Complex Training Reexamined: Review and Recommendations to Improve Strength and Power

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ABSTRACT

MANY SPORTS REQUIRE ATHLETES TO POSSESS BOTH STRENGTH AND POWER FOR OPTIMAL PERFORMANCE. HOWEVER, BECAUSE OF TIME CONSTRAINTS, IT IS OFTEN DIFFICULT FOR ATHLETES TO DEDICATE THE TIME NEEDED FOR BOTH THE TRAINING AND RECOVERY TO PROMOTE THE DEVELOPMENT OF STRENGTH AND POWER. COMPLEX TRAINING (CT) IS A METHOD USED TO ENHANCE BOTH STRENGTH AND POWER IN THE SAME SESSION, THUS PROVIDING AN EFFICIENT TRAINING METHOD. ALTHOUGH FURTHER RESEARCH ON CT IS NEEDED, THE PURPOSE OF THIS ARTICLE IS TO PROVIDE THE READER WITH A REVIEW AND RECOMMENDATIONS ON HOW BEST TO IMPLEMENT CT.

INTRODUCTION

Complex training (CT) is a training method designed to improve both strength and power in the same training session. After visiting the Soviet Union in 1986, Fleck and Kontor (20) wrote the first peer-reviewed article on CT. As described by Fleck and Kontor (20), the procedure of CT is performed by the use of a heavy resistant exercise followed by a lighter exercise of a similar biomechanical movement pattern. The heavy resistant exercise, also referred to as the conditioning activity (4), can be in the form of a slow speed/high load exercise (i.e., 5 repetition maximum [5RM] back squat) or a high speed/moderate load exercise (i.e., power clean) (16). Baker (2) suggests that as long as the lighter exercise's resistance is less than the heavier exercise's, subsequent power performance may be augmented for the lighter exercise (Table 1).

The pairing of 2 biomechanically similar exercises (i.e., back squat and counter movement vertical jumps) is termed a "complex pair," whereas performing 3 similar movement patterns in a complex is known as a "complex triad" (16). Complex training theoretically elicits properties of the neurological, muscular, and/or psychomotor systems to allow the individual to produce more power on the subsequent lighter set (2,18). More specifically, CT may stimulate motor unit excitability (thus increasing motor unit recruitment, synchronization, and central input to the motor unit), may increase phosphorylation of the myosin light chain, which allows the myofilaments to become more sensitive to calcium, and may also decrease presynaptic inhibition (21), which theoretically will allow subsequent power output to be augmented. This response is referred to as postactivation potentiation (PAP). To allow the reader to understand fully the research on CT and/or the research used to explain CT, the authors will review the theories and properties of PAP, the research on acute and nonacute effects of CT, the hormonal response to CT, and agonist-antagonist paired sets.

POSTACTIVATION POTENTIATION

Although the exact acute physiological mechanisms behind CT are not completely understood, CT's ability to increase the power of the lighter exercises is said to be brought about from PAP. As defined by Robbins (33), "PAP refers to the phenomenon by which acute muscle force output is enhanced as a result of contractile history and is the premise on which "complex training" is based" (p. 453). PAP is said to occur in individuals with greater maximal strength (2,9,14,38). For example,

KEY WORDS:
complex training; postactivation potentiation; strength; power

Table 1
Example of complex pairs for complex training

Conditioning activity (heavy exercise)	Explosive movement (light exercise)
Olympic-style lifts (power clean, hang clean, clean and jerk, push press, power shrug, snatch)	Jump and reach (low)
	Squat jump (low)
	Jump to box (low)
	Lateral box jump (medium)
	Double leg tucks (medium)
	Depth jumps (high)
	Depth jumps to a second box (high)
	Pike jump (high)
Bilateral lower body (back squat, front squat, leg press)	Jump and reach (low)
	Squat jump (low)
	Jump to box (low)
	Lateral box jump (medium)
	Double leg tucks (medium)
	Depth jumps (high)
	Depth jumps to a second box (high)
	Pike jump (high)
Unilateral lower body (lunge, split squat, step up)	Single leg push-off (low)
	Alternating leg push-off (low)
	Lateral push-off (low)
	Split squat jump (medium)
	Single-arm alternate leg bound (medium)
	Side-to-side push-off (medium)
	Cycled split squat jump (high)
	Single leg vertical jump (high)
	Single-leg tuck jump (high)
Horizontal pressing (barbell bench press, dumbbell bench press, weighted push-ups)	Medicine ball chest pass (low)
	Kneeling power ball pass (low[a])
	Depth push-up (medium)
	Plyometric push-up (medium[a])
	Clap push-up (medium[a])
	Behind the back clap push-up (high[a])
	Medicine ball power drops (high)
	Explosive bench press throws on Smith machine (high[a])

The intensity of the plyometric exercises, listed in parenthesis after the exercise, is categorized according to NSCA's classification of plyometric exercises (32). The exercises are either classified as low, medium, or high. NSCA = National Strength and Conditioning Association.

[a]An exercise indicates that the NSCA's book does not label that particular exercise.

Baker (2) studied 16 rugby players with at least 1 year of resistance training experience. The 2 participants with the greatest amount strength had the highest power output on the "light" exercise (explosive bench press throws on a "Smith machine") by 6.2% after the "heavy" exercise (bench pressing at 65% of their 1 repetition maximum [1RM]) compared with the 2 individuals with the lowest amount of strength whose power output only increased 0.8%. This is in agreement with research from Chiu et al. (9) who compared athletes versus recreationally trained individuals, as well as Young et al. (38) and Duthie et al. (14) who noted the greatest PAP enhancement among the strongest participants in their respective studies. However, research by Jensen and Ebben (23) on CT showed no difference in response to performance for the counter movement vertical jump after 5RM heavy squatting between the strongest individuals (6 men and 2 women) and the weakest individuals (6 women and 2 men) in their study using 21 division I anaerobic athletes. Similarly, Mathews et al. (29) showed no variation in performance between the stronger and weaker individuals in response to CT; however, in this study, using 12 male basketball players, the authors stated that none of the subjects were "strong." Therefore, it has been recommended that athletes should only engage in CT after they have obtained certain levels of strength (18), such as the National Strength and Conditioning Association's (NSCA) (32) prerequisites for implementing plyometric training. Refer to Table 2 for additional scientific and evidence-based considerations and recommendations when implementing CT.

Because it seems that PAP is observed most in stronger individuals, Batista et al. (4) wanted to determine the amount of PAP displayed in power track and field athletes, bodybuilders, and physically active individuals with no history of resistance training. The purpose was to determine the degree of PAP among strong individuals with different training methods. The authors designed the study so that the power athletes and bodybuilders had the same level of dynamic strength (leg press) and the bodybuilders and physically active individuals had similar power (counter movement vertical jumps). The authors concluded that all 3 groups had similar responses to PAP despite the variation in training and degree of dynamic strength and power between the groups. However, it is important to note that in this study, none of the groups had observable affects from the methods involving maximal voluntary isometric contractions to induce PAP. Therefore, future research of a similar design should be performed where PAP is induced in at least some of the groups. It should be noted that range of motion may have an effect on eliciting PAP as shown in a study by Esformes and Bampouras (19). According to the authors (19), both quarter squats and parallel squats elicited PAP and significantly improved the measured variables (jump height, peak power, impulse, and flight time) when using their respected 3RM (3 repetition maximum); however, the parallel squats significantly improved all the measured variables to a greater extent than the quarter squats.

ACUTE STUDIES ON COMPLEX TRAINING

Several acute studies have been performed on the use of CT and its ability to elicit subsequent power on various explosive activities such as counter movement jumps (11,23,24), depth jumps (24), medicine ball power drop exercises (17), explosive bench press-style throws on guided machines (2,8), basketball push passes (29), hockey sprints (28), and land sprints (10). Some of these acute studies have shown CT to be beneficial (2,8,28,29), whereas other studies do not show CT to elicit greater power than non-CT interventions (10,11,16,23,24).

It should be noted that most of the studies that found no significant improvements in power from CT indicated that CT was not counterproductive (11,16,23,24); therefore, CT seems to be a viable method for combining strength and power in the same session thus creating a more efficient workout. However, minimal rest such as 10 and 15 seconds seems to decrease subsequent power (8,23) in acute studies. Therefore, one very important consideration when implementing CT is the intracomplex rest interval (ICRI), which is the time between the heavy resisted and the light resisted exercises (23). There has been a wide range in the research literature involving the ICRI, which has ranged from 10 seconds (23), to 5 minutes (17), all the way up to 20 minutes (24) and 24 minutes (8).

Comyns et al. (11) studied the effects of CT using an ICRI of 30 seconds, 2, 4, and 6 minutes for counter movement jumps after 5RM back squat for both men (n = 9) and women (n = 9). Although only the men displayed any improvement in jump performance while using the 4 minute ICRI, Comyns et al. (11) suggested that using a 4 minute ICRI is optimal for exploiting PAP for both men and women. In addition to this, the results indicated that using a 30-second or 6-minute ICRI decreases subsequent power to baseline readings. The authors also noted that the subjects responded differently to CT regarding their jump performance with certain ICRI; therefore, it is important to note the individualistic response when using CT, which is in agreement with other research (8,12,14,29). However, the authors (11) found no differences between genders regarding the optimal ICRI. Similar to the findings of Comyns et al. (11), Jensen and Ebben (23) suggest that gender does not affect the response to the ICRI in CT. Jensen and Ebben (23) studied 11 men and 10 women who were division I athletes in their response to counter movement vertical jump after 5RM squatting with an ICRI of 10 seconds, 1, 2, 3, and 4 minutes. Besides showing that gender does not affect the ICRI for CT, Jensen and Ebben showed that an ICRI of 1–4 minutes did not impair nor improve the counter movement vertical jump; however, an ICRI of 10 seconds did decrease performance for the counter movement vertical jump (23).

In a similar study, Jones and Lees (24) investigated how 8 trained male

Table 2
Recommendations for complex training

When implementing CT, strength coaches should consider such factors as the ICRI, training age, training history, degree of absolute strength, exercise selection, load, days of recovery, and individual response to CT. Exercises, such as the barbell bench press, that require the individual to slow the bar down should not be used for the light exercise because the athlete will have to decelerate the bar, thus limiting force development.
Although the literature varies, it seems that PAP appears to be the most pronounced in individuals with higher levels of strength; therefore, novice lifters should not engage in CT until after a base level of strength is obtained. Before implementing CT, the individuals should have been introduced to plyometrics to ensure proper form for long-term athletic development.
The NSCA (32) recommends the following guidelines before starting a plyometric program: (a) Lower-body strength—The athlete should be able to squat 1.5 times their body weight, (b) Upper-body strength—Larger athletes (>220 lbs) should be able to bench press their body weight. Smaller athletes (<220 lbs) should be able to bench press 1.5 times their body weight or perform 5 clap push-ups in a row, (c) Lower-body speed—The athlete should be able to perform 5 repetitions of the back squat with 60% of their body weight in 5 s or less, and (d) Upper-body speed—The athlete should be able to perform 5 repetitions of the bench press with 60% of their body weight in 5 s or less.
CT should be a part of a periodized program involving progression of exercise difficulty, as well as manipulation of the intensity and volume. It is often recommended that CT be implemented during a strength and power phase and/or power phase when the athlete is dedicating their training to strength and power and engaging in larger work to rest ratios. It should be noted that athletes might need repeated exposure to CT to gain any benefit.
Research has shown that individuals' PAP peaks at various times. However, the authors recognize that determining an athlete's PAP response is difficult to determine in the real world, especially if you consider the potential for different intensity and exercises to elicit different PAP responses. Coaches may want to avoid short ICRI such as 10–15 s, because recent research has shown this to be counterproductive in the acute setting. However, implementing shorter ICRI may be applicable for certain sports that require power endurance and/or if the coach is trying to increase training density.
It seems an ICRI of 1–12 minutes is more appropriate for peak PAP stimulation; and although an ICRI of 1–12 minutes may not augment subsequent performance, this time frame seems not to decrease performance when compared with baseline values. Finally, the exact optimal ICRI is impossible to prescribe because the research uses numerous protocols to try to induce PAP. The most prudent advice would be to base your decisions on the time allotted in the weight room, as well as the training goals and current research.
Exercise selection is of the utmost importance for complex pairs and complex triads. The exercises need to be biomechanically similar to one another, as well as the sport itself. For example, unilateral sports should use more single limb exercises.
The athlete needs adequate time to recover from CT sessions. Athletes should not engage in CT in an excessively fatigued state when trying to develop strength and power. The athlete should have a minimum of 48 hours to recover from CT, but should not exceed 96 hours of recovery for risk of detraining.
Although it is generally agreed on that the conditioning activity for CT should be ≥85% of a person's 1RM, research has shown that CT using as little as 65% of a person's 1RM for the bench press is beneficial in activating PAP. Thus, coaches can use CT on both the hard and light days in an undulating periodization cycle designed to enhance strength and power.
Strength coaches should monitor their athletes for progress, as well as signs of overtraining. Because of the nature of research to create high internal validity, often times research may not be practical in the application setting. Therefore, strength coaches are strongly urged to apply their practical knowledge with the latest research in hopes to create the optimal training protocol for their specific athletes in their training.

CT = complex training; ICRI = intracomplex rest interval; NSCA = National Strength and Conditioning Association; PAP = postactivation potentiation.

subjects' performance for counter movement jumps and drop jumps would be affected from squatting at 85% of their 1RM for 5 repetitions with a Smith machine. In addition to this, the authors measured electromyographic (EMG) activity for the rectus femoris, vastus lateralis, and biceps femoris of the dominant leg. The authors chose the counter movement jumps to assess slow reactive strength, and the drop jumps to measure fast reactive strength. The subjects rested for 3, 10, and 20 minutes after the Smith machine squats. Jones and Lees (24) concluded that there was no ergogenic effect from the heavy squatting regarding counter movement jumps and drop jumps. The authors noted that only the EMG activity for the bicep femoris during the drop jumps was affected from the heavy squatting on the Smith machine. It should be noted that there were trends that CT may elicit greater power production;

however, because of the small sample size, no significance was detected. As mentioned, the subjects used a Smith machine as the conditioning activity, which the authors suggested may not provide as much muscular tension as squatting with a barbell. Finally, CT did not decrease subsequent performance, which is in agreement with other research (11,17,23). Therefore, CT could provide an efficient way to train for strength and power in the same session.

Some studies indicate that individuals respond differently to the ICRI. For example, Bevan et al. (8) studied CT on 26 professional rugby players who performed ballistic bench press on a Smith machine after heavy bench pressing with an ICRI of 15 seconds, 4, 8, 12, 16, 20, and 24 minutes. Although the authors showed a significant improvement in the ballistic bench press at 8 minutes (throw height and peak power output) for the subjects, they also noted the individualistic responses to CT. Fifteen of the 26 subjects (58%) had the greatest peak power output at 8 minutes, 7 subjects obtained their peak at 12 minutes, 3 subjects had their greatest value at 16 minutes, and 1 subject had his highest peak power output at 4 minutes. Batista et al. (4) noted the interperson variability of PAP; therefore, Batista et al. (4) suggest that coaches should identify the responders when implementing CT; however, in the real world, this may not be always possible. For example, in the collegiate setting, strength coaches only have a limited amount of time to train their athletes and are usually in charge of several athletes/sport teams. Therefore, assessing each athlete individually would not be possible. In addition to this, the average strength coach does not have the ability to measure their athletes through electromyography or force plates and must rely on performance-based assessments (i.e., vertical jumps), which are not as sensitive as laboratory equipment.

In their review article, Docherty et al. (12) suggest that subjects need repeated exposure to CT to learn to use PAP to its fullest. To test this statement, Comyns et al. (10) studied CT on 11 professional union male rugby players using a 3RM back squat followed by 30-m sprints (4-minute ICRI) over 5 sessions. Over the 5 testing sessions, there was no significant effect improving the subjects' sprint times after the intervention compared with the preintervention sprint times. However, the authors noted a trend of improving sprint times in their study. Therefore, to determine whether CT can elicit sprint performance in an acute setting, future research should be performed using more sessions, greater sample size, and mature experienced resistance-trained athletes.

Finally, when implementing CT, it seems that the conditioning activity should be relatively heavy (i.e., ≥85% of 1RM). This is evident from research from Matthews et al. (29) who showed that their subjects (12 competitive male basketball athletes with at least 6 months of resistance training) significantly improved their basketball push pass after bench pressing at 85% of their 1RM for 5 repetitions, whereas no improvement was noted after a conditioning activity of medicine ball push passes. In this acute study, the subjects varied greatly in their response for the medicine ball push passes, which is in agreement with other research (8,12,14) showing the varying responses between the subjects and their PAP response.

NONACUTE STUDIES ON COMPLEX TRAINING

When designing a resistance training program, it is always important to recognize carryover strength. Carryover strength, as defined by Hoffman and Faigenbaum (22), is "the degree of strength improvement achieved during exercise that is reflected in improved performance in another activity (i.e., activities of daily living or sporting events)." Therefore, when implementing CT into a training program, one must consider the carryover affects from using CT over several micro and/or mesocycles. Researchers (13,25,26,31,37) have investigated CT over the duration of multiple weeks (i.e., 4–10 weeks) to determine if CT can produce favorable results without involving the acute stimulation of PAP.

MacDonald et al. (26) studied the effects of CT in comparison with resistance training and plyometric training twice a week for 6 weeks. The 6 weeks was divided into two 3-week mesocycles and utilized 30 recreationally trained college-aged men. The study revealed that the resistance, plyometric, and CT groups significantly increased their strength for the back squat, Romanian deadlift, and standing calf raise with no differences observed between the 3 groups. The 3 groups' body mass and girth measurements for their quadriceps and triceps surae increased with no differences between the groups. The authors (26) suggest that future research be performed with an athletic population with a longer duration to see if CT can affect muscle hypertrophy greater than plyometrics or resistance training. The authors (26) advocate that recreationally trained college men may need longer than 6 weeks of CT to see any difference in hypertrophic gains.

MacDonald et al. (25) published a secondary research article using data gathered from the previously mentioned study (26). This study (25) investigated CT's ability to alter vertical jump height, peak ground reaction force, derived peak power, derived peak power per kilogram, and derived peak power per kilogram of fat-free mass while using countermovement vertical jumps. The authors determined that CT produced similar results compared with resistance and plyometric training when using counter movement vertical jumps. Therefore, the authors (25,26) concluded that CT is a viable training method when compared with plyometric or resistance training because of similar improvements without any detriment to performance. The reader should note that for both these studies (25,26) the CT group's total volume was greater than both the resistance and plyometric training group's volume because it encompassed both training styles.

Santos and Janeir (37) measured the effects on squat jumps, counter movement jumps, Abalakov test, depth jumps, mechanical power, and medicine ball throws over 10 weeks during the in-season for male basketball players who were aged 14–15 years had no previous exercise training experience, and who were in the Tanner stage 3 or 4 for development. The control group (n = 10) did not perform any resistance and plyometric training, whereas the experimental group (n = 15) performed resistance exercises using a 10 repetition maximum (10RM) and plyometric training. After 10 weeks, the experimental group significantly improved in the squat jumps, counter movement jumps, Abalakov test, and medicine ball throws. Nonsignificant improvements were noted in depth jumps and mechanical power, whereas the control group improved significantly only in the medicine ball throws. In addition, the control group significantly decreased their counter movement jumps, Abalakov test, and mechanical power. The researchers did not use the traditional method of CT, which is pairing biomechanically similar heavy load and lighter load exercises in an alternating fashion. The experimental group performed plyometric exercises on the basketball court immediately after resistance training in the weight room. As the authors, we emphasize this article because the study is often cited in the literature as validation that CT is ergogenic for power development in the long term. However, it should be noted that any proper exercise training in the form of resistance training or plyometric training would more than likely facilitate the ability to express power for this age group with no previous exercise training experience. Future research should be performed on this population with a CT training group, a plyometric only group, a resistance training only group, and a control group.

Research (13) involving 45 male division II junior college baseball players investigated the effects of CT, heavy resistance training, and plyometric training ability on 20, 40, and 60 yard sprint times, vertical jumps, standing broad jumps, and the T-agility test. The researchers used a randomized crossover design with three 5-week mesocycles (15 total weeks) where each player participated in each training modality for 4 weeks with a recovery week of active rest between each mesocycle. The heavy resistance training and plyometric training involved 3 exercises using 4 sets of 6 repetitions with a progressive intensity of 80–90% of their 1RM and 0–30% of their 1RM, respectively. To equate for total volume, the CT mesocycle consisted of 3 heavy resistance exercises for 2 sets of 6 repetitions and 3 plyometric exercises for 2 sets of 6 repetitions. Although there was no significant difference among the training modalities ($P = 0.11$), CT had ergogenic effects for all the variables, whereas heavy resistance training only had ergogenic effects on the 60-yard sprint, vertical jumps, standing broad jumps, and T-agility test, and plyometric training only had ergogenic influences on vertical jumps, and standing broad jumps. Therefore, based on the findings of their study, the authors suggest that CT has a trend to improve lower-body power slightly more than heavy resistance training or plyometric training; however, the reader should be cautious in concluding that CT is superior to the other modalities because there were no significance differences between each modality. It should be mentioned that the authors noted that the analysis for the training order effect was nonsignificant, indicating that the exercise rotation order did not influence their results.

Mihalik et al. (31) compared CT with compound training (the use of traditional resistance training and plyometric training performed on separate days) for trained male and female college club volleyball players. The subjects participated in a 4-week training study of equal training volumes and were assessed each week on vertical jump height and power output. The authors concluded that both the CT and compound training groups significantly improved their vertical jump height and power output. Mihalik et al. (31) noted that the compound training (6 men and 10 women) increased their vertical jump by approximately 9.1% (4.77 cm) and their mean power output by approximately 7.5%, whereas the CT group (5 men and 10 women) increased their vertical jump and mean power output by approximately 5.4% (2.7 cm) and approximately 4.8%, respectively. There were no significant differences for the improvements in vertical jump and power output. There was no significant difference in the rate of improvement. Both groups improved significantly in the vertical jump and power at the third and fourth week assessments. Therefore, both CT and compound training can lead to significant improvements in power in as short as 3 weeks of training. Because CT utilizes strength training and plyometric training in the same session, it may be more appropriate for strength coaches who have limited access to their athletes in a given week. Furthermore, Mihalik et al. (31) noted no difference in improvements between genders for either condition, which is in agreement with other research (23). However, the article does not mention if the subjects were experienced lifters, or if the subjects were currently implementing a weight training or plyometric program. Furthermore, the article does not mention the subjects' strength levels, which were determined through a 10RM squat test. Therefore, the reader should be careful when interpreting the data from this article. Future research should be performed with a longer duration, use a homogenous group (i.e., inexperienced or experienced weightlifters), and determine if any difference in strength gains were observable between the 2 training modalities.

HORMONE RESPONSES TO ACUTE COMPLEX TRAINING

To the best of authors' knowledge, one study has been published on the hormonal response to CT. Beaven et al. (7) studied the salivary testosterone and cortisol responses to the following 4 different training formats: (a) power-power, (b) power-strength, (c) strength-power, and (d) strength-strength with a 3-minute rest between sets, and a 4-minute rest between exercises. Each subject completed each exercise session twice, over a 4-week period while working out twice a week thus totaling 8 exercise bouts. The strength-power bout produced the greatest increase in testosterone when compared with the power-power, power-strength, and strength-strength sessions. Therefore, this study suggests that the traditional CT format involving a heavy conditioning exercise followed by lighter biomechanically similar movement may promote an enhanced anabolic hormonal milieu for the participants. According to earlier research performed by Beaven et al. (5,6), basing exercise prescription off salivary hormonal response will produce superior gains in strength.

AGONIST-ANTAGONIST PAIRED SETS

As mentioned, CT is the employment of heavy resistant exercise followed by a lighter exercise of a similar biomechanical movement pattern to elicit PAP. Some research (3,36) suggests the use of a style of CT that uses agonist-antagonist paired sets (APS); however, other research (35) recommends avoiding the term CT when describing APS because the movements are not similar because of the fact that the muscles targeted are not the same. Regardless of this discrepancy, examining research for APS and using it to improve strength and power is necessary to avoid APS to be mistakenly classified as CT.

Baker and Newton (3) suggest that "if some augmentation to force output occurs because of a neural strategy of enhanced reciprocal inhibition of the antagonist musculature, then contrasting strategies involving the antagonist musculature may also prove fruitful for enhancing power output" (p. 202). To study this, Baker and Newton (3) measured the acute effect on power output assessed by explosive bench press style throws (40 kg) on 24 college-aged rugby players. Twelve subjects were in the control group (no antagonist intervention), and 12 subjects were in the experimental group, which consisted of 8 forceful repetitions on the prone bench pull. The authors noted a 4.7% increase in power when using the antagonistic strategy, whereas the control group had no improvement in power output. Baker and Newton (3) suggest further research be performed on the effects of this type of training over the long-term, as well as investigate the potential benefits of using such strategies as a warm-up intervention for tasks such as pitching.

Robbins et al. (36) studied agonist and antagonist resistance training on 18 conditioned men and its effect on the bench press throw, throw height, peak velocity, peak power, bench pull volume load, and EMG activity. The authors noted no difference between traditional resistance training and agonist and antagonist resistance training for any of the variables. Therefore, Robins et al. (36) concluded that this training method may not be valid for augmenting power during a training session; however, they do recommend this training style as an efficient approach to weight training as evident by shorter workouts while not effecting performance on the antagonist or agonist musculature. The reader should note that Robbins et al. (36) suggest that the contradicting findings of their study compared with those by Baker and Newton (3) could be because of the fact that Baker and Newton (3) used ballistic style lifting for their antagonist intervention.

To the best of authors' knowledge, only 1 longitudinal study has investigated agonist-antagonist training. Robbins et al. (34) studied 15 trained men over the course of 8 weeks for throw height, peak velocity, and peak power in the bench press and 1RM for the bench press and bench pull exercises using either traditional style training ($n = 7$) or agonist-antagonist training ($n = 8$). The traditional style training executed the bench pull exercise before the bench press exercises, compared with the agonist-antagonist group who performed the exercises in alternating pattern. The agonist-antagonist group had greater increases in their 1RM for the bench pull and bench press exercises, whereas the traditional style group had greater increases in peak power. The authors concluded that at this time, agonist-antagonist style training may offer no benefit in the long term for power development, but may be better suited for the development of strength. In addition to this, agonist-antagonist style training was more efficient by reducing the time to train by half. The authors suggested that future research be performed using a higher training volume with more subjects. Finally, as suggested by a review article written by Robbins et al. (35), when performing future research or implementing agonist-antagonist training, consideration needs to be given to training status, training age, genetics, anthropometry, gender, relative strength, and absolute strength.

CONCLUSIONS

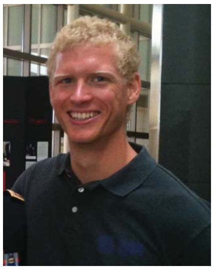
When implementing CT, strength coaches should consider such factors as the ICRI, training age, training history, degree of absolute strength, exercise selection, load, duration of the session, and days of recovery, as well as which individual is a responder to the conditioning activity (2,4,8,15,17,18,27,38). It seems that there is no difference in response to CT regarding gender when other factors are considered (11,23,31). Matthews and Comfort (27) stress that when implementing CT to increase speed and power, that the athlete should not become fatigued, the session should not induce metabolic fatigue, and the emphasis is on high velocity/quality movements. Baker (2) urges that when implementing CT into a program, the lighter exercise be performed explosively throughout the entire range of motion. Traditional exercises such as the bench press and back squat should be reserved for the heavy exercise because the executor has to slow down the movement as the concentric phase ends. Although future research is warranted for CT, Ebben (15) suggests that a 3- to 4- minute ICRI is optimal for CT; however, other research suggests an 8- and/or 12-minute ICRI (8) may be optimal. Implementing a 8- to 12-ICRI will more than likely not be possible or an efficient use of time; therefore, the more prudent advice would be to determine which individuals are responders (4), as well as establish the optimal ICRI for each athlete if conditions are possible (8,11,12,14). However, in the real world, determining which athlete is a responder and at what time their PAP peaks will not be possible, and the strength coach should rely on scientifically established guidelines and experience to prescribe the optimal ICRI for their particular athlete(s).

Although more research on the validity on CT's ability to improve power is needed, especially in the long-term, it seems CT provides a more efficient workout without inhibiting exercise performance when allowing adequate rest between the sets (3,31,34,36). Most strength coaches will not have the time to implement CT with a 3- to 4-minute ICRI, much less an 8- to 12-ICRI. Typically, strength coaches employ CT during the strength/power and power phases in the off and preseasons. When training for strength and power, the NSCA (1) recommends a rest period of 2–5 minutes between sets and a load ≥75 and ≥85% of an athlete's 1RM for power and strength exercises, respectively. Therefore, one useful tip for strength coaches with a limited time in the weight room who are abiding by the minimum 2-minute recovery period when training for strength and power is to use an ICRI of 1 minute. An ICRI of 1 minute will allow the athlete 1 minute to prepare for the lighter exercise after the heavy exercise and 1 minute to prepare for the next set of the heavy exercise after the lighter exercise.

Complex training can be implemented in a well-designed periodized strength training program. Remember that when training for the enhancement of strength and power, "force equals mass times acceleration." Therefore, strength coaches can use traditional weight lifting, plyometric training, Olympic-style lifting, and CT in a periodized program to provide a unique training stimulus for their athletes. As mentioned, strength coaches typically use CT during strength/power and power phases during the off and preseasons; however, coaches have implemented CT during the in-season in efforts to maintain strength and power (30). It has been suggested that CT may benefit the athlete by preparing the body physiologically and psychologically through conditioning the athlete to produce powerful contractions while in a somewhat fatigued state (30). However, when implementing CT, the athletes' technique and power should not be affected from metabolic fatigue.

Finally, it is well known that the amortization/transition phase is the most important period when implementing plyometrics (32). The amortization phase of a plyometric drill is the period between the eccentric action (prestretching of the muscles and tendons), and the concentric contraction. If the athlete's amortization phase is prolonged, all of the elastic energy generated from the series elastic component will be dissipated as heat (32). One suggestion when implementing CT with novice athletes is to use acyclical plyometrics for the lighter exercise. The authors define acyclical plyometrics by having the athletes pause between each repetition (i.e., counter movement jump), and then perform an explosive repetition (counter movement jump) with a minimal amortization phase. By allowing the athletes to reestablish themselves between repetitions before performing the subsequent repetition, the quality of movement (technique) may be maintained while using a small amortization phase. The athlete should only pause for 1–2 seconds, which should be enough time to reestablish their balance, and then perform another explosive movement. Furthermore, this can be a great opportunity to teach the athlete proper landing mechanics, which may reduce noncontact anterior cruciate ligament injuries in sports such as soccer, basketball, and volleyball. Once the athlete becomes more familiar with the movement, the athlete can perform cyclical plyometrics as long as the exercise quality is maintained and the amortization period is minimal.

Conflicts of Interest and Source of Funding: The authors report no conflicts of interest and no source of funding.



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