American Journal of Sports Science and Medicine, 2014, Vol. 2, No. 5, 202-207
Available online at http://pubs.sciepub.com/ajssm/2/5/5

DOI:10.12691/ajssm-2-5-5

Effects of Power-based Complex Training on Body Composition and Muscular Strength in Collegiate Athletes

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Received October 31, 2014; Revised November 03, 2014; Accepted November 05, 2014

Abstract This study examined the effects of power-based complex training (PCT) on body composition and muscular strength in male and female collegiate athletes. Twenty one athletes (12 female soccer players and 9 male football players) participated in a supervised PCT program for 6 weeks, which consisted of a variety of Olympic-style and traditional weightlifting movements and plyometrics. Following the 6-week PCT program, males did not significantly alter body composition, whereas females positively altered body composition without a significant change in body weight by increasing muscle mass (+1.32 kg, $p = 0.044$) and decreasing fat mass (-1.90 kg, $p = 0.005$) and % body fat (-2.60%, $p = 0.006$). The 6-week PCT program significantly increased upper and lower body strength in both males and females: 1) clean [males: +10.47%, $p = 0.001$ and females: +19.98%, $p = 0.001$], 2) incline press [males: +8.81%, $p = 0.021$ and females: 8.93%, $p = 0.002$], and 3) squat [males: +13.17%, $p = 0.002$ and females: +17.44%, $p = 0.001$]. A post-training percent change in clean for females was significantly greater than males (19.98 vs. 10.47%, $p = 0.001$), while the other post-training percent changes were not different. The current study suggests that the 6-week PCT program can positively alter body composition particularly for female athletes and significantly improve upper and lower body strength for both male and female athletes, which will contribute to improvement in athletic performance.

Keywords: *Olympic-style weightlifting, plyometrics, resistance training, collegiate athletes, undulating periodization*

Cite This Article: Joshua Miller, Yunsuk Koh, and Chan-Gil Park, “Effects of Power-based Complex Training on Body Composition and Muscular Strength in Collegiate Athletes.” *American Journal of Sports Science and Medicine*, vol. 2, no. 5 (2014): 202-207. doi: 10.12691/ajssm-2-5-5.

1. Introduction

Designing and determining an optimal strength training program is always challenge for athletes, coaches, and strength conditioning professionals. In general, a typical resistance training program targeting strength gains usually requires a higher training intensity with lower training volume, while a resistance training program specifically targeting improvement in power needs to focus more on the amount of work completed over a unit of time [1]. The primary goal of an effective resistance training program for athletes is to improve both power and strength simultaneously, which can be accomplished by applying a high force to a heavy weight that will move the weight at an accelerated rate [2].

The combination of traditional weightlifting movements followed by plyometric movements is termed complex training. Complex training is considered a very effective training program for developing power, since it alternates high load weightlifting movements with biomechanically similar plyometric movements in the same workout. The theory of complex training is that the stimulus for the plyometric movements will be higher when a resistance movement is performed prior because of the heightened motor neuron excitability brought on by the weight lifted [3]. The two factors of muscle force production that should be considered when implementing complex training are the speed of the muscle stretch and the amount of force developed by the stretched muscle [4]. Traditional resistance training components of complex training will improve force production, and plyometric components of complex training will increase the speed of the stretch and the force produced. Therefore, resistance training combined with plyometric movements will result in greater power production [3].

In a resistance training program, the implementation of periodization has been shown to improve power and strength in both males and females, regardless of training experiences [5,6]. The two types of periodization models that are commonly used are linear and undulating periodization [7,8]. According to the previous studies, implementing either linear or undulating periodization to resistance training can improve strength in a variety of populations [6,7,8,9]. Although some studies suggest that a linear periodization model may be better in strength development [5,10], it is generally believed that an undulating periodization model can provide a more effective, greater improvement in strength and power in athletes [8,11].

One of the important factors that one should consider when designing a resistance training program for athletes is that the resistance exercises must mimic movements the athletes perform on the playing field [12]. In this regard, Olympic-style weightlifting movements should be implemented and emphasized in a resistance training program for athletes in certain sports such as football and soccer that require high force and power production when running, sprinting, or jumping, since Olympic-style weightlifting movements mimic sport specific movements by enhancing triple extension and rapid contraction of the ankle, knee, and hip. Thus, a resistance training program that includes a combination of Olympic-style weightlifting movements (variations of clean, jerk, and snatch) and complex training (traditional weightlifting movements with plyometrics) may be the most preferred training method [12], since it does not only mimic the movements that the athletes perform on the playing field, but it also allows athletes to improve both strength and power simultaneously [13]. Therefore, the present study examined the effects of a 6-week power-based complex training (PCT) program with undulating periodization on body composition and muscular strength in male and female collegiate athletes.

2. Materials and Methods

2.1. Subjects

Twenty one collegiate athletes (12 female soccer players and 9 male football players) between the ages of 18 and 23 participated in the present study. All subjects were informed of the risks that may be associated with participation in the study, signed written informed consent prior to any testing, and were required to fill out medical history forms in order to determine any prior or current medical conditions that did not allow subjects to safely participate in the study. All study protocols and procedures were reviewed and approved by the Institutional Review Board. Additionally, all experimental procedures involved in the study conformed to the ethical consideration of the Helsinki Code. The subjects refrained from strenuous exercises other than the PCT program during the study period. Although it was not the purpose of the study, the subjects were encouraged to keep a well-balanced diet during the study period.

2.2. Study Design and Procedures

2.2.1. One Repetition Maximum (1-RM) Test

The subjects performed 1-RM tests for 3 exercises including clean, incline press, and squat (Olympic-style back squat with an angle of knee < 90°) after a 15-min warm up that was composed of a hurdle mobility routine, core work, and bar progressions. Each 1-RM test was performed on a separate day to prevent from any potential injury and to provide a full recovery from the prior test. The initial weight for the 1-RM test was determined by each subject's training history. Once the subjects successfully lifted the first weight, the resistance increased by 2 – 5 kg until the subjects were unable to complete a lift successfully. The subjects rested for 3 minutes between each 1-RM attempt, and the last successful lift was recorded as the 1-RM. The 1-RM for other upper and lower body movements were estimated from the pre-determined 1-RM of clean, incline press, and squat. For instance, the 1-RM for the following Olympic-style weightlifting movements were estimated from the clean 1-RM; snatch – 60% of clean 1-RM, clean pull – 120% of clean 1-RM, hand clean and Romanian deadlift (RDL) – 90% of clean 1-RM, jerk variations – 90% of clean 1-RM, snatch pull – 72 % of clean 1-RM (equivalent to 120% of snatch 1-RM), and hang snatch – 54% of clean 1-RM (equivalent to 90% of snatch 1-RM). The 1-RM for the traditional horizontal bench press was estimated to be 120% of incline press 1-RM. The Olympic-style back squat 1-RM was used to estimate the 1-RM for the front squat (80% of squat 1-RM) and lunge variations (25% of squat 1-RM).

2.2.2. Body Composition

Body composition including muscle mass, fat mass, and % BF were measured using a bioelectrical impedance analyzer (BIA-101A, RJL Systems). The subjects refrained from physical activity, sauna, or alcohol consumption within 12 hours prior to the measurement of body composition. During the measurement, the subjects lay supine on the floor with arms away from the body with no shoes, socks, or any jewelry, and electrodes were placed on a hand and foot as instructed by the manufactural procedure. The subjects remained lying on the floor until the completion of the measurement, and then resistance and reactance were recorded, which were later used to estimate muscle mass, fat mass, and % BF using body composition software (BC 2.1, RJL Systems).

2.2.3. Power-based Complex (PCT) Program

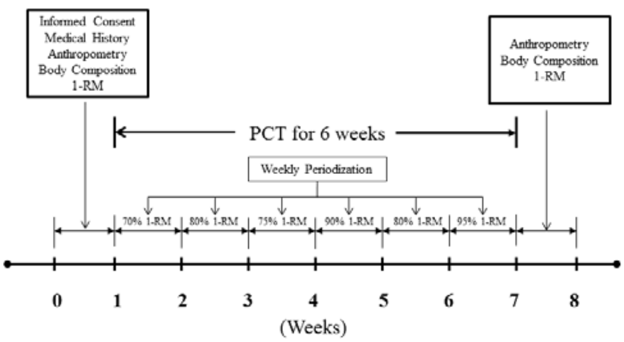

Figure 1. Study design

Note. RM = repetition maximum; PCT = power-based complex training.

To ensure maximum compliance (i. e. proper warm-up, lifting technique, reps, sets, and cool-down), a certified strength and conditioning professional supervised and led all resistance training sessions for each subject. No competitive football or soccer games were scheduled during the study period, and the subjects were instructed to perform no other resistance training during any down time (Wednesdays, Saturdays, and Sundays were scheduled off days). The PCT program was performed for 4 days per week (Monday, Tuesday, Thursday, and Friday) for 6 weeks. Each session lasted 60 minutes, and consisted of multiple sets (3 – 6), repetitions (dependent on the different movements), and exercises (8 – 10). The present study utilized weekly undulating periodization as shown in Figure 1. The PCT program consisted of a combination of Olympic-style and traditional weightlifting movements and plyometrics as shown in Table 1. A cool down was performed for 10 minutes post workout each day, and consisted of a variety of proprioceptive neuromuscular facilitation (PNF) stretches targeting different upper and lower body muscle groups on a different training day: 1) chest, rotator cuff, deltoids, and upper back for upper body (Tuesday and Friday) and 2) hamstrings, hips/glutes, low back, and quadriceps for lower body (Monday and Thursday).

Table 1. Power-based complex training (PCT) program

	Monday (Lower Body)	Tuesday (Upper Body)	Thursday (Lower Body)	Friday (Upper Body)
Warm up	Ankle Disc, Rotator Cuff Series, Rotex or Slide board, Hurdle Mobility Routine, Speed Ladder Routine, Jump Rope Routine, Neck Machine, Weighted or Non-weight Abdominal Circuit			
Olympic-style Weightlifting	Clean, Snatch Pull, Hang Snatch	Split Jerk	Snatch, Clean Pull, Hang Clean	Power Jerk
Traditional Weightlifting	Clean Grip RDL, Back Squat, Snatch Grip Lunges	Incline Press, Bar Rows, Single Arm Dumbell Bench, Pullups/Pulldowns	Single Leg RDL, Front Squat, Side Lunges	Bench Press, Dumbell Rows, Standing Military Press, Alternating Dumbell Incline
Plyometrics (sets X reps)	Platform Plyos (lateral jumps – 3X5, each way), Bear Squat Jumps (3X6)	Hurdle Hops, Power Bears (3X5)	Incline Medicine Ball Press (3X8), Medicine Ball Slams (3X9)	Medicine Ball Bench Press (3X8), Single Leg Overhead medicine Ball Toss (3X6, each leg)
Supplemental Movements (sets X reps)	Swiss Ball Hamstring Work (3X12), Single Leg Goodmornings (2X8, each leg)	Alternating Dumbell Military Press (3X8, each arm), Dumbell Reverse Flys (3X10)	Gluteham (3X8)	Bar Sit Ups (3X12), Inverted Rows (3X10), Hanging Abs (3X25)
Cool down	PNF (lower body)	PNF (upper body)	PNF (lower body)	PNF (upper body)

Note. RDL = Romanian deadlift; PNF = proprioceptive neuromuscular facilitation.

2.3. Statistical Analysis

Given α = 0.05, effect size = 0.40, and power = 0.80, the sample size was calculated using G*Power 3.1.0 [14]. The appropriate sample size was estimated to be 18 subjects for the current study. Statistical analyses were performed using the Statistical Package for the Social Science 19.0 (IBM SPSS, Armonk, NY). All data are reported as means ± standard deviations (SD). The Shapiro-Wilk test was conducted to examine the normality of dependent variables (body composition and muscular strength) for males and females, and the result indicated all the dependent variables were normally distributed for each gender ($p > 0.05$). The independent samples t-tests were used to examine the differences in body composition (muscle mass, fat mass, and % BF) and muscular strength (clean, incline press, and squat) at baseline between males and females. Since body composition and strength at baseline were significantly different between males and females, the separate paired samples t-tests were used to examine the changes in body composition and strength for each gender. Additionally, the independent samples t-tests were used to compare the post-training percent changes in body composition and strength between males and females. The level of statistical significance was set at $p < 0.05$.

3. Results

As compared with females, males had significantly lower % BF and higher muscle mass and absolute strength in clean, incline press, and squat at baseline and post training (Table 2). Following the 6-week PCT program, males did not alter body composition, whereas females positively changed body composition without a significant change in body weight. For instance, females decreased fat mass (-1.9 kg, from 21.23 ± 5.19 to 19.33 ± 4.92 kg, $p = 0.005$) and % BF (-2.6%, from 32.30 ± 4.44 to 29.70 ± 4.84%, $p = 0.006$) and increased muscle mass (+1.32 kg, from 43.64 ± 3.82 to 44.96 ± 3.89 kg, $p = 0.044$).

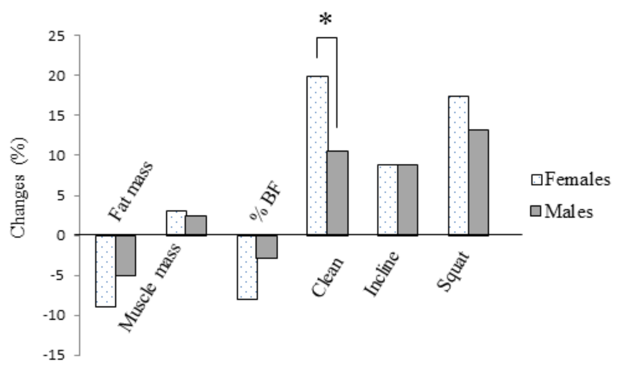

Figure 2. Post training percent changes in body composition and strength variables for each gender

Note. % BF: percent body fat; * $p = 0.009$, significantly different from males.

Both males and females significantly improved upper and lower body strength following the 6-week PCT program: 1) clean [males: +10.47% or +12.53 kg (from 119.70 ± 11.73 to 132.22 ± 10.88 kg, $p = 0.001$) and females: +19.98% or +8.94 kg (from 44.74 ± 7.34 to 53.67 ± 7.35 kg, $p = 0.001$)], 2) incline press [males: +8.81% or +9.85 kg (from 111.87 ± 14.36 to 121.72 ± 15.50 kg, $p = 0.021$) and females: +8.93% or +2.84 kg (from 31.82 ±

4.33 to 34.66 ± 5.75 kg, p = 0.002)], and 3) squat [males: +13.17% or +19.95 kg (from 151.51 ± 16.31 to 171.46 ± 21.92 kg, p = 0.002) and females: +17.44% or +11.1 kg (from 63.64 ± 7.63 to 74.74 ± 10.26 kg, p = 0.001)]. A post-training percent change in clean for females was significantly greater (19.98 vs. 10.47%, p = 0.009) than males, whereas the other post-training percent changes in incline press and squat were not significantly different between males and females (Figure 2).

Table 2. Changes in anthropometric, body composition, and strength variables

	Females (n = 12)				Males (n = 9)			
	Pre-training	Post-training	P-value	% Changes	Pre-training	Post-training	P-value	% Changes
Age (year)	19.00 ± 0.65	19.00 ± 0.65	--	0.00	21.00 ± 1.13	21.00 ± 1.13	--	0.00
Height (cm)	167.11 ± 6.44	167.11 ± 6.44	--	0.00	180.90 ± 8.28	180.90 ± 8.28	--	0.00
Weight (kg)	65.00 ± 8.21	64.43 ± 7.52	0.328	-0.87	102.58 ± 18.30	101.26 ± 17.09	0.198	-1.29
Fat mass (kg)	21.23 ± 5.19	19.33 ± 4.92	0.005*	-8.95	28.90 ± 9.78	27.42 ± 8.17	0.158	-5.12
Muscle mass (kg)	43.64 ± 3.82	44.96 ± 3.89	0.044*	+3.02	73.44 ± 9.51	73.62 ± 10.47	0.820	+2.45
% BF (%)	32.30 ± 4.44	29.70 ± 4.84	0.006*	-8.04	27.59 ± 5.22	26.79 ± 4.38	0.287	-2.90
Clean 1-RM (kg)	44.74 ± 7.34	53.67 ± 7.35	0.001*	+19.98†	119.70 ± 11.73	132.22 ± 10.88	0.001*	+10.47
Incline 1-RM (kg)	31.82 ± 4.33	34.66 ± 5.75	0.002*	+8.93	111.87 ± 14.36	121.72 ± 15.50	0.021*	+8.81
Squat 1-RM (kg)	63.64 ± 7.63	74.74 ± 10.26	0.001*	+17.44	151.51 ± 16.31	171.46 ± 21.92	0.002*	+13.17

Note. RM = repetition maximum; % BF = percent body fat; *significantly different from pre-training within each group; †p = 0.009, significantly different from males.

4. Discussion

We examined the effects of the 6-week PCT program, which consisted of a variety of Olympic-style and traditional weightlifting movements and plyometrics, on body composition and strength in male and female collegiate athletes. In the current study, male subjects did not significantly change body composition following the 6-week PCT program, whereas female subjects positively altered body composition without a significant change in body weight by increasing muscle mass (+1.32 kg) and decreasing % BF (-2.6%) and fat mass (-1.9 kg). This result was similar to other previous studies [9,15,16]. Both recreationally-trained and untrained young women significantly changed body composition following the 12-week resistance training [9,15]. More specifically, recreationally-trained women decreased fat mass and % BF by -2.39 kg and -3.82%, respectively, and increased muscle mass by +3.07 kg [9]. Similarly, a significant decrease in % BF (up to 12.73%) and fat mass (up to 9.32%) and an increase in muscle mass (up to 4.73%) were observed in untrained women following a 12-week resistance training, which was composed of multiple sets of muscular endurance training [15]. After completing a 10-week crossfit-based high-intensity power training program, consisting of Olympic-style lifts such as squat, deadlift, clean, snatch, etc., both healthy men and women decreased % BF up to -4.2% and increased maximal aerobic capacity as well [16]. According to one of a few review studies, young female athletes can increase muscle mass up to 1.5 kg (average of 0.3 kg) and decrease % BF up to -2.1% (average of -0.4%), and male athletes can increase muscle mass up to 1.4 kg (average of 0.8 kg) and decrease % BF by -3.0 % (average of -1.7%) following resistance training [17]. Although male athletes in the current study tended to decrease fat mass (-1.48 kg) and % BF (-0.69%) and increase muscle mass (0.18 kg), they were not statistically significant. One of the possible explanations by which males did not significantly change body composition may be due to their long history of heavy resistance training. Most of our male subjects as football players have been participating in some forms of heavy resistance program for several years, and it is suggested that athletes who have participated in heavy resistance training for a long period of time may be less responsive to altering body composition [18]. Of several factors determining athletic performance, body composition is one of the key component affecting athletic performance in many sports. An athlete with a greater muscle to fat ratio is generally believed to perform better in certain sports where speed is required [19].

Male subjects in the current study had greater absolute strength in clean, incline press, and squat than female subjects at baseline and post training, which may be attributed to greater muscle mass and body weight male subjects had [20]. Despite this initial difference in absolute strength, both males and females significantly improved upper and lower body strength following the 6-week PCT program. In addition, females made a greater post-training percent change in clean than males (+19.98 vs. +10.47%), while the other post-training percent changes in incline press and squat were not different between males and females. These results were consistent with other studies [6,8,9]. Kell reported that both young males and females significantly improved upper and lower body strength for squat, bench press, lateral pull down, and shoulder press following the 12-weeks of periodized resistance training (average volume and intensity: 571 repetitions per week at 70% of 1-RM). Similar to the current study, female subjects in Kell's study had a greater percent increase in strength (26.2% at week 8 and 38.1% at week 12) than male subjects [6]. Some studies reported a beneficial effect of complex training on strength and power development [21,22,23], while others observed no greater improvement of power and strength than regular resistance training [24,25]. Young basketball players significantly improved upper and lower body explosive strength such as squat jump, countermovement jump, Abalakov test, depth jump, and medicine ball throw following a 10-week complex training program [23]. Dodd and associates reported that a 4-week complex training program showed greater percent improvements than a heavy resistance or plyometric training intervention for various power-specific performances including short distance sprints, standing broad jump, and T-agility in college-aged male athletes [22]. Both Olympic-style weightlifting and plyometric training programs provided greater improvement in power production than traditional resistance training in youth [26]. Moreover, Olympic-style weightlifting training produced even greater improvement in countermovement jumps, vertical jumps, and 5- and 20-m sprint times than plyometric training [26] or vertical jump training in young males [27].

In contrast, Jensen and colleagues reported no beneficial effect of complex training, which consisted of a countermovement jump, a set of squats, and 5 trials of countermovement vertical jump at different intervals, on jump performance in collegiate male and female athletes [24]. McDonald and colleagues reported that three different types of 6-week training programs including complex training, regular resistance training, and plyometric training showed equal improvement in strength for squat, Romanian dead lift, standing calf raise in recreationally trained college-aged men [25]. Although complex training did not produce significantly greater improvement in power and strength than non-complex training, it is recommended that complex training be implemented to resistance training because it provides a more efficient workout by combining strength and power movements in the same session, and does not hinder the positive effects of non-complex training has on strength and power [25,28].

According to the position stand statements by American College of Sports Medicine, resistance training can improve strength up to 20 and 16% for moderately-trained and trained individuals, respectively [18]. Although some physiological differences such as body composition and hormones exist between males and females, the mechanism by which resistance training improves muscular strength and muscle mass is same for both genders. Strength gains observed at the early phases of resistance training is mainly associated with neuromuscular adaptation followed by changes in muscle fiber distributions [9,10]. In the current study, considering several important factors such as the PCT program lasting only 6 weeks, the subjects coming off winter break, and no significant change in body weight at post-training, significant strength gains observed following resistance training may be resulted from neural adaptations [9,10].

5. Conclusions

In conclusion, male athletes have greater absolute strength than female athletes, but both genders equally, significantly improve upper and lower body strength following the 6-week PCT program. Additionally, female athletes tend to be more responsive to the PCT program since they positively altered body composition by decreasing fat mass and % BF and increasing muscle mass, and made greater improvement than males in the post-training percent change in clean. Thus, coaches and strength conditioning professionals should consider implementing the PCT program when designing a resistance program for athletes since it could positively change body composition and effectively improve upper and lower body strength, which will consequently lead to improvement in athletic performance

Statement of Competing Interest

The authors have no completing interest.

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