization strategies were superior to either no periodization (18) or to a high-intensity single-set training program (16). This study seems to be one of the first investigations to examine the efficacy of different variations of off-season periodized or nonperiodized training programs in experienced, resistance trained, competitive strength/power athletes, but within the context that these athletes were beginning their training after a prolonged period of active rest.

Only 3 studies are known that have compared linear with nonlinear periodized training programs (2,5,26). All 3 studies examined recreational lifters exercising 3 $d \cdot wk^{-1}$ for 9–12 weeks. Although 2 studies were unable to see any significant difference in strength gains between linear, nonlinear, and nonperiodized training programs (2,5), Rhea et al. (26) have demonstrated that nonlinear training was more effective in eliciting strength gains than a traditional, linear resistance training program. The mechanisms underlying these differential findings are not clear, but differences in training volume between the studies were apparent. In the studies that have shown no significant differences between training paradigms, training volume was equated (2,5). However, Baker and colleagues (2) still used a higher volume (5 sets per exercise in the core exercises) of training than Rhea et al. (3 sets per exercise for all exercises) (26). Similar to Rhea and colleagues (26), training volumes between the groups in this study were not equated. It was believed that this represented a realistic comparison of 3 different training regimens that are used to train competitive strength/power athletes within the context of this sequence of time. Regardless, no significant between-group differences were seen. Although these results support the work of Baker et al. (2) and Buford et al. (5), it is likely that a longer duration of training is necessary to differentiate differences in training paradigms in experienced resistance trained athletes (9).

Practical Applications

There are a variety of training paradigms that can be used to train competitive athletes; however, no specific training design has proven to be more efficacious than the other. The results of this study do not provide clear evidence to support either periodized linear, planned nonlinear, or nonperiodized training programs during a 15-week off-season resistance training program in college football players. However, it is important to place this study in the appropriate context regarding the time frame in which it was conducted. Subjects began this study after a period of active rest in which they were likely detrained. Any of the resistance training programs would likely have stimulated rapid strength improvements. In addition, this study used a single nonlinear training model. There are many possible nonlinear training sequence models that emphasize different training characteristics of strength and power that can be used to train athletes (17). Incorporation of a different nonlinear model may have resulted in different adaptations. The results do not provide a clear indication as to the most effective training program for strength and power enhancement in already trained football players. Although recovery of training-related performance was achieved after only 7 weeks of training, further gains were not observed. These data indicate that longer periods of training may be needed after a long-term active recovery period and that active recovery may need to be dramatically shortened to better optimize strength and power in previously trained football players.

References

1. Baker, D. Applying the in-season periodization of strength and power training to football. *Strength Cond J* 20(2): 18–27, 1998.
2. Baker, D, Wilson, G, and Carlyon, R. Periodization: the effect on strength of manipulating volume and intensity. *J Strength Cond Res* 8: 235–242, 1994.
3. Baumgartner, TA, and Jackson, AS. *Measurement for Evaluation* (3rd ed.). Dubuque: Wm. C. Brown Publishers, 1987. pp. 173–216.
4. Berger, RA. Optimal repetitions for the development of strength. *Res Q* 33: 334–338, 1962.
5. Buford, TW, Rossi, SJ, Smith, DB, and Warren, AJ. A comparison of periodization models during nine weeks with equated volume and intensity for strength. *J Strength Cond Res* 21: 1245–1250, 2007.
6. Deschenes, MR, Giles, JA, McCoy, RW, Volek, JS, Gomez, AL, and Kraemer, WJ. Neural factors account for strength decrements observed after short-term muscle unloading. *Am J Physiol Regul Integr Comp Physiol* 282: R578–R583, 2002.
7. Fleck, SJ. Periodized strength training: a critical review. *J Strength Cond Res* 13: 82–89, 1999.
8. Häkkinen, K, Alen, M, and Komi, PV. Changes in isometric force- and relaxation-time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiol Scand* 125: 573–585, 1985.

9. Häkkinen, K, Pakarinen, A, Alen, M, Kauhanen, H, and Komi, PV. Neuromuscular and hormonal adaptations in athletes to strength training in two years. *J Appl Physiol* 65: 2406–2412, 1988.

10. Harris, GR, Stone, MH, O'Bryant, HS, Proulx, CM, and Johnson, RL. Short-term performance effects of high power, high force, or combined weight-training methods. *J Strength Cond Res* 14: 14–20, 2000.

11. Hoffman, JR. *Physiological Aspects of Sport Training and Performance.* Champaign: Human Kinetics, 2002. pp. 81–142.

12. Hoffman, JR. *Norms for Fitness, Performance and Health.* Champaign: Human Kinetics, 2006. pp. 27–39.

13. Hoffman, JR, Fry, AC, Deschenes, M, and Kraemer, WJ. The effects of self-selection for frequency of training in a winter conditioning program for football. *J Appl Sport Sci Res* 4: 76–82, 1990.

14. Hoffman, JR, Fry, AC, Howard, R, Maresh, CM, and Kraemer, WJ. Strength, speed, and endurance changes during the course of a Division I basketball season. *J Appl Sport Sci Res* 5: 144–149, 1991.

15. Hoffman, JR, Ratamess, NA, Faigenbaum, AD, Mangine, GT, and Kang, J. Effects of maximal squat exercise testing on vertical jump performance in college football players. *J Sports Sci Med* 6: 149–150, 2007.

16. Kraemer, WJ. A series of studies–the physiological basis for strength training in American football: fact over philosophy. *J Strength Cond Res* 11: 131–142, 1997.

17. Kraemer, WJ and Fleck, SJ. *Optimizing Strength Training–Designing Nonlinear Periodization Workouts.* Champaign: Human Kinetics, 2007.

18. Kraemer, WJ, Hakkinen, K, Triplett-McBride, NT, Fry, AC, Koziris, LP, Ratamess, NA, Bauer, JE, Volek, JS, McConnell, T, Newton, RU, Gordon, SE, Cummings, D, Hauth, J, Pullo, F, Lynch, JM, Mazzetti, SA, and Knuttgen, HG. Physiological changes with periodized resistance training in women tennis players. *Med Sci Sports Exerc* 35: 157–168, 2003.

19. Kraemer, WJ and Ratamess, NA. Fundamental of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 36: 674–688, 2004.

20. Marx, JO, Ratamess, NA, Nindl, BC, Gotshalk, LA, Volek, JS, Dohi, K, Bush, JA, Gomez, AL, Mazzetti, SA, Fleck, SJ, Hakkinen, K, Newton, RU, and Kraemer, WJ. Low-volume circuit versus high-volume periodized resistance training in women. *Med Sci Sports Exerc* 33: 635–643, 2001.

21. Moore, CA and Fry, AC. Nonfunctional overreaching during off-season training for skill position players in collegiate American football. *J Strength Cond Res* 21: 793–800, 2007.

22. Newton, RU, Rogers, RA, Volek, JS, Hakkinen, K, and Kraemer, WJ. Four weeks of optimal load ballistic resistance training at the end of the season attenuates declining jump performance of women volleyball players. *J Strength Cond Res* 20: 955–961, 2006.

23. O'Shea, P. Effects of selected weight training programs on the development of strength and muscle hypertrophy. *Res Q* 37: 95–102, 1966.

24. Plisk, SS, and Stone, MH. Periodization strategies. *Strength Cond J* 25 (6): 19–7, 2003.

25. Poliquin, C. Five steps to increasing the effectiveness of your strength training program. *NSCA J* 10: 34–39, 1988.

26. Rhea, MR, Ball, SD, Phillips, WT, and Burkett, LN. A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J Strength Cond Res* 16: 250–255, 2002.

27. Staron, RS, Leonardi, MJ, Karapondo, DL, Malicky, ES, Falkel, JE, Hagerman, FC, and Hikida, RS. Strength and skeletal muscle adaptations in heavy-resistance-trained women after detraining and retraining. *J Appl Physiol* 70: 631–640, 1991.

28. Stone, MH, O'Bryant, H, and Garhammer, J. A theoretical model for strength training. *J Sports Med* 21: 342–351, 1982.

29. Stone, MH, Potteiger, JA, Pierce, KC, Proulx, CM, O'Bryant, HS, Johnson, RL, and Stone, ME. Comparison of the effects of three different weight-training programs on the one repetition maximum squat. *J Strength Cond Res* 14: 332–337, 2000.

30. Stowers, T, McMillan, J, Scala, D, Davis, V, Wilson, D, and Stone, M. The short-term effects of three different strength-power training methods. *NSCA J* 5: 24–27, 1983.

31. Tan, B. Manipulating resistance training program variables to optimize maximum strength in men: a review. *J Strength Cond Res* 13: 289–304, 1999.

32. Walsh, MS, Ford, KR, Bangen, DJ, Myer, GD, and Hewett, TE. The validation of a portable force plate for measuring force-time data during jumping and landing tasks. *J Strength Cond Res* 20: 730–734, 2006.

33. Willoughby, DS. The effects of mesocycle-length weight training programs involving periodization and partially equated volumes on upper and lower body strength. *J Strength Cond Res* 7: 2–8, 1993.