The Effect of Autoregulatory Progressive Resistance Exercise vs. Linear Periodization on Strength Improvement in College Athletes

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Abstract

Mann, JB, Thyfault, JP, Ivey, PA, and Sayers, SP. The effect of autoregulatory progressive resistance exercise vs. linear periodization on strength improvement in college athletes. *J Strength Cond Res* 24(7): 1718–1723, 2010—Autoregulatory progressive resistance exercise (APRE) is a method by which athletes increase strength by progressing at their own pace based on daily and weekly variations in performance, unlike traditional linear periodization (LP), where there is a set increase in intensity from week to week. This study examined whether 6 weeks of APRE was more effective at improving strength compared with traditional LP in division I College football players. We compared 23 division 1 collegiate football players (2.65 ± 0.8 training years) who were trained using either APRE (n = 12) or LP (n = 11) during 6 weeks of preseason training in 2 separate years. After 6 weeks of training, improvements in total bench press 1 repetition maximum (1RM), squat 1RM, and repeated 225-lb bench press repetitions were compared between the APRE and LP protocol groups. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were used to determine differences between groups. Statistical significance was accepted at $p \leq 0.05$. Autoregulatory progressive resistance exercise demonstrated greater improvement in 1RM bench press strength (APRE: 93.4 ± 103 N vs. LP: −0.40 ± 49.6 N; ANCOVA: F = 7.1, p = 0.02), estimated 1RM squat strength (APRE: 192.7 ± 199 N vs. LP: 37.2 ± 155 N; ANOVA: F = 4.1, p = 0.05) and the number of repetitions performed at a weight of 225 lb (APRE: 3.17 ± 2.86 vs. LP: −0.09 ± 2.40 repetitions; ANCOVA: F = 6.8, p = 0.02) compared with the LP group over the 6-week training period. Our findings indicate that the APRE was more effective than the LP means of programming in increasing the bench press and squat over a period of 6 weeks.

Key Words resistance training, strength and conditioning, football

Introduction

For decades, strength improvement has been a goal for the athlete attempting to secure a competitive advantage over the competition. The ultimate goal of any strength training program must be to deliver the greatest gains in strength to optimize athletic performance. For the exercise scientist and strength coach working with the athlete, determining the most effective program for eliciting maximal strength gains should be a primary focus.

There is no universally agreed-upon approach to maximize strength gains in the athlete, but most coaches do agree that there needs to be a planning or periodization of the training stimuli. Periodization is a programed manipulation of several key training variables (rest, overall training volume, sets per workout, repetitions per set, intensity of training, and training frequency) throughout a training cycle. Periodization can be traced back to Selye's (10) work on stressors and adaptation. Selye theorized that the body will adapt to meet the demand of stressors on the system, which has led to the specific adaptation to imposed demands (SAID) principle (11). The theoretical product of integrating the SAID principle with the progressive overload principle implies that the athlete's strength will gradually adapt to a steady increase in the intensity and volume of training. In simple terms, the muscular and nervous systems adapt to meet the needs of lifting an increasing load, requiring that loads continue to increase for strength to improve.

Classic linear periodization (LP) is a breakdown of macrocycles, mesocycles, and microcycles, in which intensity gradually increases and volume gradually decreases within and between cycles (1). Studies have shown that periodized programming elicits better gains in strength and performance than nonperiodized programming (7,13); however it

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is currently not clear what type of periodization is most effective. Daily undulating periodization has been found to be more effective than LP in some studies (8,9) even with equated volume and intensity of training.

A less common and understudied form of periodization is "autoregulation" of training (12). Autoregulation is a form of periodization that adjusts to the individual athlete's adaptations on a day-to-day or week-to-week basis. This type of periodization allows the athlete to increase strength at their own pace by catering the program to the athlete's individual strength or performance on a daily basis (12). Because individuals increase strength or respond to training stimuli at different rates, it is possible that the use of autoregulation may maximize the amount of strength gained over a training cycle. A specific autoregulatory program derived from the original Delorme progressive resistance exercise (PRE) system (2) and outlined by Siff is the autoregulating progressive resistance exercise (APRE) method (12). To our knowledge, no studies have compared strength gains elicited by a traditional LP program vs. an APRE protocol.

The purpose of this study was to compare the effect of an APRE training program vs. a traditional LP training program on strength improvement in National Collegiate Athletic Association (NCAA) division I football players during a 6-week off-season program. We hypothesized that an APRE program that adjusts to the day-to-day variation in performance capabilities would result in larger strength gains in previously strength trained individuals compared to a program employing the traditional LP method.

Methods

Experimental Approach to the Problem

The goal of this investigation was to compare the effects of APRE to LP in strength trained college athletes. The primary dependent variables in the study consisted of bench press 1RM, estimated squat 1RM, and the 225-lb repeated bench press test. All dependent variables were obtained after the off-season (January–May) spring conditioning program (baseline) and after the preseason (June–July) conditioning program (post).

Subjects

We compared 23 division I collegiate football players who were trained using either APRE ($n = 12$) or LP ($n = 11$) for 6 weeks of resistance training during the preseason conditioning program at the University of Missouri in 2 separate years. Demographic characteristics of each group can be seen in Table 1.

All subjects had previously performed the LP program in previous training cycles. The LP group consisted of athletes who were trained during the 2004 off-season, whereas the APRE group consisted of athletes who were trained the following year (2005 off-season) using the new training method. All athletes had similar training histories (see Table 1), were trained during the same time period in consecutive years, and were trained by the same training staff, which limited seasonal variability or differences in application of the programs. We sought to determine which of the 2 6-week training programs resulted in the greatest increase in estimated 1 repetition-maximum (1RM) bench press strength, estimated 1RM Squat, and the 225-lb bench press repetitions test compared with their final off-season spring results. The retrospective analysis of human subject data was approved by the University of Missouri Institutional Review Board.

Table 1. Subject characteristics.*†‡

	APRE group ($n = 12$)	LP group ($n = 11$)
Age (y)	20.2 ± 1.0	20.3 ± 1.6
Training age (y)	2.9 ± 0.7	2.43 ± 0.7
Body mass (kg)	111.3 ± 21.9	104.1 ± 22.5
Height (m)	1.85 ± 0.7	1.87 ± 0.3

*APRE = autoregulatory progressive resistance exercise; LP = linear periodization.
†Values are presented as mean ± *SD*.
‡No significant differences were found between the APRE and LP groups.

Autoregulating Progressive Resistance Exercise and Linear Periodization Protocols

In this study, APRE was implemented for the bench press and squat exercises. Over the 6-week training period, APRE used 3 protocols: a 10RM program, a 6RM program, and a 3RM program. For each program, subjects performed a set number of repetitions at a certain percentage of the 10RM, 6RM, and 3RM based on Delorme's PRE program (12). Each of the 10RM, 6RM, and 3RM resistance training protocol consisted of 4 sets each. The 6RM program will be described here, because it was the one that was used for the greatest portion of the study. During set 1, subjects performed 10 repetitions at 50% of the anticipated 6RM. During set 2, subjects then performed 6 repetitions at 75% of the anticipated 6RM. Finally, during set 3, subjects performed as many repetitions as they could at 100% of the anticipated 6RM until they reached failure. The weight used during set 4 was based on the performance during the third set using an adjustment table (see Table 2). During set 4, repetitions were performed until failure, and the number of repetitions and load used were then used to determine the initial resistance for the following week's training.

The LP group began their resistance training protocol with sets of 8 at 70% 1RM and worked up to a 5RM by moving up a weekly predetermined percentage for the repetitions required. For the squat, 3 sets of 8 repetitions at 70% 1RM were performed during week 1, 4 sets of 6 repetitions at 75% 1RM were performed during week 2, 4 sets of 5 repetitions at 80% 1RM were performed during week 3, and 4 sets of

Table 2. APRE protocol for 6RM and set 4 adjustment.*

Repetitions	Intensity (% of 6RM)
APRE protocol for 6RM	
10×	50%
6×	75%
Maximum	6RM
Maximum	Adjusted weight
Repetitions for set 3	Set 4 adjustment (lb)
6RM routine adjustment	
0–2	−5 to −10
3–4	0 to −5
5–7	No change
8–12	+5 to +10
>13	+10 to +15

*APRE = autoregulatory progressive resistance exercise; LP = linear periodization; 6RM = 6 repetitions maximum.

5 repetitions at 85% 1RM were performed during week 4. Maximal strength testing was then performed on week 5. For the bench press, week 1 was 3 sets of 8 at 70%, week 2 was 4 sets of 6 at 75%, week 3 was 4 sets of 5 at 80%, week 4 was 4 sets of 5 at 82%, week 5 was 4 sets of 5 at 85%, week 6 was the test. For the bench press, 3 sets of 8 repetitions at 70% 1RM were performed during week 1, 4 sets of 6 repetitions at 75% 1RM were performed during week 2, 4 sets of 5 repetitions at 80% 1RM were performed during week 3, 4 sets of 5 repetitions at 82% 1RM were performed during week 4, and 4 sets of 5 repetitions at 85% 1RM were performed during week 5. Maximal strength testing was then performed on week 6.

Training Protocol

This study examined whether APRE was more effective at increasing upper and lower body strength compared to LP. To our knowledge, no study has been done comparing APRE to LP among football players at a major division I college football program. There was no attempt to match volume and intensity and intensity of training between the 2 protocols as the volume and intensity of the APRE were set each day and weekly by the individual's performance. Both groups were a part of the same program and underwent the same demands related to off-season conditioning and sports-specific drills. In addition, athletes in both groups performed very similar resistance training program and exercises, both performing a heavy barbell bench press at >85% of 1RM 1 session per week, a heavy dumb bell bench press 1 session per week with 3 sets of 6 repetitions, and the 225-lb multiple repetition bench press 1 session per week. For the lower body, both groups performed squat exercises 1 session per week, front squat exercises 1 session per week, step-ups 1 session per week, lunges 1 session per week, glute-hamstring raises 1 session per week, and Romanian deadlifts 1 session per week. The LP group increased intensity from 70 to 85% of 1RM over the course of the cycle, whereas the APRE group performed the APRE 6RM protocol with the appropriate daily and weekly adjustments to their training resistance.

Testing

Subjects participated in their normal strength and conditioning program for the off-season. There was no pretesting or baseline measures taken before the initiation of the APRE and LP programs during the preseason because this was not standard practice of the football program at the time. Rather, posttraining (LP or APRE) strength values obtained at the end of the preseason training cycle (June–July) were compared to strength values obtained at the conclusion of the previous off-season training cycle (January–May).

Bench Press

Maximal bench press was an estimated 1RM based on 5 or fewer repetitions to failure. The 225 bench press repetitions test was done by determining the number of repetitions that 225 lb could be successfully completed, a protocol commonly used by the National Football League scouts to determine strength. For both measures of bench press, the athletes were expected to start the lift from full arm extension, touch the chest with the bar, and then return the bar to full arm extension for the repetition to count. In addition, it was expected that the glutes remain in contact with the bench during the entire repetition. Repetitions that did not meet these 2 qualifications did not count in the final score.

Squat

The Squat maximum was an estimated 1RM based on 5 or fewer repetitions to failure. The Squat depth was determined by descending to the point of the hip joint being even with the knee joint and returning to a standing position.

Statistical Analyses

Change scores for bench press and squat strength were calculated by subtracting the off-season baseline value from the preseason posttest value, and the change score was used as the dependent variable in the analysis. Independent samples *t*-tests were used to determine differences in baseline strength before training. *T*-tests were also used to determine demographic differences between groups. One-way analysis of variance (ANOVA) was used to determine differences in the improvements in bench press, squat, and the bench press repetition test between groups using SPSS V. 15 (Chicago, IL, USA). When statistically significant differences existed in baseline strength values, one-way analysis of covariance (ANCOVA) was employed, using the baseline value as the covariate and change score as the dependent variable. Statistical significance was accepted at $p \leq 0.05$.

Results

All data are expressed as means ± *SD*. The subject's characteristics including age, weight, height, and training history are

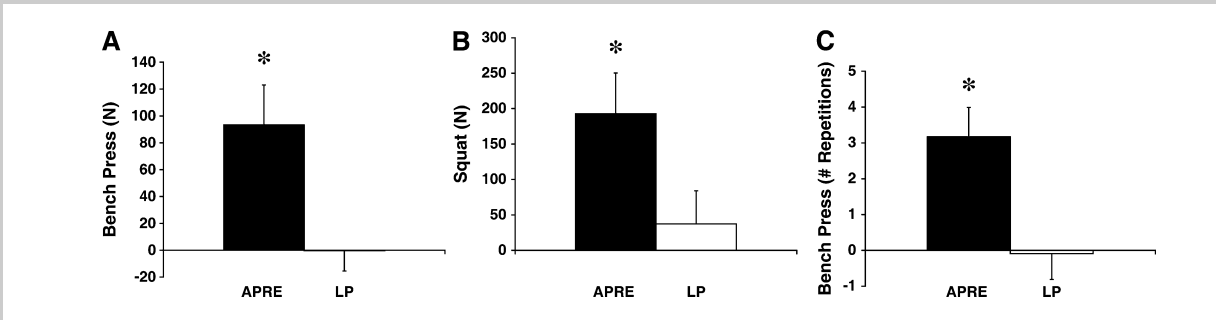

Figure 1. Change in A) bench press, B) squat, and C) repeated bench press from off-season to preseason for autoregulating progressive resistance exercise (APRE) and linear periodization (LP) groups. All data are presented as mean ± *SEM*. *Significant differences between APRE and LP at the $p \leq 0.05$ level.

listed in Table 1. There were no significant differences between groups for any of the subjects' characteristics (all $p > 0.05$).

There were differences in bench press strength (APRE: 1314 ± 122 N; LP: 1510 ± 188 N; $t = -2.9$ [df = 21]; $p < 0.01$) and repeated bench press strength (APRE: 9.9 ± 4.2; LP: 15.3 ± 5.9; $t = -2.6$ [df = 21], $p = 0.02$) between the APRE and LP groups at baseline. There was no difference between groups in squat strength (APRE: 1922 ± 357 N; LP: 2112 ± 230 N; $t = -1.5$ [df = 21], $p = 0.15$) at baseline.

Pre to posttraining changes in absolute bench press and squat strength were compared between the APRE and LP trained groups. Autoregulatory progressive resistance exercise demonstrated greater improvement in 1RM bench press strength (APRE: 93.4 ± 103 N vs. LP: −0.40 ± 49.6 N; ANCOVA: $F = 7.1$, $p = 0.02$) (Figure 1A) and estimated 1RM squat strength (APRE: 192.7 ± 199 N vs. LP: 37.2 ± 155 N; ANOVA: $F = 4.1$ $p = 0.05$) (Figure 1B) compared with the LP group over the 6-week training period.

The 225-lb bench press repetition to fatigue test was also measured to determine which program would have the greatest effect on improving strength endurance. Autoregulatory progressive resistance exercise demonstrated greater improvement in the number of repetitions performed at a weight of 225 lb compared with LP (APRE: 3.17 ± 2.86 vs. LP: −0.09 ± 2.40 repetitions; ANCOVA: $F = 6.8$; $p = 0.02$) (Figure 1C) over the 6-week training period, indicating that the APRE is also more effective than LP in increasing upper body strength endurance.

Discussion

This study was one of the first to compare the effects of APRE to LP and certainly the first to compare these training programs among NCAA division I football players in a major university program. Autoregulatory progressive resistance exercise was found to be more effective at improving bench press strength, squat strength, and upper body endurance in previously strength trained division I athletes over a 6-week period compared to LP. These findings provide strong evidence that autoregulation of training may be important to consider when choosing a program to elicit maximal gains in previously trained athletes.

Programs to systematically improve muscle strength were first described in the research literature by DeLorme (2) who developed a method known as progressive resistance exercise (PRE) to progressively overload the quadriceps to improve strength after femoral fractures. Knight et al. (4) modified the original DeLorme PRE program for rehabilitation of quadricep strength after knee surgery and developed a daily autoregulated progressive resistance exercise (or DAPRE). For DAPRE, the principles of PRE were used to determine the appropriate resistance for 2 sets of 5–7 repetitions. A third set was then used to determine the training load during the fourth set, and the fourth set was used to determine the training loads for the following week. This method demonstrated improvements in quadricep strength compared to traditional methods (3). Autoregulatory progressive resistance exercise used in the present study varies slightly from the DAPRE but the rationale is similar. Autoregulatory progressive resistance exercise has 2 working sets followed by sets adjusted according to individual daily variations in strength and performance. Like PRE or DAPRE, the goal of APRE is to work toward a repetition maximum. The difference between APRE and other protocols and the difference within APRE protocols itself is that they are designed for different training needs. There is an APRE 3 (3 repetitions) for strength and power, an APRE 6 for strength and hypertrophy, and an APRE 10 for hypertrophy. DeLorme's PRE only had the original 10RM protocol (2), and the DAPRE evolved to a 6RM protocol (5). The present study focused primarily on APRE 6 protocol for strength and hypertrophy, because these are the favorable adaptations wanted in a collegiate football player.

Although APRE has not been compared to LP previously in the literature, Stone and Herrick (13) compared progressive overload training (of which APRE is one type) to LP. The researchers reported that there were no significant differences in strength between the progressive overload and LP groups in untrained women at the conclusion of the

15 week study; however, the LP group continued to gain strength, whereas the progressive overload group appeared to reach a plateau in their strength gains. These findings led the researchers to theorize that LP might be a better method to use in a yearly plan. However, the strength improvements observed during short term APRE training (6 weeks) in the present study conflicts with these findings from Stone and Herrick (13). The discrepancy may have been because of the benefits of the autoregulation of PRE or using this method on highly trained vs. untrained individuals.

Flexible non-LP is a similar type of programming as APRE, and it has proven to be a successful approach among collegiate athletes (6). However, in flexible non-LP, the practioner makes daily choices about the athlete's status and workout based on the demands that will be placed on the athlete for that given day. For example, a day in which a training session occurred after a 3-hour practice with heavy loads of conditioning would require a different strength training workout than a prepractice strength training session (6). Flexible non-LP allows adaptation by the coach or practitioner based on demands of stressors such as increased conditioning or periods of increased competition; APRE, on the other hand, allows adaptation of a particular workout by the individual athlete based on their abilities for that particular day.

The mechanisms behind the effectiveness of APRE are not known. However, it could be that the greater strength gains resulting from APRE were because of a constant adjustment of repetitions. It has been postulated by experts in the field that when a constant training protocol is used over a period of weeks to months that the body begins to adapt leading to reduced effectiveness (8). Autoregulatory progressive resistance exercise training prevents this adaptation because repetitions used are governed by the athletes' ability on that given day and will change from set to set and week to week. Theoretically, the athlete could continue a typical 6-week training cycle and never repeat the same repetition and intensity scheme throughout the entire cycle. This also fits with the theoretical basis of undulating periodization (8) as workouts use a repetition maximum that will not only vary from week to week but within the workout. Undulating periodization has shown effectiveness at improving strength. For example, Rhea et al. (8) found that by alternating the RM trained in each workout, strength was improved to a greater degree than by changing the RM every 4 weeks. Rhea et al. also reported that undulating periodization was more effective at improving endurance (9). The variation in repetitions from set to set and week to week allows APRE training to work like undulating periodization, which could explain its effectiveness.

There were several limitations to this study: First, the study was not set up as a traditional prepost design and therefore has a methodological limitation. However, the novel aspect of this study is the application of these training protocols on strength trained NCAA division I college football players at a major Big-12 program. Because the football program was so structured in its off-season and preseason agendas, obtaining baseline measures of strength before the implementation of APRE and LP was not possible. We believe the findings, however, are intriguing enough to warrant future evaluations of the benefits of APRE in competitive athletes. Second, the generalizability of these findings is limited to strength trained competitive athletes; however, the benefits of APRE would likely be most applicable to this trained population. Finally, there was no way to completely equalize the volume and intensity of training between APRE and LP, so it is possible that any differences could have contributed to differences in strength observed in the study.

This is the first study to examine the effectiveness of APRE compared to LP in trained division I college football players. The data from our study suggest that the APRE protocol elicits greater strength gains than linear periodized programs in terms of the bench press strength, squat strength, and bench press endurance. It is reasonable to conclude from these data that additional strength performance (other than bench press and squat) would likely benefit from this type of training, although future studies are warranted.

Practical Applications

Because of the short duration of typical off-season and preseason programs, it is critical for strength coaches to achieve maximal gains in strength in as short a term as possible. It has been theorized that progressive overload training such as the PRE and APRE might be an excellent tool for shorter training periods (4) typical of preseason or off-season training cycles. We recommend using the APRE method of training in highly trained athletes with greater than 2 years of previous training during short (6-week) training cycles because it appears to be more effective than LP in improving strength and strength-endurance gains. For the strength coach or practitioner who must demonstrate the greatest strength gains during short-duration training cycles, APRE training is effective.

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