COMPLEX TRAINING AND COUNTERMOVEMENT JUMP PERFORMANCE ACROSS MULTIPLE SETS: EFFECT OF BACK SQUAT INTENSITY

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Abstract:

The purpose of this investigation was to determine the acute effects of back squats on countermovement jump performance across multiple sets using a strength-power potentiation complex training protocol. Fifteen elite volleyball players performed three unloaded countermovement jumps (CMJ) following three repetitions of the back squat performed at either 65% or 87% of 1-RM, respectively, repeated for 10 sets. A control session of three CMJs was also repeated for 10 sets. Mean jump height performance was enhanced compared to performing CMJs only irrespective of which intensity was used (65% 1-RM: +3.3 ± 2.2% [CI: 1.0 to 5.6]; 87% 1-RM: 2.6 ± 1.9% [CI: 0.7 to 4.5]). Subjects with a greater relative strength possessed a very likely large (97%; ES = 1.51) chance of improvement in jump height across 10 sets of the protocol prescribed using the intensity of 87% 1-RM and a likely moderate (89%; ES = 0.94) and very likely large (97%; ES = 1.76) chance of improvement in maximum concentric impulse (N·s) using intensities of 65% and 87%1-RM, respectively. Performance (jump height and maximum concentric impulse) may be enhanced across 10 sets of the strength power potentiation complex training protocol prescribed irrespective of intensity, with a greater effect observed for the subjects with a greater relative strength and with the 87% 1-RM heavy load back squat condition. In practice, coaches should consider the athlete's strength level when designing such a complex training protocol to generate any post-activation potentiation effect across multiple alternating sets to enhance jump performance.

Key words: *complex training, postactivation potentiation, PAP, conditioning stimulus*

Introduction

Alternating a specific resistance exercise with a biomechanically similar plyometric exercise has been referred to as complex training (CT) (Comyns, Harrison, Hennessy, & Jensen, 2007). The use of a strength-power potentiation complex training protocol aims to benefit from the transient increase in muscle contractile performance after a brief maximal or near-maximal voluntary contraction (Robbins, 2005). This response is known as post-activation potentiation (PAP) whereby acute muscle force output is enhanced as a result of contractile history and is the premise upon which complex training is based (Robbins, 2005). An increased excitability of the central nervous system is reported as the primary physiological mechanism observed during the PAP response and lasts for up to 8-10 minutes (Sale, 2002; Smilios, Pilianidis, Sotiropoulos, Antonakis, & Tokmakidis, 2005). In practice, the use of heavy back squats, for example, as a conditioning stimulus prior to the performance of a countermovement jump (CMJ), performed as a 'complex set' or 'complex pair', has shown positive responses (Esformes, Cameron, & Bampouras, 2010; Gourgoulis, Aggeloussis, Kasimatis, Mavromatis, & Garas, 2003; Kilduff, et al., 2008; McCann & Flanagan, 2010; Mitchell & Sale, 2011; Rixon, Lamont, & Bemben, 2007; Smilios, et al., 2005; Young, Jenner, & Griffiths, 1998) (e.g., 2.9% increase in CMJ height at 4 min [Mitchell & Sale, 2011]), while either a decrease (Jensen & Ebben, 2003; Jones & Lees, 2003; Mangus, et al., 2006; Rixon, et al., 2007; Scott & Docherty, 2004) (e.g. 10% decrease in CMJ height immediately following heavy back squats [Jensen & Ebben, 2003]), or no improvement (Hanson, Leigh, & Mynark, 2007; Jones & Lees, 2003; Khamoui, et al., 2009) (e.g. 0.01%, -0.02%, -0.03% change in CMJ height at 3, 10 and 20 min respectively [Jones & Lees, 2003]) has been found in other studies. The reasons for these somewhat conflicting findings are not all understood, but athlete strength levels, conditioning stimulus nature (including type, volume and intensity) and the time course between the stimulus and the performance measure are likely the most important determinants (Seitz & Haff, 2016).

As previously reported (Weber, Brown, Coburn, & Zinder, 2008), conditions that have been proposed to be effective and characteristics for promoting, seemingly, PAP to the greatest extent include the observation that PAP is more effective in: biomechanically similar sets (Robbins, 2005); athletes more so than non-athletes; individuals with a greater relative strength (Duthie, Young, & Aitken, 2002); athletes with a greater proportion of FT muscle fibers (Hamada, Sale, Macdougall, & Tarnopolsky, 2000b); heavy loads (<6 repetition maximum (RM) lifts) (Duthie, et al., 2002; Hamada, Sale, Macdougall, & Tarnopolsky, 2000; Smith, Fry, Weiss, Yuhua, & Stephen, 2001; Young, et al., 1998) and rest intervals (intra-complex rest interval) between two and five minutes (min) (Robbins, 2005), although more recent research has suggested rest intervals of between 8 and 12 min are necessary to exhibit a PAP effect in some populations (Comyns, Harrison, Hennessy, & Jensen, 2006; Kilduff, et al., 2007, 2008). Fatigue and PAP can co-exist in skeletal muscle and muscle performance following heavy resistance exercise (HRE) will depend on the balance between muscle fatigue and muscle potentiation (Rassier & Macintosh, 2000). Baker (2009) has suggested that most studies that have not reported a significant performance benefit during CT have used in excess of 85% 1-RM or 5-RM for the HRE and recommended that using lighter resistances in the range of 60-75+% 1-RM is generally more effective when using CT (Baker, 2003, 2009; Baker & Newton, 2005, 2006), but not always (Crum, 2012). This is even though maximal resistance has been suggested to be necessary for full motor unit recruitment and thus may be an important contributor to the stimulation of a PAP effect. A considerable amount of neural fatigue will result following the use of a 3-RM or 5-RM protocol, which may explain why longer rest periods are required prior to a subsequent plyometric exercise. In addition, evidence suggests that an individual's muscular strength may determine a PAP effect or response following a conditioning contraction (Tillin & Bishop, 2009) (e.g. Gourgoulis et al. (2003) found a 4% increase in CMJ height following heavy load back squats in subjects able to squat a load > 160 kg). Ruben et al. (2010) found that the individuals who were able to back squat ≥ 2.0 times body mass were able to exhibit a PAP effect in a horizontal plyometric activity (hurdle jumps) following an ascending squat protocol (average peak power output: 38.3 ±26.27 % increase; average peak velocity: 24.8 ± 19.3% increase). The recent meta-analysis by Seitz and Haff (2016) also suggested that stronger individuals were able to exhibit a greater PAP effect (effect size [ES] = 0.410 than weaker counterparts (ES = 0.32), which might be explained by the fact that stronger individuals might possess a greater percentage of type II muscle fibers and thus greater phosphorylation of myosin light chain, which was one of the peripheral factors proposed as a mechanism underpinning PAP. Furthermore, Seitz and Haff (2016) suggested that balance between fatigue and PAP following a conditioning stimulus might be affected by a strength level of the individual, with stronger individuals developing some level of fatigue resistance to heavier loads after a near-maximal effort.

While these studies have examined the acute effects of dynamic maximal voluntary contractions (MVCs) on CMJ performance, there appears to be only two studies (Andrews, et al., 2011; Duthie, et al., 2002) that have investigated the set-to-set combination of a HRE followed by a subsequent biomechanically similar plyometric exercise such as a CMJ conducted over multiple sets, which may be more typical of an applied complex training session. Andrews et al. (2011) investigated CMJ performance across three sets using either heavy load back squats or hang cleans as the conditioning stimulus in a complex pair vs. CMJs only in trained college-aged women (back squat = 1.49 ± 0.30 body weight [BW], hang clean = 1.01 ± 0.15 BW). The hang clean (0.30 cm decrease) was superior to the back squat (2.0 cm decrease) in maintaining consistent CMJ performance across three sets with three min of intra-complex and between-set rest intervals, while performing only CMJs demonstrated a 1.6 cm decrease in performance. However, as reported by Andrews et al. (2011), the results of this study may not extend to other populations such as elite male athletes or individuals of differing training status. Duthie et al. (2002) compared the use of alternating the 3-RM half squat and loaded jump squats (concentric only) across three sets (defined as 'contrast' training) with a traditional training session involving three sets of loaded jump squats (JS) undertaken prior to three sets of the half squat in resistance trained women. Stronger athletes (mean predicted 1-RM half squat: 139kg) were able to benefit from the CT with an increase in peak power (+4%) and maximum force (+2%) compared to the traditional training. Conversely, weaker athletes (mean predicted 1-RM half squat: 116kg) were unable to benefit from this form of priming. Despite these studies and their varying protocols and outcomes, it remains unclear whether using a CT protocol across multiple sets may provide a performance benefit or PAP effect.

If a CT protocol is to be used during training in a trained athletic population, the optimal balance between volume and intensity needs to be established along with an appropriate intra-complex rest interval. Consequently, an examination of volume and intensity pertaining to the use of CT over a number of sets or a training session is warranted should practitioners be seeking to utilize the proposed performance enhancing benefits of this form of training PAP.

Therefore, the aim of this study was to determine how specific CT protocols, varying in load intensity, affect the PAP benefit over multiple sets of a training session in elite volleyball players with an extensive training history. More specifically, the purposes of this study were to: (i) investigate the global effect of varying load intensity of back squats on CMJ performance conducted over multiple sets in the form of a complex training; (ii) investigate whether absolute or relative strength may be a criteria for identifying responders or non-responders to changes in CMJ performance; and (iii) examine whether a particular time course for performance may be established across 10 sets of CT, and whether this is related to athletes' strength characteristics.

Methods

Subjects

Fifteen (n = 15) male elite volleyball players from senior teams competing in the Tunisian national volleyball competition (national team, n = 6; and professional, n = 9) were recruited for the study (mean ± SD: age 24.3 ± 2.6 years, body mass 88.95 ± 7.9 kg, body height 1.93 ± 0.08 m, training volume 12 ± 2 hours a week). All volleyball players had a minimum of two-year experience in performing the back squat and had been familiarized throughout the training year with various forms of CT including those that contained the back squat and CMJ. Athletes had just commenced the early phase of the post-competitive volleyball season and were about to commence preparation for a final series. No structured resistance or other training program was undertaken by any athlete during the time of testing. All subjects completed informed written consent documents after the approval from the University Human Research Ethics Committee at the Edith Cowan University and the Ethics Committee of the National Centre of Medicine and Science in Sports, Tunis, Tunisia. The study also conformed to the recommendations of the Declaration of Helsinki.

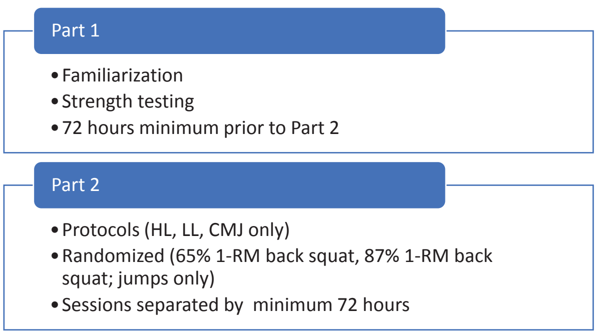
Design

In this study, we examined the effect of manipulating load intensity of a dynamic back squat on CMJs performed over multiple sets in elite senior-level volleyball players. Fifteen elite male volley ball players performed two CT protocols using either a heavy load (HL), using 87% 1-RM, or lighter load (LL), using 65% 1-RM back squat in a randomized design (Figure 1). Subjects performed three unloaded countermovement jumps (CMJ) on a force platform following three repetitions of a back squat protocol, using either a HL or LL, and this complex was repeated for 10 sets (Figure 2). Baseline CMJs served as a baseline in each session and were compared with the post-squat CMJs for each set during each session.

An additional control session involving 10 sets of unloaded CMJs was also undertaken to examine whether any effect on the selected performance parameters was observed in the absence of a back squat CT protocol. The order of the three conditions was randomized across three separate days.

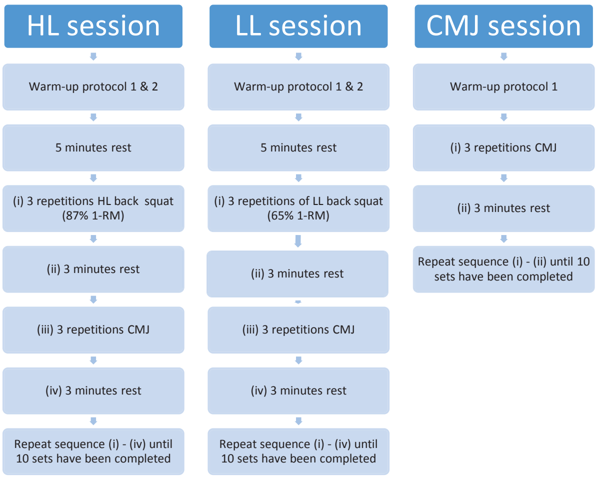
Methods

This study was completed in two parts undertaken over four separate sessions (Figures 1 and 2). All subjects arrived at the training facility at the same time each day and were tested at the same time. A minimum of 72 hours separated each testing session. Subjects were asked to refrain from alcohol, caffeine, or any strenuous activities, resistance, or plyometric training at least 48 hours prior to each testing session. Consumption of water (500 ml) was permitted during each test and verbal encouragement was provided to maximize performance.



Note. HL = heavy load; LL – light load; CMJ = countermovement jump; RM = repetition maximum.

Figure 1. Outline of Part 1 and Part 2.



Note. HL = heavy load; LL – light load; CMJ = countermovement jump; RM = repetition maximum.
Note. 15-second rest was undertaken between each CMJ.

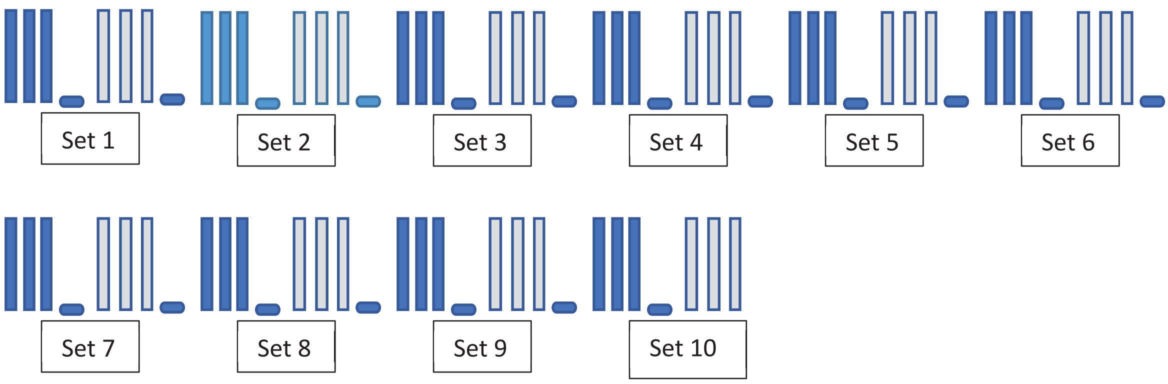
Figure 2. Description of 3 randomized protocols.

Part 1. Before the main experimental trials (Part 2), subjects visited the laboratory to become familiar with the testing methods (complex training protocol) and to have their 3-RM back squat determined. On their first arrival at the laboratory, each subjects' age, body height (BH; m) and body mass (BW; kg) was recorded. A full description of the CT testing procedures was explained in detail to the subjects. Athletes were required to undertake a standardized dynamic warm-up protocol (warm-up protocol 1) adapted from Moir et al. (Chaouachi, et al., 2011; Moir, Dale, & Dietrich, 2009). This involved performing a series of dynamic exercises consisting of two sets of 10 body-weight squats and two repetitions of lunge walks over 10 m with two minutes of recovery between sets. Athletes then performed two sets of three CMJs at intensities of 60% and 80% of maximum effort, separated by a recovery period of two minutes. A 10-second recovery separated each individual jump. Athletes then progressed to a more specific warm-up protocol (warm-up protocol 2) in preparation for heavy load back squat adapted from previous research investigating PAP (Chaouachi, et al., 2011; Kilduff, et al., 2008). Warm-up protocol 2 involved subjects performing three warm-up sets of eight repetitions at 50% of their previously determined 1-RM, 4 repetitions at 70% 1-RM and two repetitions at 80% 1-RM.

Back squat testing session. Following the final warm-up set, each participant attempted three repetitions of the chosen set load (3-RM). If the lift was successful, the weight was increased until the weight could not be lifted through the full range of motion. All subjects were required to have their 3-RM determined within a maximum of three attempts. A 5-minute rest was imposed between all attempts to allow adequate time to recover (Kilduff, et al., 2008). A lift was deemed successful as described by the International Powerlifting Federation (2007) rules for performing the back squat requiring the subject to descend to a point where the inguinal fold was lower than the patella and ascend to the starting position without assistance (Hanson, et al., 2007). Each athlete's 3-RM back squat was determined and 1-RM was then estimated using the tables provided by Haff and Triplett (Haff & Triplett, 2016).

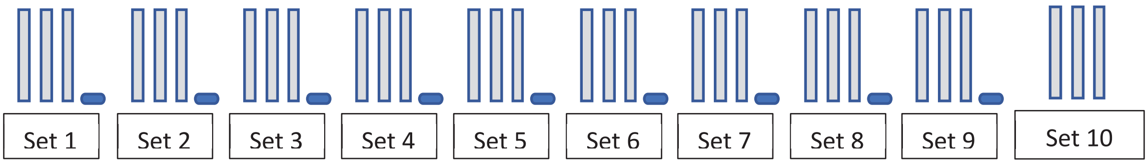
Part 2. Subjects participated in three testing sessions, randomized and counterbalanced over two weeks, involving two CT protocols, a HL and LL protocol, as well as a CMJ only session. Warm-up protocols were adhered to as described previously.

Countermovement jump assessment. Vertical jump performance was assessed as previously described (Chaouachi, et al., 2011) on a Quattro Jump portable piezoelectric force plate (Kistler Instru-



Note. = 1 repetition of back squat; = 1 repetition of CMJ; = 3-minute recovery; 15-second recovery was undertaken between each CMJ.
Complex Training Protocol represented in repetition format for the LL (65% 1- RM back squat) and HL (85% 1-RM back squat) with 3-minute recovery prior to completing 3 CMJs.

Figure 3. Complex training protocol.



Note. ▯ = 1 repetition of CMJ; ▬ = 3-minute recovery; 15-second recovery was undertaken between each CMJ. Complex training protocol represented in repetition format for CMJ session.

Figure 4. Countermovement jump session.

ment AG, Winterthur, Switzerland) at a sampling rate of 500 Hz. Athletes performed CMJs according to the protocol described by previous researchers (Chaouachi, et al., 2011). Athletes were required to keep their hands on their hips throughout the entire jump to minimize lateral and horizontal displacement and prevent any influence of arm movements on jump performance while minimizing coordination as a confounding variable in the assessment of the leg extensor neuromuscular performance (Chaouachi, et al., 2009). Countermovement depth was self-selected by the subjects and they were asked to jump as high as possible (Cormack, Newton, & McGuigan, 2008).

Raw data from the vertical component of the ground reaction force (N) was extracted and selected parameters analyzed using custom made software (Force Plate Data Analyzer, Copyright © Aspire 2010 Version 1.2.1.0). Force data were filtered using a fourth-order low pass Butterworth filter with a 28-Hz cutoff frequency.

Session descriptions

High load (HL) session with a 3-minute intra-complex recovery. Athletes performed three repetitions of the back squat at 87% 1-RM followed by a rest period of three minutes before completing three CMJs separated by a 15-second rest between each repetition on the force platform. This was repeated for a total of 10 sets with a 3-minute recovery between each set. The premise of selecting a 3-minute intra-complex and inter-set recovery period was to provide a realistic time-frame for the use of complex training in the practical setting based on a multi-set protocol or training session while remaining consistent with recent research investigating the use of complex training conducted over multiple sets (Andrews, et al., 2011). Rest intervals of 2-5 minutes have been previously recommended when training for strength and power (Haff & Triplett, 2016) while increases in CMJ height have previously been demonstrated following heavy load back squat using a rest interval of three minutes (Rixon, et al., 2007).

Light load (LL) session with a 3-minute intra-complex recovery. Athletes performed five repetitions of the back squat at 65% 1-RM followed by a rest period of three minutes before completing three CMJs on the force platform. This was repeated for a total of 10 sets with a 3-minute recovery between each set.

Countermovement jump session. Athletes performed 10 x sets of three CMJs on the force platform separated by a rest period of three minutes between each set.

Statistical analysis

Data in text and tables are presented as means ± standard deviations (SD). Relative changes (%) in performance are expressed with 90% CI (90% confidence intervals). All data were log-transformed prior to the analysis to reduce bias arising from the non-uniformity error.

As a preliminary step, we wished to establish the most reliable and sensitive parameters derived from CMJs. The reliability of each parameter obtained from the Quattro Jump was established from the baseline measurements in each testing session (Table 1). Three trials were analyzed for each parameter using the Hopkins method (Hopkins, 2009) to derive typical errors (TE) expressed as both the percentage of coefficient of variation (CV) and the standardized one (based on Cohen's approach). We therefore selected the most reliable parameter for further analysis based on the standardized TE, i.e., maximum concentric impulse (N·s), and jump height (cm) because it is still the most reported measure in the CMJ literature (Chiu, et al, 2004; Duthie, et al., 2002; Gourgoulis, et al., 2003; Jensen & Ebben, 2003; Ruben, et al., 2010; Tillin & Bishop, 2009). The majority of the most reliable parameters (e.g., maximum power, maximal concentric power) were demonstrated similar responses and, for clarity and conciseness, in this investigation we chose to focus our attention on these two parameters (jump height and maximum concentric impulse).

To examine the effect of intensity of back squat load on performance (jump only, 65% 1-RM, 87% 1-RM) across 10 sets of the heavy load back squat – CMJ complex pair, average values were calculated to obtain a single value for each subject of each selected parameter. The difference in performance in each parameter between the three conditions (jump only, 65% 1-RM, 87% 1-RM) were expressed as the standardized mean differences (Cohen's d). The criteria used to interpret the magnitude of Cohen's d were: ≤ 0.2 trivial, > 0.2-0.6 small, > 0.6-1.2 mod-

Table 1. Reliability of specific parameters of countermovement jump performance (n = 15)

Parameter	CV	CV CL (Lower)	CV CL (Upper)	ICC	ICC CL (Lower)	ICC CL (Upper)	TE	TE CL (Lower)	TE CL (Upper)
Max concentric impulse: [N/s]	**2.7**	**2.2**	**3.5**	**0.93**	**0.84**	**0.97**	**0.3**	**2.3**	**4.4**
Max power: [watt]	2.8	2.1	4.0	0.94	0.86	0.97	0.28	0.21	0.4
Take-off velocity (from force): [m/s]	3.6	2.7	4.1	0.72	0.43	0.87	3.6	2.7	5.1
Max relative power: [watt/kg]	3.9	3.0	5.7	0.87	0.71	0.94	0.42	0.32	0.6
Maximum pushing (concentric) force: [newton]	5.1	3.9	7.4	0.87	0.7	0.94	0.42	0.33	0.61
Maximum relative concentric force:	5.2	4.0	7.5	0.61	0.27	0.82	0.85	0.66	1.22
Average concentric power: [watt]	6.6	5.0	9.5	0.78	0.54	0.9	0.58	0.45	0.83
Average relative concentric power: [watt/kg]	6.9	5.3	10.1	0.68	0.37	0.85	0.73	0.57	1.05
Jumping height from force: [m]	**7.2**	**5.6**	**10.6**	**0.72**	**0.44**	**0.87**	**0.67**	**0.52**	**0.96**
Breaking (eccentric) phase duration: [s]	7.8	6.0	11.5	0.48	0.09	0.75	1.09	0.85	1.57
Ratio breaking (eccentric)/ pushing (concentric):	11.8	9.0	17.3	0.37	-0.06	0.68	1.39	1.07	1.99
Pushing (concentric) phase duration: [s]	14.5	11.1	21.5	0.03	-0.39	0.43	6.27	4.85	9.01
Time of maximum concentric force: [s]	18.9	14.3	28.2	0.11	-0.32	0.5	2.98	2.31	4.29
Overall system stiffness: [N/s]	19.1	14.5	28.6	0.59	0.24	0.81	0.88	0.69	1.27
Max relative RFD: [1/s]	21.5	16.3	32.3	0.62	0.28	0.82	0.83	0.65	1.2
Max RFD: [N/s]	21.6	16.4	32.5	0.67	0.35	0.85	0.75	0.58	1.08
Average breaking power: [watt]	25.7	19.2	39.7	0.78	0.52	0.9	0.58	0.45	0.85
Max concentric RFD: [N/s]	60.9	44.2	100.3	0.35	-0.09	0.67	1.45	1.12	2.12
Max relative concentric RFD: [1/s]	61.0	44.2	100.5	0.38	-0.06	0.69	1.35	1.04	1.97

Note. CV – coefficient of variation expressed as a percentage; ICC = intraclass correlation coefficient; TE – typical error; C.L. = confidence limit.

erate, >1.2 large (Hopkins, et al, 2009). In addition, data were also assessed for practical meaningfulness using an approach based on magnitude of change (Batterham & Hopkins, 2006; Hopkins, et al., 2009). An assessment of the chances that the (true) performance values were greater (i.e., greater than the smallest practically important effect, or the smallest worthwhile change, SWC [0.2 multiplied by the between-subject standard deviation, based on the Cohen's principle (Cohen, 1988)]), was undertaken. Quantitative chances of higher or smaller performance responses across the 10 sets were assessed qualitatively as follows: <1%, almost certainly not; 1-5%, very unlikely; >5- 25%, unlikely; >25-75%, possible; >75-95%, likely; >95-99%, very likely; >99%, almost certain (Hopkins, et al, 2009). If the chance of having beneficial/better or detrimental/poorer performances were both >5%, the true difference was assessed as unclear (Hopkins, et al., 2009).

To examine individual responses to the intensity of back squat load (jump only, 65% 1-RM, 87% 1-RM) subjects were divided into groups (responders or non-responders) based on their responses compared with jump only.

Groups were divided into non-responders (both intensities = jump only), responders to either 65% 1-RM (65% > jump) or to 87% 1-RM (87% > jump), for each parameter. A cut-off point of half the CV for each parameter was utilized as determining the smallest worthwhile response in performance for either condition (jump only, 65% 1-RM or 87% 1-RM). This cut-off value of half of a CV has been suggested as being important for detecting the smallest worthwhile performance enhancement in athletes, irrespective of the level of group homogeneity (Hopkins, Hawley, & Burke, 1999). Relative or absolute strength of each group (non-responders, responders to 65% 1-RM, or responders to 87% 1-RM) were then compared, using the same magnitude-based analysis as for between-condition comparisons as described above.

To examine the effect of the intensity of back squat load on potential fatigue development, the time course of performance across the 10 sets was established with the changes in the selected parameters modeled using 3-polynomial functions when appropriate. Model A was used to describe performance changes following a bell shape formation, model B presented as a decrease initially followed by an increase in later sets, while model C presented a decrease across all 10 sets.). Each athlete, for each condition, was then allocated into families based on their individual responses (A, B, C, or no model). Each time course was allocated to either model A, B or C based on best fit and r^2 values. If an individual time course did not fit either model based on best fit and/or r^2 value ($r^2 <0.7$), they were allocated to the group 'no model'. As above, relative and absolute strengths of the distinct groups were compared.

Results

When examining the effect of the intensity of back squat load on global performance, mean jump height performance across 10 sets of heavy load back squat and CMJs, performed as a 'complex pair', was likely or possibly enhanced, irrespective of the back squat load (65% 1-RM or 87% 1-RM, respectively) (Table 2). Interestingly however, it is almost certain that performing a heavy load back squat with either intensity as a 'complex pair' will provide a similar performance outcome in maximum concentric impulse compared to performing only 10 sets of CMJs.

Table 2. Effect of a heavy back squat intensity on CMJ performance (n = 15)

Parameter	Mean ± SD	Δ (%) ± SD (90% CI)	Standardized (Cohen) differences (90% CI) (Rating)	Percentage chances for subjects to have better/similar/poorer performance with load	Rating
Maximum concentric impulse[N/s]					
65%	268.3 ± 27.31				
87%	268.82 ± 26.58				
Jump only	267.48 ± 26.83				
65% vs. jump only		0.3 ± 0.6 (-0.3 to 0.9)	0.03 (-0.03 to 0.08) (trivial)	0/100/0	Almost certainly similar
87% vs. jump only		0.5 ± 0.7 (-0.2 to 1.2)	0.05 (-0.02 to 0.11) (trivial)	0/100/0	Almost certainly similar
87% vs. 65%		0.2 ± 0.8 (-0.1 to 1.0)	0.02 (-0.05 to 0.09) (trivial)	0/100/0	Almost certainly similar
Jump height (cm)					
65%	0.42 ± 0.04				
87%	0.42 ± 0.05				
Jump only	0.40 ± 0.04				
65% vs. jump only		3.3 ± 2.2 (1.0 to 5.6)	0.28 (0.09 to 0.48) (small)	77/23/0	Likely higher
87% vs. jump only		2.6 ± 1.9 (0.7 to 4.5)	0.22 (0.06 to 0.38) (small)	59/41/0	Possibly higher
87% vs. 65%		-0.7 ± 3.6 (-4.2 to 2.9)	-0.06 (-0.37 to 0.25) (trivial)	8/70/22	Unclear

Note. CI = confidence interval; SD = standard deviation; n = number of subjects; ES = effect size (qualitative outcome, see "Methods" for thresholds used); Intensity = jumps only, 65%, or 87% 1-RM.

Table 3. Responders vs. non-responders to load

	Maximum concentric impulse			Jump height		
	n	Absolute strength (kg)	Relative strength (kg/BW)	n	Absolute strength (kg)	Relative strength (kg/BW)
Non-Responders	2	178.2 ± 22.91	1.87± 0.11	5	187.7 ± 32.3	2.0 ± 0.3
Responders 65% only	7	189.9 ± 27.12	2.15 ± 0.35	6	187.6 ± 14.4	2.2 ± 0.4
Responders 87% only	5	203.04 ± 27.96	2.30 ± 0.29	4	216 ± 29.3	2.4 ± 0.2
Responders to both (65% and 87%)	1	226.8	2.39			
65% vs. non-responders % difference (90% CI) Effect size (rating) % Chances for 65% values to have		6.0 ± 97.1 (-46.2; 109.0) 0.34 (Small) 57/16/27	14.0 ± 16.1 (-1.8; 32.4) 0.95 (Moderate) 89/7/4		0.9 ± 19.0 (-15.2; 20.1) 0.06 (Trivial) 40/27/33	8.3 ± 17.4 (-7.8; 27.1) 0.51 (Small) 70/18/12
better/similar/poorer results Rating 65% vs. non-responders		Unclear	Likely		Unclear	Unclear
87% vs. non-responders % difference (90% CI) Effect size (Rating) % chances for 87% values to have		13.6 ± 100.0 (-43.2; 127.1) 0.73 (Moderate) 72/9/19	22.4 ± 15.7 (5.7; 41.7) 1.76 (Large) 97/1/2		15.7 ± 23.4 (-6.3; 42.7) 0.79 (Moderate) 82/11/7	21.5 ± 15.6 (5.1; 40.4) 1.51 (Large) 97/2/1
better/similar/poorer results Rating 87% vs. non-responders		Unclear	Very likely		Unclear	Very likely

Following investigation of responders vs. non-responders to load (number of athletes is presented in Table 3), results indicated that the subjects with a greater relative strength possessed a very likely chance of improvement in both jump height and maximum concentric impulse when performing 10 sets of a squat – CMJ complex training protocol using an intensity of 87% 1-RM compared to non-responders (Table 3). In addition, the athletes with a greater relative strength were able to also improve maximum concentric impulse performance across the 10 sets of complex training utilizing an intensity of 65% 1-RM heavy back squat as the conditioning stimulus when compared to non-responders.

Finally, individual performance modelling (Tables 4 and 5) across 10 sets of either jumps only or a complex pair involving back squat (65% or 87% 1-RM) and CMJs, utilizing the protocols provided, indicated the highly individual responses of each athlete. Some athletes exhibited a bell-shaped curve across the 10 sets (model A), while others demonstrated a decrease followed by a late increase in latter sets (model B). Alternatively, several athletes' performance measures could be modelled as a direct decrease in performance across the 10 sets (model C). However, the majority of athletes could not be modelled based on either fit and/or r^2 values although it did appear that athletes with a greater absolute and relative strength were more likely to be modelled as opposed to the athletes who were weaker.

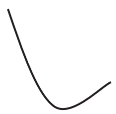
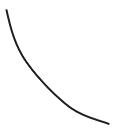
Discussion and conclusions

To our knowledge, this is the first study to investigate the possible PAP benefit using a specific CT protocol varying in load intensity over multiple sets of a training session in elite male volleyball players. The main findings of this study were as follows:

(1) When examining the effect of the intensity of back squat load on performance across 10 sets of a complex pair, mean jump height was enhanced irrespective of the load intensity used (65% 1-RM: +3.3 ± 2.2% [CI: 1.0 to 5.6]; 87% 1-RM: +2.6 ± 1.9% [CI: 0.7 to 4.5]). Interestingly however, for the variable maximum concentric impulse, it appears that utilizing either intensity provided similar performance outcomes to performing CMJs only across 10 sets (65% 1-RM: +0.3 ± 0.6% [CI: -0.3 to 0.9]; 87% 1-RM: +0.5 ± 0.7% [CI: -0.2 to 1.2]). These results highlight the specificity of the effect of the current complex protocol, which likely affects jump height but not concentric impulse, suggesting some alterations in movement efficiency/strategy (Cabrera, Morales, Greer, & Pettitt, 2009).

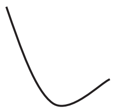
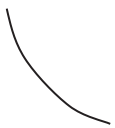
(2) When examining responders vs. non-responders to load, the subjects with a greater relative strength possessed a very likely large chance

Table 4. Time course model – maximum concentric impulse

Jumps Only					65% 1-RM Intensity				87% 1- RM Intensity			
Model	n	Model (r^2)	Absolute Strength (kg)	Relative Strength (kg/bw)	n	Model (r^2)	Absolute Strength (kg)	Relative Strength (kg/bw)	n	Model (r^2)	Absolute Strength (kg)	Relative Strength (kg/bw)
A 												
B 	3	.74	216.0 ± 22.5 **Model B vs. C** Δ = 11.0 ± 35.0 (-17.7; 49.9) E.S. = 0.5 (Small) ++ 67/16/17 (Unclear) **Model B vs. No Model** Δ = 16.7 ± 18.4 (-1.4; 38.2) E.S. = 1.1 (Moderate) ++ 91/5/4 (Likely)	2.2 ± 0.3 **Model B vs. C** Δ = 2.0 ± 44.2 (-4.5; 4.7) E.S. = 0.1 (Trivial) ++ 49/21/30 (Unclear) **Model B vs. No Model** Δ = 3.6 ± 14.4 (-9.5; 18.5) E.S. = 0.3 (Small) ++ 53/26/20 (Unclear)	3	.81	191.1 ± 2.9 **Model B vs. No Model** Δ = 0.6 ± 10.3 (-8.7; 11.0) E.S. = 0.1 (Trivial) ++ 36/36/28 (Unclear)	2.3 ± 0.5 **Model B vs. No Model** Δ = 7.7 ± 41.6 (-23.9; 52.4) E.S. = 0.4 (Small) ++ 60/18/22 (Unclear)	2	.8	197.1 ± 11.5 **Model B vs. No Model** Δ = 12.9 ± 15.3 (-2.1; 32.2) E.S. = 1.1 (Moderate) ++ 89/6/5 (Likely)	2.2 ± 0.1 **Model B vs. No Model** Δ = 9.4 ± 19.2 (-8.2; 30.3) E.S. = 0.6 (Moderate) ++ 73/16/11 (Unclear)
C 	3	.73	196.2 ± 38.3 **Model C vs. No Model** Δ = 10.0 ± 24.5 (-11.6; 37.0) E.S. = 0.6 (Moderate) ++ 73/14/12 (Unclear)	2.2 ± 0.46 **Model C vs. No Model** Δ = 8.5 ± 23.9 (-12.4; 34.4) E.S. = 0.5 (Small) ++ 67/18/16 (Unclear)	2	.75	216 ± 15.3 **Model C vs. B** Δ = 12.9 ± 37.8 (-18; 55.5) E.S. = 0.3 (Small) ++ 65/28/7 (Unclear) **Model C vs. No Model** Δ = 13.6 ± 18.6 (-4.2; 34.8) E.S. = 0.9 (Moderate) ++ 87/7/6 (Unclear)	2.4 ± 0.1 **Model C vs. B** Δ = 4.8 ± 39.8 (-25; 46.5) E.S. = 0.2 (Small) ++ 51/24/26 (Unclear) **Model C vs. No Model** Δ = 12.8 ± 12.2 (0.5; 26.6) E.S. = 1.0 (Moderate) ++ 92/5/3 (Likely)	6	.8	207.0 ± 23.4 **Model C vs. B** Δ = 4.5 ± 15.7 (-9.7; 21.0) E.S. = 0.4 (Small) ++ 65/18/9 (Unclear) **Model C vs. No Model** Δ = 20.4 ± 13.3 (6.3; 36.4) E.S. = 1.4 (Large) ++ 98/2/1 (Very Likely)	2.2 ± 0.2 **Model C vs. B** Δ = 1.5 ± 15.7 (-12.3; 17.5) E.S. = 0.2 (Small) ++ 49/21/30 (Unclear) **Model C vs. No Model** Δ = 14.1 ± 17.7 (-3.0; 34.2) E.S. = 0.8 (Moderate) ++ 85/10/5 (Likely)
No Model	9		187.9 ± 23.5	2.2 ± 0.3	10		192.2 ± 31.43	2.1 ± 0.3	7		184.5 ± 30.7	2.13 ± 0.5

Note. N = number of subjects; Results for absolute and relative strength are presented as mean values ± SD; Δ = % difference in group means ± SD (lower; upper confidence limits); ES = effect size (rating) (qualitative outcome, see “Methods” for thresholds used); Magnitude of the between group differences (++) = % chances (90% CI) for values to have a better, similar or poorer result (rating).

Table 5. Time course model – jump height

Jumps only					65% 1-RM intensity				87% 1-RM intensity			
Model	n	Model (r^2)	Absolute strength (kg)	Relative strength (kg/BW)	n	Model (r^2)	Absolute strength (kg)	Relative strength (kg/BW)	n	Model (r^2)	Absolute strength (kg)	Relative strength (kg/BW)
A 					1		190.1	2.2	1		237.6	2.7
B 	5	.71	204.3 ± 22.7 **Model B vs. C** Δ = 4.9 ± 42.6 (-26.4; 49.6) E.S. = 0.23 (Small) ++ 52/21/27 (Unclear) **Model B vs no model** Δ = 0.0 ± 14.8 (-5.0; 25.2) E.S. = 0.6 (Moderate) ++ 77/15/8 (Unclear)	2.3 ± 0.3 **Model B vs. C** Δ = 7.4 ± 45.6 (-26.2; 56.4) E.S. = 0.33 (Small) ++ 58/19/23 (Unclear) **Model B vs. no model** Δ = 14.0 ± 14.3 (-0.2; 30.3) E.S. = 0.96 (Moderate) ++ 91/6/3 (Likely)	2	.72	208.4 ± 26.0 **Model B vs. no model** Δ = 14.9 ± 36.7 (-15.9; 57.1) E.S. = 0.81 (Moderate) ++ 78/9/12 (Unclear)	2.4 ± 2.2 **Model B vs. no model** Δ = 13.3 ± 17.1 (-3.2; 32.7) E.S. = 1.08 (Moderate) ++ 89/6/6 (Unclear)				
C 	3	.72	196.2 ± 38.3 **Model C vs. no model** Δ = 3.9 ± 34.2 (-22.6; 39.5) E.S. = 0.18 (Trivial) ++ 49/23/29 (Unclear)	2.2 ± 0.6 **Model C vs. no model** Δ = 6.1 ± 45.6 (-27.1; 54.5) E.S. = 0.27 (Small) ++ 54/20/25 (Unclear)	5	.73	208.6 ± 21.9 **Model C vs. B** Δ = 0.1 ± 87.6 (-46.7; 87.7) E.S. = 0.0 (Trivial) ++ 40/21/39 (Unclear) **Model C vs. No Model** Δ = 15.0 ± 15.0 (0.0; 32.2) E.S. = 0.95 (Moderate) ++ 91/6/3 (Likely)	2.4 ± 0.4 **Model C vs. B** Δ = 2.1 ± 21.3 (-15.8; 23.9) E.S. = 0.13 (Trivial) ++ 46/25/3- (Unclear) **Model C vs. No Model** Δ = 15.7 ± 19.1 (3.5; -3.4) E.S. = 0.86 (Moderate) ++ 87/9/5 (Likely)	7	.83	194.6 ± 23.9 **Model C vs. no model** Δ = 2.9 ± 14.3 (-10.0; 17.6) E.S. = 0.19 (Trivial) ++ 49/28/22 (Unclear)	2.2 ± 0.2 **Model C vs. no model** Δ = 3.9 ± 14.9 (-9.6; 19.3) E.S. = 0.25 (Small) ++ 54/27/19 (Unclear)
No model	7		188.2 ± 27.1	2.1 ± 0.3	7		182.7 ± 29.3	2.0 ± 0.3	7		189.7 ± 28.0	2.1 ± 0.4

Note. N = number of subjects; Results for absolute and relative strength are presented as mean values ± SD; Δ = % Difference in group means ± SD (lower; upper confidence limits); E.S. = effect size (rating) (qualitative outcome, see “Methods” for thresholds used); Magnitude of the between group differences (++) = % chances (90% CI) for values to have a better, similar or poorer result (rating).

of improvement in jump height when CMJs were performed across 10 sets of a squat – CMJ CT protocol using an intensity of 87% 1-RM compared to non-responders. However, this was unclear using an intensity of 65% 1-RM. Also, the subjects with a greater relative strength possessed a likely moderate or very likely large chance of improvement in maximum concentric impulse during CMJs performed across 10 sets of a squat – CMJ CT protocol using an intensity of 65% and 87% 1-RM, respectively, compared to non-responders

(3) The individual modelling of jump performance across the 10 sets of CT revealed the highly individual responses of each athlete. It appears that a time course for performance is more likely to be established in the athletes with a greater absolute or relative strength although the majority of the athletes in our investigation did not conform to any model applied.

Effect of intensity on global performance

The present study investigated performance outcomes during CT across multiple sets, which is typical of an applied training session in elite male athletes. While several studies have found increases in CMJ height following heavy load back squats, no study has investigated the performance outcomes of undertaking a complex pair of exercises involving a conditioning stimulus (e.g., heavy load back squats) and plyometric activity (e.g., CMJs) over multiple sets in elite athletes using different load intensities. Our findings demonstrated that mean jump height might be enhanced across 10 sets of CT using the protocol prescribed in elite male volleyball players irrespective of the load used in our investigation (65% 1-RM or 87% 1-RM back squat). In contrast, Andrews et al. (2011) found a 2.0 cm (3.7%) decrease in CMJ performance across three sets of CT involving 75% 1-RM back squat coupled with CMJs as a complex pair in college-aged female athletes. It is difficult to compare the results of Andrews et al. (2011) with our investigation due to the differences in gender (males vs. females), training status (elite volleyball players vs. college-aged athletes competing in a variety of sports) and heavy load back squat intensity. We also investigated CMJ performance across 10 sets as opposed to three sets (Andrews et al., 2011), in order to examine the effect of a higher volume of CT, which is typical of an applied training session in elite athletes. Fatigue and PAP can co-exist in skeletal muscle and performance in an activity (e.g., CMJ) following HRE (e.g., heavy load back squat) will depend on the balance between muscle fatigue and muscle potentiation (Rassier & Macintosh, 2000). This balance between fatigue and potentiation and its possible effect on the subsequent performance in a plyometric activity has been reported in several studies (Tillin & Bishop, 2009). Tillin and Bishop (2009) suggested that following a conditioning stimulus, an optimal recovery time is required to diminish fatigue and realize a PAP effect. However, evidence is inconsistent in support of this theory due to the variety of protocols used in the PAP and CT literature. The magnitude of fatigue and PAP responses, generated by the conditioning stimulus, may also directly be related to the strength level of athletes. Seitz and Haff (2016) have suggested that the time course of a PAP effect appears to be dictated by a strength level with stronger individuals expressing the greatest PAP response 5-7 min following a conditioning stimulus, while weaker individuals achieve a maximal PAP response after at least 8 min of recovery.

While globally we have found that CMJ performance using the current CT protocol was enhanced across the 10 sets using either intensity (65% 1-RM or 87% 1-RM) compared to performing only CMJs, it is unknown whether similar benefits could be realized using shorter or longer intra- complex recovery periods or higher or lower intensities. In addition, there is an absence of research literature reporting the cumulative effect of performing multiple, alternating sets of dynamic MVCs (e.g., heavy load back squats) and plyometric activity (e.g., CMJs), typical of CT practices in an applied setting in terms of the intricate balance between fatigue and any potential PAP effect. We found, however, that it was almost certain that similar CMJ performance outcomes were obtained in maximum concentric impulse whether the athletes were exposed to load or performed only CMJs. As our athletes were elite volleyball players, jump height is a crucial factor in overall performance in the sport. Impulse is the product of force and the time during which the force is imparted also described as the product of an object's mass and a change in its velocity (Koziris, 2012). Kirby, Mcbride, Haines and Dayne (2011) recently examined the effect of different squat depths on relative net vertical impulse, jump height, peak force and peak power, during the concentric phase of the body weight CMJs and static jumps (SJ's). The researchers found that in both jumps, a greater squat depth produced a greater relative net vertical impulse (impulse applied above body weight and expressed per kilogram of body mass), greater peak velocity and greater jump height. Correlations also suggested that relative net vertical impulse was a strong predictor of jump height in both types of jumps regardless of jump height (Kirby et al., 2011; Koziris, 2012). Concentric impulse by definition is the area under the force time curve from the point of maximum displacement (zero velocity) to the instant of takeoff. Given that similar performance outcomes were presented globally across the 10 sets of CT compared with performing CMJs only irrespective of intensity, it may be suggested that the PAP effect influenced the entire movement (eccentric and concentric phases) and there was less of an effect on the maximum concentric impulse. While not investigated in our study, it may be suggested that the CT protocol utilized influenced eccentric mechanisms and potentially had acute effects on changing muscle-tendon architecture. Reardon et al. (2014) were unable to demonstrate a PAP response using a moderate intensity (MI) (75% 1-RM) back squat protocol involving 3 sets x 10 repetitions or a high intensity (HI) (90% 1-RM) protocol involving 3 sets x 3 repetitions on CMJ performance using a similar intra-complex recovery period of three minutes in resistance trained men. However, muscle architecture responses appeared to be sensitive to the different CT protocols with the MI protocol demonstrating to have the greatest effect of muscle cross sectional area and pinnation angle in the rectus femoris and vastus lateralis. It is recommended that further research investigates the PAP effect in the eccentric phase and associated potential acute changes in muscle-tendon architecture.

Responders versus non-responders

While acknowledging that analysis of responders versus non-responders may have limitations due to a low number of subjects, the present results may be used as a starting point toward understanding individual responses to CT. Importantly however, the statistical analysis utilized is well suited for quantifying the magnitude of differences in the specific variables between groups of small sample size. The hypothetical model of the relationship between PAP and fatigue following a pre-conditioning contraction protocol, as previously presented by Tillin and Bishop (2009), suggests that when conditioning volume is low, PAP is more dominant than fatigue and the PAP effect in subsequent performance may be realized immediately (window 1). As the conditioning volume increases, fatigue becomes dominant, negatively effecting subsequent performance. Following the conditioning contraction, fatigue dissipates at a faster rate than PAP and a potentiation of subsequent performance may be realized at some point during the recovery period (window 2). It appears that the intricate balance between fatigue and any PAP effect is highlighted in the individual responses to the CT protocol provided in our study.

As suggested by Weber et al. (2008), one characteristic that seems to promote PAP to the greatest extent includes greater relative strength of the individual (Duthie, et al., 2002). The female athletes in the Andrews et al. (2011) investigation exhibited a substantially lower relative strength in the back squat (relative strength: 1.49 ± 0.30 BW) than those in our study, which may have been a contributing factor to the performance decrement observed. The athletes in our study demonstrated higher absolute and relative lower body strength results following 1-RM back squat assessment (absolute strength: 189.22 ± 27.53 kg; relative strength: 2.14 ± 0.35 BW). Despite the variations in protocols in CT literature, it appears that initial strength levels are one of many individual characteristics influencing a possible acute PAP effect on subsequent performance following a conditioning stimulus (Chiu, et al., 2003; Duthie, et al., 2002; Gourgoulis, et al., 2003; Ruben, et al., 2010). It also appears that initial strength levels of our subjects may be a contributing factor to the observed increases in mean jump height performance (Table 2) across 10 sets of a complex pairing of heavy load squats and CMJs. While we chose to investigate acute performance response across multiple sets, our results are consistent with previous research investigating CMJ responses to heavy load back squat (Esformes, et al., 2010; Gourgoulis, et al., 2003; Kilduff, et al., 2008; McCann & Flanagan, 2010; Mitchell & Sale, 2011; Rixon, et al., 2007; Smilios, et al., 2005; Young, et al., 1998) (e.g., 2.9% increase in CMJ height (Mitchell & Sale, 2011)). Gourgoulis et al. (2003) observed a 4% increase in jump height immediately following five sets of back squats in subjects able to squat > 160 kg, while Ruben et al. (2010) found that individuals who could squat ≥ 2.0 BW produced a significantly greater PAP effect than weaker individuals (<1.7 BW).

As supported by Seitz et al. (2016) and Crewther et al. (2011), the responses found in our study may be explained by the fact that stronger individuals develop fatigue resistance to heavier loads (Chiu, et al., 2003; Jo, Judelson, Brown, Coburn, & Dabbs, 2010; Parry, 2008) after near or maximal efforts (Chiu, et al., 2003; Parry, 2008). The stronger athletes (> 2.2 BW) in our investigation may have expressed fatigue resistance to heavier loads and dissipated fatigue earlier following each set of the CT protocol outlined. While it is unknown how the balance between any PAP effect and fatigue manifested itself across multiple alternating sets of the CT protocol prescribed, it certainly appears that the stronger individuals in our study were able to exhibit a PAP response across 10 alternating sets of our specific CT protocol.

As supported by a number of researchers (Crewther, et al., 2011; Hamada, et al., 2000; Parry, 2008; Tillin & Bishop, 2009), another explanation for individual responders in our study may be that stronger individuals displayed elevated mysosin light chain phosphorylation and tend to have larger and stronger type II muscle fibres (Hamada, et al, 2000; Tillin & Bishop, 2009). Furthermore, type II muscle fibres exhibit greater neural excitation following high intensity resistance training exercises and potentially have a greater number of higher order motor units in reserve, which could be activated via decreased transmitter failure, following a conditioning contraction (Tillin & Bishop, 2009). Thus, the combined effect of greater myosin regulatory light chain (RLC) phosphorylation and greater neuromuscular excitation could theoretically predispose individuals with a higher percentage of type II muscle fibres to a greater PAP response (Tillin & Bishop, 2009).

Time course model for performance

While Seitz et al. (2014) demonstrated in elite junior rugby league players that stronger individuals (able to squat > 2 BW) expressed a PAP effect earlier in comparison to weaker counterparts in squat jump (SJ) performance following three repetitions of back squats 90% 1-RM) the inability to predict any model for the majority of players however demonstrates highly individual responses of each individual and the numerous potential PAP interactions that exist following a CT protocol such as that utilized in our study. Conditioning intensity and volume together with the cumulative effect of alternating CT sets may influence the extent to which the mechanisms of any potential PAP effect and fatigue interact, while individual subject characteristics such as muscle strength, fibre type distribution and training level, not to mention recovery periods, may have all affected the ability to predict any model. It is also unknown whether a time course model may have been established with a greater number of subjects. While a predicted model for performance was unable to be established in the current study, future research should still investigate a time course for any potential PAP effect using complex training over multiple sets typical of an applied training practice in the field.

In conclusion, the results of the present study suggest that irrespective of intensity (65% or 87% 1-RM heavy load back squat), overall performance as assessed by jump height may be enhanced across 10 sets of the CT protocol utilized. In addition, it appears that subjects with a greater relative strength exhibit a greater PAP effect as demonstrated by improved jump height using an intensity of 87% 1-RM back squat and improved net concentric impulse using either intensity (65% or 87% 1-RM back squat) as the conditioning stimulus in the prescribed CT protocol. Finally, we were unable to establish a generic time course model for performance changes across the 10 sets most likely due to the varied individual responses to the CT protocol described.

Practical applications

Practitioners should exhibit caution in interpreting the results of this investigation and application to the field environment given the numerous interactions that are present when examining any potential PAP effect using the CT prescribed with elite volleyball players. Based on the results of this study, strength and conditioning practitioners should consider the athlete's strength level when designing a CT protocol to generate any PAP effect with the aim of improving jump performance utilizing a back squat – CMJ complex pair. It appears that stronger athletes who are able to back squat at least two times their body mass may express a greater PAP effect following either 65% or 87% 1-RM back squat in the form of alternating sets of back squat – CMJ using the CT protocol utilized in this study. It is unknown whether similar results may be exhibited in other athlete populations using longer or shorter recovery periods or different intensities.

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