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Peer Review

CHANGES IN UPPER BODY CONCENTRIC MEAN POWER OUTPUT RESULTING FROM COMPLEX TRAINING EMPHASIZING CONCENTRIC MUSCLE ACTIONS.

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ABSTRACT
Contrasting resistance complex (CRC) training is the alternating of sets of heavier and lighter resistances in an effort to evoke an acute increase in power output while lifting the lighter resistance. The effectiveness of CRC has been well established in elite athletes when researchers utilize an optimal manipulation of training variables but equivocal for other studies that have used a very heavy resistance to "stimulate" the neuro-muscular system. It was theorized that very heavy resistances could conceivably fatigue the processes associated with the stretch-shorten cycle (SSC). The purpose of this study was to determine the effects of CRC when utilizing concentric-emphasis exercises that negate the role or effect that the SSC may have upon power output. Eleven professional rugby league players volunteered to perform a CRC consisting of two sets of three repetitions each of paused concentric-only bench throws with 60 kg (CO BTP60) alternated with paused concentric-emphasis narrow grip bench presses to a board device placed upon their sternum. The board device consisted of 2 x 5 cm wide boards nailed together such that the barbell rested upon this 10 cm thick board device rather than impacting the chest at the bottom of the movement. Mean concentric power output during CO BTP60 increased by about 3% as a result of the intervention of the heavier paused board BP. The results of this study demonstrate that the CRC is enhancing performance without use of the normal SSC action. Such a result is likely to be caused by an increase in neural drive associated with the CRC.

KEY WORDS - Concentric, strength training, power training, explosive.

INTRODUCTION

Upper body muscular power output appears to be an important muscular attribute capable of distinguishing the playing level of professional rugby league players (1, 4, 6, 10, 12, 14). Consequently training methods aimed at increasing upper body power output are of interest to strength and conditioning coaches working with these athletes. Contrasting resistance complex (CRC) training is one such method and is characterized by the alternating of sets of heavier and lighter resistances in an effort to evoke an acute increase in power output while lifting the lighter resistance (3, 5, 6, 17, 20, 33). Sometimes these heavy sets are called the "stimulation" or "strength" set whereas the lighter set is often called the "power" set (5, 6).

The effectiveness of CRC has been well established in elite athletes when researchers utilize an optimal manipulation of training variables (3, 5, 7, 8, 16, 21) but equivocal for other studies that have used a very heavy resistance set (eg. > 5RM or > 85%1RM) to stimulate the neuro-muscular system (15, 17, 19, 23, 25-28, 33). Rixon et al reported significantly higher changes in the power set when the stimulation set was a maximal isometric exercise compared to a traditionally performed heavy dynamic SSC exercise (90% 1RM) (25). It was argued that very heavy resistances could conceivably fatigue the processes associated with the stretch-shorten cycle (SSC) of the power exercise negating the possibility of any potentiation from CRC and accordingly for CRC to be effective, the stimulation set needed to be only moderately heavy (eg. 60-80% 1RM) (3, 6, 9). It has been proposed that fatigue of the SSC resulting from heavy exercise in CRC training may be due to a complex process mediated by a combination of metabolic (eg. Immediate depletion of ATP-PC stores), mechanical (changes in stiffness regulation – the higher the SSC resistance, the higher the stiffness, the diminished SEC augmentation to movement) and neural (eg. Changes in the succinct timing and quantity of neural output) factors (3, 15, 21, 25).

This gives some credence to the belief that for CRC to be effective, the stimulation set should be either, 1. only moderately heavy (eg. 60-80% 1RM) if utilizing a traditionally performed heavy dynamic SSC exercise, 2. use an accommodating resistance like bands or chains with some portion of barbell resistance (eg. 60% 1RM in barbell + 15% 1RM in chains), or 3. use exercises or methods that don't use or fatigue the SSC, such as isometrics or concentric-only muscle actions (5-7). A combination of these three factors have been shown to be effective in acutely increasing SSC power during CRC training (5, 7).

The purpose of this study was to determine if a CRC that emphasized concentric contractions for both exercises would result in changes in concentric power output of a similar magnitude to previous CRC research that utilized SSC exercises. If so, then this result would suggest that the effectiveness of CRC lie in stimulating force production (or negating inhibition) without fatiguing the SSC.

Specifically this study entailed determining the effect heavy paused concentric-emphasis narrow grip board bench presses exert upon the mean concentric power output of paused concentric-only bench throws.

METHODS

Approach to the problem

Eleven professional rugby league players performed an upper body contrasting resistance complex that consisted of two sets of three repetitions of paused concentric-only bench throws (CO BTP60, power exercise) alternated with a set of three repetitions of paused narrow-grip bench presses to a board device upon the chest (heavy stimulation exercise). After warming up, power output was assessed during the first set of bench throws with 60 kg (Pre or base-line CO BT P60). This set served to provide the initial base-line power scores for the investigation. That is, could these power scores be altered by the intervention strategy? The intervention strategy consisted of the athletes then performing a set of heavier narrow grip bench presses to a board device upon the chest. This was then followed by the remaining set of bench throws to determine if the intervention strategy resulted in any acute changes in power output.

Subjects

Eleven professional rugby league players who were undergoing pre-season specific preparation training served as subjects in this study. They are described in Table 1. They were informed of the nature of the study and consented to testing during their usual training session.

Table 1. Description of subjects. Mean (SD).

Age	Height	Mass	1RM BP
22.1 (3.3)	187.1 (2.6)	102.9 (3.9)	135.8 (10.8)

Procedures

An intensive power training warmup and a portion of their usual training session (split jerks and split leg power clean from hang, 3 x 3 each exercise) preceded the Pre-test for CO BTP60 power output. This procedure ensured all the subjects were adequately warmed-up and prepared to exert maximal power during the first set of CO BTP60, which occurred 3-minutes after the completion of the board bench press (BBP) warmup set (60 kg x 5 repetitions). All paused CO bench throws were performed in a Smith machine that has been described previously (1-14). The stops of the Smith machine were placed in a position whereby the bar rested upon them at a height of about 10-15 cm from the chest. This was the start position from where the CO BT exercise was initiated (see Figure 1). An approximate 1-second pause was implemented between repetitions to negate any significant usage of elastic energy from the SSC contributing to the resultant power output (24, 30, 31). A resistance of 60 kg was chosen for paused bench throws as it represented a mean of 44.6 (3.5) % 1RM, which is a resistance that has been previously recommended for BT power training (1, 4, 7, 14) and CRC training specifically (6, 9). It is also a resistance that allows for maximal power generation in stronger subjects and/or for those subjects in the middle of a training cycle (1, 7, 14). Three repetitions were performed in each set as recent research shows that BT power with a resistance of 60 kg is often maximized on the third repetition of a set and then starts to slowly decline after about 5-6 repetitions (11).

An optical linear encoder that was attached to the barbell determined power output from the lifting velocity and position data during the bench throw (GymAware, ACT, Australia). The encoder samples data every 50 msec and it has been previously validated for use in other studies (18). Only the repetition with the highest mean power output was recorded for each set. Test-retest reliability for mean power during bench throws with a resistance of 60 kg was established at $r = 0.93$ ($n = 21$). This reliability was previously established by having professional rugby league players perform a similar warm-up and then perform two COBTP60 tests 4-5 minutes apart (ie. Without active intervention).

Training complex

The athletes performed two sets of three repetitions in the CO BT with 60 kg (CO BTP60) alternated with three repetitions in the paused narrow grip board bench press (BBP). The first set of BT P60 served as the initial base-line (Pre) measure for power output as previous research has shown that mean power output during bench throws will not change without active intervention (2, 3, 8).

The performance of the narrow grip BBP is illustrated in Figure 2. The board device was placed upon the sternum and consisted of two 5cm boards nailed together so that when the barbell rested upon the board device, it was about 10 cm off the chest. When the barbell was lowered to the device, it was paused for 1-second to negate the use of elastic energy and accentuate concentric force production. Furthermore this position 10 cm above the chest is typically where any SSC augmentation to bench press barbell kinematics diminishes and is where large concentric force production contributes to bench press movement (18, 30, 31). The free weight narrow grip BBP resistance was

85-100 kg for each subject, with a mean of 91.8 (6.0) kg, which equated to 67.9 (1.9) % 1RM of the normal grip bench press for each subject, a resistance that has been previously recommended and has been shown to be effective in this type of BT/BP complex training (1-9).

A rest period of 90-120 seconds occurred between the sets of paused BT and BBP, which has been shown to be adequate to facilitate potential increases in power output during CRC training (5).

Statistical Analyses

A repeated measures analysis of variance (ANOVA) was performed to determine if the intervention strategy of moderately-heavy BBP resulted in changes in mean concentric power during CO BT with 60 kg. In the event of a significant F-ratio, Fisher PLSD was used for post hoc comparisons to see where the differences occurred. Significance was accepted at an alpha level of $p < 0.05$. Due to the low subject numbers and the elite nature of the subjects, the changes were also analysed according to the concept of Smallest Worthwhile Change (SWC, 22). Briefly, SWC is a reference value (calculated as 0.2 of the between athlete standard deviation) that permits the calculation of the probability that an observed change in score is large enough to have an important effect on performance. This statistical methodology has been advocated when studying elite athletes who display smaller changes than typical or less trained populations (22). These small changes sometimes may not achieve traditional statistical significance despite being possibly worthwhile in the competition environment of the elite athletes. The SWC is a value expressed as a percentage of likelihood that the difference between pre- and post-intervention scores are large enough to have an important effect on performance of that elite athlete. Cohen's effect size statistics (ES) were also calculated for the magnitude of difference observed between the sets of bench throws (22). ES differences between the first set of bench throws, which served as the base-line condition and the set following the intervention strategy were calculated by dividing the difference between the results by the pooled standard deviation of the test results.

Figure 1. The starting position for the paused concentric-only bench throw with 60 kg. The barbell rests upon the specifically positioned pins of the Smith machine for at least 1-second between repetitions to dissipate the use of elastic recoil energy, accentuating the muscle contractile elements contribution during the ensuing concentric contraction

Figure 2. The starting position for the board bench press with a pause. The barbell rests upon the board device for at least 1-second between repetitions to dissipate the use of elastic recoil energy, accentuating the muscle contractile elements contribution during the ensuing concentric contraction.

RESULTS

The results for changes in mean concentric power output during CO BT P60 are contained in Table 2. The intervention strategy of performing a set of heavy resistance BBP between sets of CO BT P60 caused a small but statistically significant increase of 3.6% in the mean concentric-only power output (ES 0.24). The SWC of 19 watts was also achieved for the post-intervention set.

Table 2. Changes in Mean (SD) concentric-only bench throw mean power output in professional rugby league players when alternated with heavy, concentric-only board bench presses during complex training. Data is expressed as the mean (standard deviation) for the best repetition in a set.

	Power output (w) Pre-Set	Post-Set
Best power output/set	635 (96)	658 (93) *
% change		3.6%
ES	-	0.24

* denotes statistically significant, $p \leq 0.05$,

DISCUSSION

The basic finding of this study is that the intervention strategy of interspersing a set of a moderately-heavy BBP exercise that emphasized the concentric muscle action and negated the SSC augmentation, with sets of a similarly performed concentric-only bench throw resulted in a small increase in concentric-only power output. This is an expected finding with regards to CRC training, however the augmentation to power output is less than what was reported in previous CRC studies using exercises entailing the SSC despite similar methodologies and subjects. This lesser augmentation may be ascribed to some differences in the neural output between SSC and concentric-only power exercises. The reasons for this and its implication for training are discussed below.

Early pioneers in CRC training, Gulich and Schmidtbleicher recommended a "maximal contraction" to cause full motor unit recruitment and activation to achieve a "post-tetanic potentiation" during the following power exercise in CRC (21). However they used an isometric exercise, a fact that was lost on following researchers when they attempted to replicate that research with SSC exercises. Most researchers and coaches that have combined maximal strength exercises and intensities (>5RM or 85% 1RM) with power exercises during CRC training have produced equivocal results (eg. 3, 5, 7, 16 = positive results versus 15, 17, 19 = no change). In studies with non-significant results it may be that the near maximal resistances fatigue the SSC, attenuating any possible augmentation in the following power exercise. Indeed Rixon et al. (25) reported greater PAP from a maximal isometric stimulus as compared to a near maximal resistance dynamic SSC exercise. It is plausible that isometric and concentric exercises can be performed with maximal or near maximal intensities and theoretically not fatigue the processes associated with the ensuing stretch-shorten cycle (SSC) power exercise to the same extent. Conversely a near-maximal resistance SSC exercise of >85% 1RM may deliver neural stimulation but also cause SSC fatigue in the ensuing power exercise. Accordingly it may be less effective in CRC training to use near maximal intensities (eg. bench and squats, >85% 1RM) in traditional SSC strength training exercises as this would conceivably fatigue the SSC processes for the ensuing power exercise. Or, due to fatigue, the rest period between the SSC strength training exercise and the power exercise may have to be much longer (8-12 minutes) to allow for the dissipation of some of this fatigue.

What was unknown and therefore the purpose of this study was to determine if both exercises in the CRC were of a concentric-emphasis nature, would augmentation to power output still occur. Presumably this augmentation would occur through enhanced neural drive as described by Gulich and Schmidtbleicher (21). When re-analyzing some of the original work, it is evident that Gulich and Schmidtbleicher emphasized concentric-only power training to facilitate rapid rate of force development adaptations within the muscle, which are later augmented by power exercises utilizing the SSC. This way the rapid force producing capabilities of the muscle are enhanced and then added upon by SSC adaptations.

What is unclear from this current study is why the augmentation to concentric-only power output was only in the range of 3% whereas previous CRC studies have reported changes of up to 7% when SSC exercises were utilized (3, 5, 7). The neural mechanisms affected by the heavier stimulation set that are thought to account for this increase in SSC power output could be increased motor unit synchronization, increased descending activity from the higher motor centers and reduced inhibitory feedback affecting the SSC, either at the central level (eg. Renshaw cell) or peripheral level (eg. Golgi tendon organ) (3, 15-17, 21, 25). These mechanisms may not necessarily be exclusive of each other.
It could be that "stimulation sets" in traditional performed SSC strength exercises that are not unduly fatiguing to experienced athletes (eg. bench presses and squats with 60-80% 1RM x 2-6 repetitions) afford two avenues for power augmentation – increasing descending activity from the higher motor centers which affects the concentric force output and as well as some reduced inhibitory mechanism that enhances the elastic recoil during the SSC. When there is no SSC power exercise such as in this study, the augmentation comes about through only the one avenue (increasing descending activity from the higher motor centers) and thus is of a much smaller amount.

Limitations to this study

There are a few possible limitations to this study, principally being the low number of subjects and the lack of a control group. With regards to the lack of a Control group, similar studies by the author that have utilized a Control group have illustrated that: If no direct intervention occurred between BT sets, then power remained unchanged (2, 3, 8), if high repetition work bouts occurred between BT power sets, then power output is decreased (2, 13) and if appropriate

CRC training strategies were interspersed between BT power sets, then power output is increased (3, 5, 7, 8). Thus power output appears to be quiet sensitive to training variable manipulation, but if no intervention in training occurs, power output can remain unchanged between sets within a workout. Various other authors have also reported no change in power output between sets without some form of active intervention (15-17, 19, 23, 25-28). Consequently this body of data concerning power output during CRC training illustrates no change in power output would occur without some direct intervention, but that power output is sensitive to training intervention. It is posited that the lack of a Control group would not affect the basic results of this study.

When dealing with elite or professional athletes low subject numbers are sometimes inevitable. However, the subjects were quite homogenous in many attributes, typified by the small standard deviation between them in their strength and anthropometric data. For example, the standard deviation from the mean was only about 8% for the 1RM BP and 4% in body mass. As a result of this homogeneity, acute changes in power output are readily observable, either by traditional statistical power analyses, the method of SMC or by analysing ES statistics. Thus by using eleven relatively homogenous, professional athletes the changes that occurred were quite evident, which may not occur with subjects with more disparate body types and strength and power levels. In this latter type of situation, small athletically worthwhile changes can get lost in the "noise" of larger inter-subject standard deviations (22). Therefore despite the low subject numbers and lack of a Control group, the author believes the results of this study are valid to athletic populations who are experienced in resistance training.

Another limitation is the lack of EMG data to quantify the origin or nature of any possible change in neural drive associated with the change in performance and thus the nature of any neural changes is speculative. Future studies may look to include EMG analysis, however the nature of this study was more a determination of training effect than the mechanistic nature of any possible change.

PRACTICAL APPLICATIONS

CRC training need not entail maximal resistances to evoke acute increases in power output. CRC training should consist of a medium-heavy "neural stimulation exercise" (eg. 60-80% 1RM x 2-6 repetitions) which emphasizes explosive strength/power, irrespective of whether the exercise is of a concentric-only or SSC nature. The performance of this exercise must remain explosive and should not be unduly fatiguing to the contractile or SSC elements. Typically the power training set during CRC would emphasize either "ballistic" (20-40% 1RM x 5-8 repetitions) or "maximal power" development (40-60% x 2-5 repetitions), again irrespective of the exercise being of a concentric-only or SSC nature. This type of CRC power training can or should be performed on a separate training day to maximal strength training.

Coaches may use 2 to 3-week cycles of concentric-only CRC training to emphasize the fast force capabilities of the contractile elements of the musculature followed by 2 to 3-week cycles of CRC using SSC version of exercises. This would theoretically enhance power through two separate avenues – increasing contractile fast force production brought about by the concentric-only CRC and enhanced SSC efficiency brought about through SSC CRC training.

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