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Acute Effect of Alternating Heavy and Light Resistances on Power Output During Upper-Body Complex Power Training

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ABSTRACT

This study investigated the effect on upper-body power output of manipulating resistances during contrast or complex power training. This power-training strategy typically entails the athlete alternating sets of a heavy resistance in a strength-oriented exercise with sets of lighter resistances in a power-oriented exercise. Sixteen rugby league players, who were experienced in power training and who performed complex training on a regular basis, served as subjects for this study and were divided equally into a control (Con) or experimental (Exp) group. Both groups were pre- and posttested for power output while performing explosive bench press throws in a Smith machine with a resistance of 50 kg (BT P50). The Exp group performed an intervention strategy of a 6-repetition set of bench presses with a resistance of 65% of 1 repetition maximum (65% 1RM) between tests. At the pretest occasion, no differences were observed between the groups in power output; however, at the posttesting, a significant difference in power output was observed between the groups in the BT P50. The 4.5% increase in the power output recorded during the posttesting BT P50 for the Exp group was determined to be significantly different from all other scores ($p \leq 0.05$). These data indicate that the performance of a set of heavy resistance strength training exercise between power training sets will acutely enhance power output in the second power training set. This effect has been previously theorized as possibly due to some combination of acute neural or mechanical adaptations.

Key Words: contrast loading, strength, neural, bench press, bench throw

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Introduction

Recently, the training method whereby sets of heavier and lighter resistances are alternated in order to elicit an increase in power output has received some attention (2, 5, 10, 11, 13–15, 20, 26). This method, often called complex training (10, 13) or contrast loading (2) has previously received scant scientific regard despite training recommendations and prescriptions dating back over 15 years (13).

Fleck and Kontor (13), who originally reported on the Russian complex method of training, described the alternating of sets of a very heavy resistance (>85% 1 repetition maximum [1RM]) in a strength-oriented exercise such as squats or bench press with sets of a lighter resistance (30–45% 1RM) in a power-oriented exercise such as jump squats or medicine ball throws (3, 22, 23, 26). A power-oriented exercise is an exercise where acceleration occurs through the full range of movement, resulting in higher movement speeds and accordingly power outputs (18, 19, 25). The rationale for this contrasting resistance method was that the heavy resistance strength-oriented set provided some sort of enhanced neural drive to the agonist musculature (13, 15). Theoretically, this increased neural activity would carry over to the lifting of the light resistance power-oriented exercise, resulting in a higher power output with this lighter resistance than would occur without the prior heavy resistance set (10, 13–15).

Recently, a number of studies have illustrated the significant acute effect that this training method has on jumping performance (14, 24, 26). These studies have typically involved heavy resistance squats or leg presses alternated with vertical jumps or lighter resistance jump squats. More recent studies have also reported significant enhancement of power output after alternating heavier and lighter resistance sets of merely a power-oriented exercise, in these cases jump squats (3, 5). However, despite the success of the studies listed above and recent training recommendations (3, 11), very little data exists validating the effects of contrasting loading on upper-body power output. Two recent studies that examined contrast-load training during upper-body power training could not determine any performance benefit or muscular or mechanical source of augmentation (10, 15). Ebben et al. (10)

Table 1. Description of subjects; mean (standard deviation).

	1RM BP	BT Pmax	Height	Mass (kg)	Age (y)
Exp	143.7 (20.0)	694 (80)	188.1 (4.2)	107.4 (6.9)*	23.3 (3.1)
Con	137.2 (15.1)	612 (73)	182.4 (7.0)	91.5 (7.4)	22.4 (1.9)

* Denotes difference between groups, $p \leq 0.05$.

reported no performance augmentation in the power exercise (medicine ball throwing) or possible mechanism of augmentation after heavy bench pressing with a resistance of about 90% 1RM. More recently, Hrysomallis and Kidgell (15) also reported no augmentation in performance of the power exercise (explosive push-ups) following the performance of a heavy resistance 5RM bench press set. These authors were unclear why nonsignificant results may occur with complex training for the upper body considering the amount of supporting data existing for the lower body.

The purpose of this study was to report the acute effects on power output of performing a heavy resistance bench press set between bench throw power sets in athletes experienced in contrast/complex upper-body power training.

Methods

Experimental Approach to the Problem

The approach to the problem used in this study entailed an intervention strategy whereby all subjects were pretested and posttested for power output during the bench throw power training exercise; however, the experimental subjects performed the intervention strategy of heavy bench pressing between power tests. This testing strategy was devised to garner data concerning the effect, if any, that the heavy bench pressing may have on consequent power output during the posttesting occasion.

Subjects

Sixteen rugby-league players participating in the national or state league and who possessed at least 1 year of experience in contrast/complex power training served as subjects for this study. They were informed of the nature of the study and voluntarily elected to participate in the testing and intervention sessions and were divided equally into an experimental (Exp) and control (Con) group. A description of the subjects is contained in Table 1.

Testing

Power output was tested during explosive bench press-style throws with an absolute resistance of 50 kg (BT P50) using the Plyometric Power System (PPS; Norsearch, Lismore, Australia), which has been described extensively elsewhere (3–9, 18, 19, 23, 24). Briefly, the PPS is a device whereby the displacement of the barbell is limited to the vertical plane, as in a Smith weight training machine. The linear bearings that are attached to each end of the barbell allow the barbell to slide about 2 hardened steel shafts with a minimum of friction. A rotary encoder attached to the machine produces pulses indicating the displacement of the barbell. The number of pulses, denoting barbell displacement, and the time of the barbell movement were measured by a counter timer board installed in the computer. The PPS software calculated the average mechanical power (in watts, W) output of the concentric phase of the bench press throws based on the displacement of the barbell (D), time of displacement (T), and mass of the barbell (M) ($M \times G \times D/T$ = power output in watts, where G = gravity). A test-retest reliability of $r = 0.92$ was previously established with a group of 12 subjects.

Prior to pretesting, subjects warmed up by performing 5 repetitions of both the bench press and bench throw exercise with resistances of 60 and 40 kg, respectively (5). After a 4-minute rest, the subjects performed the pretest, which consisted of 5 consecutive repetitions with the 50-kg resistance (Pre BT P50). Subjects were instructed to propel the barbell as explosively as possible and were given verbal encouragement throughout. Only the repetition with the highest average concentric power output was chosen and recorded for analysis. After 3 more minutes rest, the Con group repeated the test (Post BT P50).

The intervention strategy performed by the Exp group consisted of the subjects performing 6 repetitions of the free weight bench press exercise with a resistance of 65% of their 1RM BP. After 3 minutes of rest, the Exp group performed the Post BT P50 test. Thus, after warmup, both groups had performed a Pre and Post BT P50 power output test, with the Exp subjects also performing an intervention strategy of heavy resistance bench pressing between tests. This experimental design was implemented in order to observe if there had been any augmentation to power output through the intervention of the heavy resistance set in the Exp group.

Statistical Analyses

To determine if any difference in power output existed between the groups at either testing occasion, a two-way analysis of variance (ANOVA) with repeated mea-

Table 2. Power outputs (W) during bench press throws with a barbell resistance of 50 kg (BT P50) for the control and experimental groups; mean (standard deviation).

	Pre BT P50	Post BT P50
Exp	595 (57)	621 (66)*
Con	575 (59)	574 (67)

* Denotes difference between groups, $p \leq 0.05$.

sures was used. Significance was accepted at an alpha level of $p \leq 0.05$ for all testing.

Results

The results are outlined in Table 2. At the pretest occasion, no differences were observed between the groups in power output; however, at the posttesting, a significant difference was observed between the groups in the BT P50. The 4.5% increase in the power output recorded during the posttesting BT P50 for the Exp group was determined to be significantly different from all other scores ($p \leq 0.05$).

Discussion

Similar to previous results for the lower body (1, 3, 5, 14, 20, 26) but dissimilar to previous upper-body studies (10, 15), the method of alternating heavy and light resistances had a small but significant acute effect on power output. This discussion will now focus on mechanisms via which augmentation to power output may occur as a result of the intervention of a heavy resistance set during complex training and the reasons why the current study reported significant results, in contrast with the previous upper-body studies.

The reason why power output is increased by the intervention of a contrasting heavy resistance set may be due to short-term neural or mechanical adaptations or combinations of both. In the studies listed above, the various authors have postulated on why the alternating of heavy and light resistances may increase power output. These authors have surmised that this acute augmentation in power output may be the result of neural adaptations such as increased descending activity from the higher motor centers, direct myoelectrical potentiation, increased synchronization of motor unit firing, reduced peripheral inhibition from the Golgi tendon organ (GTO), reduced central inhibition from the Renshaw cell, and enhanced reciprocal inhibition of the antagonist musculature (5, 10, 11, 13, 14, 26). None of these possible mechanisms need be exclusive and a number of the above mechanisms could function together simultaneously.

Gulich and Schmidtbleicher (14) and Young et al. (26) rationalized that the intervention strategy must be a very heavy resistance of maximal or near-maximal intensity to increase motor unit activation (≥85–90% 1RM). The fact that Young et al. (26) found greatest augmentation to jumping height in the strongest athletes using the heaviest 5RM loads would tend to support the fact that some tension-sensitive mechanisms were at least partly responsible. However, the present study entailed a much lower resistance of 65% 1RM as the contrast set. As 5 repetitions performed at a resistance of 65% 1RM is insufficient to cause a full tetany to occur, the posttetanic augmentation as theorized by Gulich and Schmidtbleicher (14) could not fully account for the augmentation to power output in the current study. Previous lower-body studies have also reported significant results with much lighter contrasting resistances (5). This would suggest that other neural strategies associated with lifting heavier, though not maximal, resistances can be used for contrast/complex training.

If the intervention mechanism is related to resistance but not necessarily to the heaviest resistance, then some tension-sensitive mechanism of the neuromuscular system that is affected by resistance/force must be at least partly responsible (14). Tension-sensitive receptors such as the Golgi tendon organ and Renshaw cell could possibly account for this consequent change in power output by reducing their negative inhibitory feedback (2, 16). An effective relaxation of the antagonist muscles to prevent excessive cocontraction must also be considered an option available to the neuromuscular system (17). Thus, it is feasible that the heavier contrasting resistance set may enable athletes to be better able to process and override inhibitory signals that occur in ensuing sets. However, the only previous study that assessed neural output levels during upper-body contrast/complex training found no change in electromyographic activity during the performance of the power exercise, but this may not be unexpected as no performance augmentation was reported either (10). Therefore, it is still unclear which, if any, neural mechanism may be responsible when augmentation to power output occurs during complex training.

Another possible avenue of augmentation is the stiffness of the musculo-tendinous unit and specifically the series elastic component (SEC) (16, 21–23, 25). Depending on the resistance to be overcome, some increased SEC stiffness may be useful in regulating force output during stretch-shorten cycle movements (16, 22, 25). A heavier resistance set of 65% 1RM may temporarily result in a favorable increase in SEC stiffness, proving favorable for power production in ensuing power training sets. However, a very heavy resistance (85–90% 1RM) set may temporarily result in a SEC that is stiffer than would be optimal considering the lighter resistance to be overcome in the power movement (22, 25).

Therefore, at this stage, it is not known exactly via which avenues an increase in power output may occur, but conceivably some acute neural adaptations and stiffness regulation of the SEC probably account for the effect. How long this effect may last is not yet known, but this would have implications for athletes who use contrast loading complexes in sport warm-ups. For example, how long could any possible augmentation to power performance last from using a weighted bat donut for baseball batters? Conceivably, if the augmentation is primarily accounted for by neural or stiffness regulation, then the effects may dissipate after a matter of minutes (perhaps less than 10 minutes). Further research into the length of time power remains elevated is warranted.

The reason why a significant result was obtained in this investigation but not in previous upper-body studies may be due to a number of reasons. Primarily, the level of the intervention resistance was not as high in this study compared with the previous upper-body studies. In the 2 studies that investigated the upper-body during complex training, subjects performed 4–5 repetitions at a resistances of about 85–90% 1RM in the bench press alternated with medicine ball drop throws or explosive push-ups, with no performance augmentation reported in either study (10, 15). In the present study, a resistance of only 65% 1RM precipitated an increase in power output during the ensuing power set. This result would directly indicate that very heavy resistances are not required to enhance the contrast effect during upper-body complex training. The use of very heavy resistances of 85–90% 1RM in contrast loading for the upper body may not be as effective as for the lower body, possible due to the smaller muscle mass involved. Certainly some pilot work involved with this investigation found equivocal results when a resistance of 90% 1RM was used for the heavy resistance set. Perhaps any intervention resistance that is markedly heavier than the power resistance and hence provides a contrast may be effective during complex training.

Another reason why power output was enhanced in this study and not in the other upper-body studies may also be the very heavy resistance being performed at much slower lifting speeds (18). According to the speed-control theory (12), the neural output may have been attuned to the slower speed of very heavy bench pressing, reducing the possibility of favorable neural adaptations occurring during the ensuing faster power exercise. Thus, it is possible that very heavy resistances of >85–90% 1RM, with inherently slower lifting speeds, may not provide an optimal stimulus for upper-body complex training, as they may temporarily attune the neural output to a slower speed than is optimal for maximum power production. However, a resistance of 65% 1RM as used in this study still allows for high lifting speeds (19) and is also markedly heavier than the typical power training resistances. In the present study, the alternated resistances were in sharp contrast with each other (mean resistance of 91.9 ± 9.3 kg during bench press alternated with 50 kg during bench throws).

Finally, the subjects in this study were trained power athletes who performed contrasting resistance complex training on a regular basis (1–2 per week) and were much stronger (by about an average of 50–60%) than the subjects in previous upper-body studies (15). Young et al. (26) reported greater performance augmentation in the strongest subjects, indicating strength levels may be an important predictor of success for contrasting resistance complex training. For example, the 2 strongest subjects in the present study had an average augmentation to performance of 6.2% compared with 0.8% for the 2 least strong subjects. This may partially explain the lack of significant results reported previously for the upper body (10, 15).

Based on this result and research on lower-body power output, coaches need not have to rely on extremely heavy resistances to provide a neural training stimulus during complex training. It is conceivable that any resistance that is markedly heavier than the power training resistance may elicit a favorable contrast loading training response (1–3, 5). The importance of this concept is that if strength coaches use a heavy-light system within the training week, they could easily integrate contrasting resistance training into the light training day of the week (e.g., alternating light-day bench presses of 65–75% 1RM with bench throws of 20–50% 1RM).

It must be noted that the lighter power exercise should be an exercise in which full acceleration can occur through the full range of motion (e.g., the weight does not need to be decelerated to remain in the subjects hand at the completion of a repetition). If a traditional exercise such as squat or bench press is performed with low resistances of 30–45% 1RM, then the large deceleration epoch that occurs at the end of the range of motion severely compromises power output (18, 19, 23, 24). Therefore it may be better to perform bench press throws (in a Smith machine), explosive push-ups, medicine ball throws, and barbell jump squats or other jumps with the lighter resistances than to attempt to perform explosive versions of the traditional bench press and squat exercises. The traditional exercises of bench press and squat are reserved for the heavy resistance set and/or strength development. Full acceleration exercises (e.g., throwing, jumping, strength training pulling movements) are required as the power training exercise. Based on these results, it is also recommended that future training and research for upper-body power training utilize resistances of 60–70% 1RM for the heavy resistance set and 25–40% 1RM for the power training set to garner significant results.

Practical Applications

An increase in power output can occur during upper-body power training when sets of a heavy-resistance, strength-oriented exercise are alternated with sets of a lighter, power-oriented training exercise. In this study, a resistance of 65% 1RM, a resistance that is lower than is commonly recommended (10, 15, 26), was heavy enough to elicit an increase in power output during the performance of the ensuing power training exercise. Resistances of 65% 1RM are typical of the resistances that many coaches often prescribe on the lighter training day of a week and accordingly contrast loading complexes of exercises could be easily integrated into the training routine on this day (3). Typically, the heavy resistance set could be about twice the resistance of the power training set, which should be enough of a contrast to have the desired stimulatory effect on the neuromuscular system. Common examples for the upper body would be bench press alternated with lighter 1-hand or 2-hand bench press throws in a Smith machine, various forms of explosive push-ups or medicine ball throwing exercises.

It is possible that acute augmentation to sport performance could be achieved by the use of contrast loading in the latter phases of the warmup. The use of weighted bat donuts, slightly heavier than normal balls or throwing implements (shot-putt, discus, hammer) are examples currently used in upper-body power-sports warmups. Astute coaches should be able to devise methods to use this technique in many other upper-body sports.

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