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Analysis of Acute Explosive Training Modalities to Improve Lower-Body Power in Baseball Players

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Abstract. Dodd, D.J., and B.A. Alvar. Analysis of acute explosive training modalities to improve lower-body power in baseball players. *J. Strength Cond. Res. 21(4):1177–1182. 2007.*—Complex training is the simultaneous combination of heavy resistance training and plyometrics. The objective of this study was to test the effects of complex training vs. heavy resistance or plyometric interventions alone on various power-specific performance measures. Forty-five male division II junior college baseball players participated in 3 separate 4-week resistance training interventions. Subjects were randomly assigned to one of three groups. In a counterbalanced rotation design, each group participated in complex, heavy resistance, and plyometric training interventions. Each individual was tested in 20-yd (SP20), 40-yd (SP40), 60-yd (SP60), vertical jump, standing broad jump, and T-agility measures pre– and post–4-week training interventions. There was no statistical significant difference ($p = 0.11$) between groups across all performance measures. Review of each distinct training intervention revealed greater percent improvements in SP20 (0.55; −0.49; −0.12), SP40 (0.26; −0.72; −1.33), SP60 (0.27; 0.15; −0.27), standing broad jump (1.80; 0.67; 1.1), and T-agility (2.33; 1.23; −0.04) with complex training interventions than with the heavy resistance or plyometric training interventions, respectively. Plyometric-only training showed greater percent changes in vertical jump (1.90) than with complex (0.97) or heavy resistance training (0.36). The present results indicate that complex training can provide strength and conditioning professionals equal, if not slightly greater, improvements in muscular power than traditional heavy resistance– and plyometric-only interventions in moderately trained athletes. Complex training can be another valuable method for short-term power and speed improvements in athletes in isolation or in conjunction with other power development methods.

Key Words. explosiveness, plyometrics, strength

Introduction

The development of power for athletic performance has been studied and evaluated comprehensively, with either heavy resistance training or high-velocity/plyometrics training as the most common modalities. Previous research has acknowledged that both forms of training, independently, are effective approaches, increasing muscular power. However, there appears to be a limited, yet growing, debate in the literature on whether combining heavy resistance and high-velocity/plyometric training, where both training methods are entwined each session, will enhance muscular power to a higher degree than previously researched heavy resistance or high-velocity–only training modalities. This mode of training, known as "complex" training, entails various sets of groups or complexes of exercises performed in a manner in which a set of heavy load resistance exercises is followed by sets of high-velocity/plyometric exercises with little or no body weight resistance. The main tenet of this style of training is designed to increase the ability to produce power quickly (13, 17).

Reaching maximal muscular power is achieved at an optimal combination of muscle contraction force and velocity (26). Therefore, when an optimal balance of force and velocity is met without one intervening over another, the question remains: will power output be at its highest? (24). It is thought that heavy resistance training for power increases maximum speed and power movements through numerous physiological mechanisms. By training at a maximal, or near maximal, level of force output, there is a greater potential increase in type II muscle fiber recruitment, motor unit firing, and synchronicity, as well as possible cross sectional fiber area development (1).

High-velocity/plyometric training drills are designed to promote the ability to use maximal force as quickly as possible by means of training muscles to rapidly switch from eccentric to concentric movements and shortening the delay time (amortization phase) between these movements, thus allowing more work to be done in less time (1, 23, 25, 34). These movements have the potential to create increases in rate of force development and efficiency of the stretch-shortening cycle, as well as increase the speed of muscular contraction during movements against moderate-to-minimal resistances. This is essential to improving the velocity component of power output (21).

The complex training technique, which consists of performing a heavy resistance exercise immediately prior to a high-velocity/plyometric movement with a lighter resistance within each set, has been shown to provide significant increases in peak power levels (4, 17, 19). Through complex training, the neurological and muscular systems at both ends of the force-velocity continuum are theoretically trained at much higher levels than traditional modalities. The heavy resistance component focuses on training the muscles' ability to produce high levels of force, whereas the high-velocity component trains the muscles' ability to exert force as quickly as possible through rapid eccentric-concentric transitional movements (7, 30).

By preceding the high-velocity movements with heavy resistance exercises, the neuromuscular system is theoretically "super stimulated" (10). The neuromuscular prepares to lift another set of heavy resistance and instead moves a lighter resistance at the previous force output, but with the ability to produce a much higher contraction velocity. In doing so, both force and velocity components of power output are being developed (5, 7, 17). The use of complex training as a method of increasing power, vs. traditional heavy resistance or plyometric training, is still under constant review and so far inconclusive as a definitive method. However, recent research has shown en-

Table 1. Counterbalanced rotation of training interventions.

Group	Weeks 1–4	Week 5	Weeks 6–9	Week 10	Weeks 11–14	Week 15
1	Complex	Rest	Heavy resistance	Rest	High velocity	Rest
2	Heavy resistance		High velocity		Complex	
3	High velocity		Complex		Heavy resistance	

couraging results toward its inclusion as a power development training approach (4, 5, 17, 19). Chu (10) suggests that power development can be up to 3 times higher by complex training methods than conventional training methods. The purpose of this study was to add to the growing literature on complex training and attempt to show the benefits of, and the effectiveness associated with, complex training in comparison to traditional heavy resistance training or plyometric training for developing lower-body muscular power.

Methods

Experimental Approach to the Problem

Extensive research has concluded that advantages are present with heavy resistance and high-velocity training interventions for improvements in power; however, the level of difference in muscular power output improvement between these modalities as well as complex training has yet to be defined. This study will provide a comparison between the 3 training modalities to identify which provides the overall greatest improvement in lower-body power development.

Complex training is still in its infancy, and absolute training guidelines for complex training have not been defined; however, current literature suggests that training variables include the following: biomechanically similar exercises for each pair of heavy resistance and high-velocity movements; training loads for each complex set with a >80% 1 repetition maximum (1RM) load for the heavy resistance set, followed by <30% 1RM for the high-velocity set; 1–3 sessions per week for no more than 6 weeks; rest periods between complex pairs of >10 seconds and between complex sets of 3–4 minutes; and recovery between complex training sessions of 48–96 hours (14, 15, 17, 30, 31). As a training modality, many questions still pertain to the most beneficial resistance training intensity, volume, and rest between complexes and between sets of complexes, as well as what specific exercises are best used to provide the greatest benefits for power development. By complying with previously suggested training protocols for power improvements for each training intervention, this study will determine how effective these protocols are at improving athletic performance.

Subjects

Forty-five men (18–23 years) participated in the study investigation over a period of 15 weeks. All subjects were division II junior college baseball players, specifically infielders, outfielders, and catchers, and had at least 1 year of previous resistance training experience. The research was conducted during the off-season. Regular cardiovascular conditioning that accompanied the participants' normal preseason program was not changed as a result of the study. All players participated in identical baseball-specific skill and cardiovascular conditioning routines outside the study 3 days per week for an average of 45 minutes per session.

All subjects had undergone a 4-week active rest period prior to commencement of the study. Subjects were required to attend at least 70% of all training sessions during each intervention to be included in the study. Any training outside the study was deemed in conflict with the training interventions and resulted in the removal of that subject from the study. Approval was provided by the Human Subjects Institutional Review Board of Arizona State University.

Procedures

Each subject participated in pre- and posttests to determine ability in 20-, 40-, and 60-yd sprinting (SP20, SP40, and SP60), vertical jump, standing broad jump, and T-agility performance measures. Testing was in accordance with guidelines set by the National Strength and Conditioning Association (3). After completion of the pretesting, the subjects were randomly assigned to one of three groups for three 4-week training interventions. This is in accordance with suggestions made by Foran (18) that the necessary periods of explosive training for off-season baseball players training be 3–4 weeks. Table 1 demonstrates the counterbalanced rotational design for each group. Upon completion of each 4-week intervention, posttest measures and a 1-week active rest were given prior to the groups rotating to the next 4-week training program.

A 10- to 15-minute dynamic warm-up preceded each training and testing session and included skill-specific movements. Each participant was allowed a maximum of 3 trials on each measure to record the best result. The order of testing included a 60-yd sprint (split times recorded at 20 and 40 yd), T-agility, vertical jump, and standing broad jump. Testing for sprint and agility measures was recorded with hand-held stopwatches. Testing for vertical jump included the use of a commercial Vertec jump and reach device, and the standing broad jump was recorded with a firmly held grounded measuring tape. Test-retest reliability of measures was maintained through the use of identical testers for each measure on all occasions.

All groups were required to attend 2 sessions per week for a total of 7 sessions per intervention. Absence of more than 2 of these sessions resulted in exclusion from the study. Training requirements for the heavy resistance and plyometric interventions consisted of 3 exercises at 4 sets of 6 repetitions with progressive intensity set at 80–90% 1RM and 0–30% 1RM, respectively. These protocols were modified for the complex training group to equate for total volume and included 3 heavy resistance exercises at 2 sets of 6 repetitions and 3 plyometric exercises at 2 sets of 6 repetitions.

The load was the only variable that changed throughout the intervention. Initial load determination began with the 6RM achieved on the first lifting day of each training cycle. Load increases were adjusted with the 2-for-2 rule, which suggests that if athletes can perform 2 or more repetitions over their assigned repetition goal in the last set in 2 consecutive workouts for the given exercise, then an increase in weight should be added for that exercise during the next training session (3). The

TABLE 2. Results of 3 training interventions on speed and power measures.*

	20-yd (seconds)	40-yd (seconds)	60-yd (seconds)	Vertical jump (inches)	Standard broad jump (inches)	T-agility (seconds)
Complex (n = 32)						
Pre	2.902	5.075	7.209	25.813	98.258	10.089
SD	0.099	0.196	0.281	3.154	7.107	0.429
Post	2.886	5.062	7.189	26.065	100.031	9.854
SD	0.096	0.183	0.263	3.130	6.827	0.329
% change	0.551†	0.264†	0.273†	0.976	1.805†	2.331†
ES†	−0.162	−0.068	−0.070	0.080	0.249	−0.548
Heavy resistance (n = 31)						
Pre	2.881	5.063	7.187	25.980	99.929	9.933
SD	0.132	0.196	0.302	3.243	8.050	0.418
Post	2.895	5.099	7.176	26.074	100.597	9.810
SD	0.103	0.158	0.261	3.164	7.470	0.385
% change	−0.493	−0.721	0.157	0.362	0.669	1.236
ES	0.108	0.186	−0.037	0.029	0.083	−0.294
Plyometrics (n = 28)						
Pre	2.899	5.048	7.158	26.196	99.94	9.849
SD	0.111	0.181	0.270	2.859	7.387	0.436
Post	2.895	5.116	7.178	26.696	101.04	9.853
SD	0.109	0.177	0.296	2.723	6.134	0.400
% change	0.124	−1.337	−0.274	1.909*	1.101	−0.042
ES	−0.032	0.372	0.073	0.175	0.149	0.009

* ES = effect size.
† Denotes greatest percent change.

heavy resistance exercises consisted of the squat, lunge, and split squat exercises, whereas the plyometric exercises consisted of box jumps, depth jumps, and split squat jumps. Rest between each complex pair was <10 seconds, and rest between each complex set was 3–4 minutes. All groups were told to refrain from any other lower-body resistance training.

Statistical Analyses

To determine the effect of the interventions on performance measures, a 3 × 2 × 3 repeated-measures analysis of variance was used. Significance was accepted at an alpha level of $p \leq 0.05$ for all comparisons. Cohen's d and standardized mean difference were calculated for the magnitude of treatment effect for all comparisons. Cohen's d and standardized mean (11):

Pre − Post Effect Size:

$$\text{Posttest Mean} - \text{Pretest Mean} \div \text{Pretest } SD$$

Analysis of the counterbalanced order of training for differences between rotation cycles was performed by a 3 × 2 repeated-measures analysis of variance. Significance was set at $p \leq 0.05$.

RESULTS

Table 2 shows the cumulative mean data for the 3 training interventions. The results include the pre-post mean results, percent changes, and treatment effect sizes for each performance measure as a result of each intervention.

Positive changes were observed across all performance measures when completing the complex training intervention. Improvements were seen in 20-yd (0.55%), 40-yd (0.26%), 60-yd (0.27%), vertical jump (0.98%), standing broad jump (1.8%), and T-agility (2.33%), whereas the heavy resistance intervention had positive changes in 60-yd (0.15%), vertical jump (0.36%), standing broad jump (0.67%), and T-agility only (1.24%), and the high-velocity training interventions showed only mean improvements in vertical jump (1.91%) and standing broad jump (1.1%).

There was no statistical significance ($p \leq 0.11$) between groups across all performance measures. All participants, when undergoing the complex training intervention, observed mean positive changes across all performance measures. For the heavy resistance intervention, participants observed mean positive changes in 60-yd, vertical jump, standing broad jump, and T-agility. In contrast, the plyometric interventions resulted in mean positive changes in the 20-yd sprint, vertical jump, and standing broad jump only. Figure 1 shows a graphic representation of the mean changes as a result of each training intervention.

Analysis for the training order effect between counterbalanced cycles was nonsignificant ($p > 0.05$), indicating that the results were not influenced by the position or rotational order each group was given.

DISCUSSION

The use of complex training within this study has shown that greater increases in lower-body speed and power are possible when compared with traditional heavy resistance training and high-velocity methods. The corresponding results support the literature that improvements can be achieved with the recommended loading parameters (6, 12, 20). The complex training methodology used >80% 1RM for the heavy resistance lift and <30% 1RM for the high-velocity movement, as recommended by previous research (28, 30, 35). These results also appear to be comparable to the physiological response expected from the varying training modalities. Although the exact physiological mechanism that promotes muscular power with complex training is still theoretical, the evidence shown by small improvements in the performance measures gives merit to possible neurological and muscular adap-

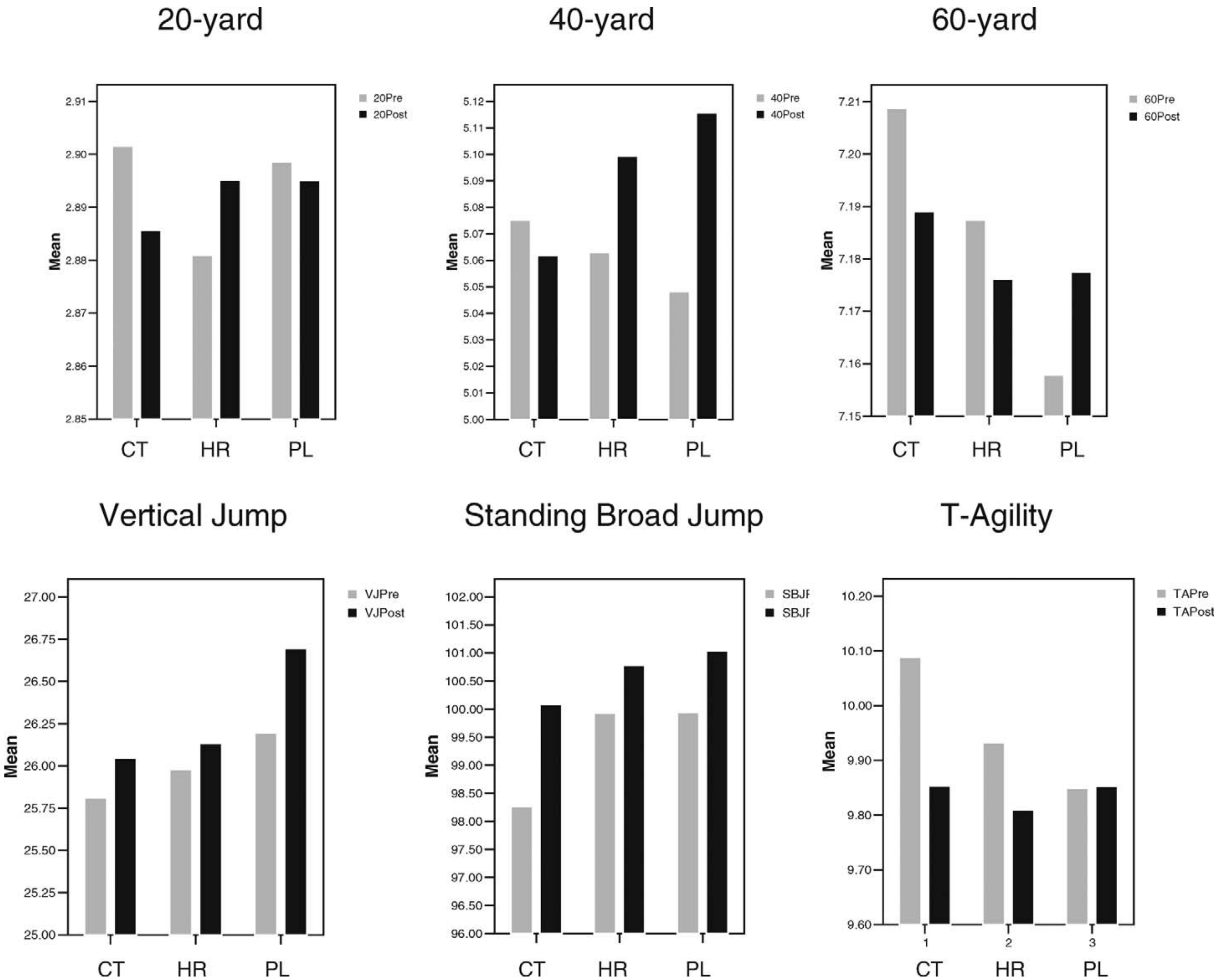

Figure 1. Mean comparisons for 20-, 40-, and 60-yd sprints, vertical jumps, standing broad jump, and T-agility. CT = complex training; HR = heavy resistance; PL = plyometrics.

tations that may occur through combining heavy and light resistance training in single episodes (10, 15, 26, 32).

The high-velocity/plyometric training interventions resulted in mean improvements in the 20-yd vertical jump and standing broad jump, which are highly explosive movements, and suggest that the high-velocity movements created some form of explosive training adaptation, more specifically, the stretch shortening cycle and rate of force production. In contrast, the heavy resistance interventions had mean improvements in the 60-yd standing broad jump, vertical jump, and T-agility, performances that require both speed and exertion of large forces over time. We could also surmise that physiological adaptations, specifically both type IIA and IIB fiber development, muscle cross sectional area increases, and, possibly, motor unit recruitment and firing patterns occurred from this heavy resistance modality. With evidence of improvement across all performance measures with the complex training intervention, these explosive and large force muscular adaptations could also be assumed to have collectively resulted in the greater performance increases.

Complex training protocols have typically used biomechanically similar exercises per complex set, such as the use of a heavy squat with countermovement vertical jumps. Recently, Baker and Newton (7) reported acute increases in leg power output with alternate agonist-antagonist exercises within the complex set. Although biomechanically similar exercises within the complex set have been shown to provide improvements in power output, this new protocol may be another methodology worth further exploration. Choices in the exercises used can also have an influential factor physiologically.

The possible transference from type IIB to type IIA fibers could have occurred through a varied choice of resistance training lifts. Power-lifting–style movements, such as squats and deadlifts, may have resulted in less than explosive fiber utilization and adaptation, as evident in the research (21, 29), whereas the inclusion of Olympic-style movements, such as cleans and snatches, may have induced type IIA to IIB changes and the subsequent transference to performance (8, 27, 29, 31). The technique difficulty in the latter style of lifts typically requires a lengthy familiarization period, which was not available and may have compromised possible desired adaptations.

The statistical magnitude of effect that each training model had on performance was described by Cohen's d and standardized mean (11). As evident in Table 2, these calculations showed trivial treatment effects across all performance measures, except for the standing broad jump (0.26) with complex training, the T-agility with complex training (0.55), and the heavy resistance training (0.29), for which moderate effect sizes were reported. These results indicate that no training modality was dominant in increasing performance over another; however, it must be noted that complex training intervention was the only modality that achieved positive and higher changes in mean and treatment effect sizes across all performance measures when compared with the accompanying training modalities.

Recommendations for rest between complex pairs have been discussed in the literature. Suggestions have included no rest to as high as 5 minutes of rest between the complex pairs (10). Obviously, inadequate rest periods between sets can produce different interpretations of results and effectiveness of the complex training approach. Ebben and Watts (15) suggest that until more research is conducted, the majority opinion about rest between exercises in a complex pair is 0–30 seconds and, about rest between sets of a complex pair, 2–10 minutes. Fees (16) suggests that the complexes should be done after full recovery of the neural and phosphagen systems. The current study utilized rest periods of <10 seconds between lifts in the complex pair and 2–3 minutes of rest between sets for all training groups.

Detection of whether this rest period was influential on the results is difficult, and in lieu of the findings from this study, together with the conflicting research on this matter, further analysis of rest periods, particularly <10 seconds and 3–4 minutes, between sets of a complex pair needs more investigation, especially as complex training is proving to be an effective method of developing power. A greater rest between complex pairs may have allowed adequate replenishment of the phosphagen system; however, the possibility of neural overload associated with the physiological theory of complex training may not have occurred with greater rest and is something still to be determined through continued research.

Because of the intensity of the training intervention, adequate unloading periods prior to peak competition or testing are a necessity to allow enough recovery and possibly optimize the adaptations that are associated with complex training (10). There is no consensus in the research about the recommended rest periods between complex training and a performance, whether it is competition or testing. However, it has been suggested that at least 96 hours of rest be given to allow adequate recovery for the next complex training session (15). On the basis of these findings, the period between the final training session and the testing day during each intervention of this study was 96 hours and typically involved all subjects having complete rest, free from outside training influences. A greater unloading period, at least 1 week and up to 4 weeks, may have provided greater changes in performance measures, particularly considering that the overall length of training was substantial (15 weeks).

Chu (9) suggests that complex training is highly valuable prior to peaking for competition where an athlete can experience small but maximal gains in a short period and is best used as an excellent short-term method (4–8 weeks) for improving power. Because the study length was compromised by the length of a college semester, each intervention had to be held to a maximum of 4 weeks. A longer training period, possibly a 6-week program, may have allowed greater physiological adaptations to occur and the full effect of each training design to become evident. In attempting to equate for volume and deter the possibilities of too many variables influencing the results, the program designs and choice of exercises were comparable for each intervention. A periodized program may have produced a different outcome. Because of the intensity of the program requirements, it is difficult to maintain improvements for extended time periods and a periodized cycle and, as with any resistance training program, may promote continual adaptations (9). Rhea (33) suggests the use of a weekly undulating cycle in which each training modality is included. The use of heavy resistance, high-velocity, and complex training within weekly sessions may provide substantial adaptations and cause improvements to occur, achieving maximal response from each training modality.

Further research into complex training should also focus on the selection of exercises, the amount of rest, and possibly the amount of volume and intensity to elicit the greatest gains in power. It is evident that complex training can produce equal, if not greater, results than traditional methods and should be addressed to identify the magnitude of benefit that can be achieved.

Practical Applications

This study has shown positive results toward the use of complex training in improving power and speed and adds to the growing literature on its effectiveness as a component of resistance training methodology. The actual training specifics to perform both heavy resistance training and high-velocity training appear to need further investigation, as many studies have shown conflicting results, and yet the overall conclusion, evident by this study and others before it, is that complex training has a place as a training modality to be used solely or in conjunction with traditional methods for power development.

The training parameters used in this study for complex training were scripted from traditional recommendations offered in the literature; however, greater insight through manipulation of these training variables needs to occur before more definitive answers can be made on the complex training ideology. This being the case, athletes can find solace in using these traditional training parameters for improvements in power output.

For strength and conditioning coaches, the benefits associated with complex training may be highly valuable to teams when limited time in the weight room occurs. Maximizing the benefits of any training program with limited time available is a focus for most strength coaches in high school, college, and professional environments. Complex training uses less time than typical heavy resistance or high-velocity training programs and yet provides equal, if not greater, training results. For strength coaches, particularly baseball coaches, complex training provides a strong option for maximizing athletic power in limited available training time for many athletic populations. With the demanding practice and game schedules imposed on baseball players, this form of training allows coaches to maximize explosive training potential and avoid overtraining, both physiologically and psychologically.

Complex training also provides an option to strength coaches when preparing athletes to peak for competition. From the evidence of this study and the available literature, adaptations that occur through the use of complex training typically respond within 4–6 weeks, giving coaches an approximate training timeline to maximize power output prior to an event.

The complex training trends that were evident in this study and have been shown in previous research indicate the value of this training method in improving athletic power. To ensure significant transference to athletic movements, the complex training protocols need to be sport- and skill-specific, and the athlete must simulate the movements with maximal effort.

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