Journal of Strength and Conditioning Research, 2005, 19(1), 202–205

Acute Effect on Power Output of Alternating an Agonist and Antagonist Muscle Exercise During Complex Training

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Abstract. Baker, D., and R.U. Newton. Acute effect on power output of alternating an agonist and antagonist muscle exercise during complex training. *J. Strength Cond. Res. 19(1):202–205. 2005.*—The efficient coordination of agonist and antagonist muscles is one of the important early adaptations in resistance training responsible for large increases in strength. Weak antagonist muscles may limit speed of movement; consequently, strengthening them leads to an increase in agonist muscle movement speed. However, the effect of combining agonist and antagonist muscle exercises into a power training session has been largely unexplored. The purpose of this study was to determine if a training complex consisting of contrasting agonist and antagonist muscle exercises would result in an acute increase in power output in the agonist power exercise. Twenty-four college-aged rugby league players who were experienced in combined strength and power training served as subjects for this study. They were equally assigned to an experimental (Antag) or control (Con) group and were no different in age, height, body mass, strength, or maximal power. Power output was assessed during bench press throws with a 40-kg resistance (BT P40) with the Plyometric Power System training device. After warming up, the Con group performed the BT P40 tests 3 minutes apart to determine if any acute augmentation to power output could occur without intervention. The Antag group also performed the BT P40 tests; however, an intervention strategy of a set of bench pulls, which is an antagonistic action to the bench throw, was performed between tests to determine if this would acutely affect power output during the second BT P40 test. Although the power output for the Con group remained unaltered between test occasions, the significant 4.7% increase for the Antag group indicates that a strategy of alternating agonist and antagonist muscle exercises may acutely increase power output during complex power training. This result may affect power training and specific warm-up strategies used in ballistic sports activities, with increased emphasis placed upon the antagonist muscle groups.

Key Words. reciprocal inhibition, triphasic pattern, acceleration

Introduction

The efficient coordination of agonist and antagonist muscles is one of the important early adaptations in resistance training responsible for large increases in strength or torque (7, 9, 17). This appears to be achieved by a neural strategy of enhanced reciprocal inhibition of the antagonist musculature. However, little research has been conducted examining the role of agonist and antagonist muscle interplay in power movements. The faster lifting speeds involved in power training may make it more difficult (as compared with traditional strength training) to efficiently control unwarranted cocontraction between agonist and antagonist muscle groups, potentially reducing power output (18).

Weak antagonist muscles may limit speed of movement (20); consequently, strengthening them leads to an increase in agonist muscle movement speed (16). It would therefore seem prudent to strengthen the antagonist muscles involved in the power-training action or movement. One method of integrating strength and power training into a training session has been labeled as complex or contrast training (1–5, 10, 11, 13, 14, 23). Traditional recommendations for contrast loading have included the alternating of sets of heavy and light resistances in similar agonist muscle exercises or movement patterns (13, 14, 23). This method of alternating contrasting resistances to enhance power output has been substantiated for the lower body on a number of different occasions (1, 3, 4, 14, 23). Heavy resistance exercises increase the concentric rate of force development, whereas lighter, plyometric exercises enhance eccentric rate of force development (20). This combination of effects partially explains the success of this combined method of power training. Regarding upper-body complex training, only 1 study to date has documented any significant effects (5), with other studies reporting no augmentation to power output or performance (10, 15).

Although the traditional method of complex power training has entailed contrasting resistances in similar agonist muscle exercises (e.g., alternating heavy and light resistances in squats and jump squats), no research exists concerning complexes of contrasting muscle actions. If some augmentation to force output occurs because of a neural strategy of enhanced reciprocal inhibition of the antagonist musculature, then contrasting strategies involving the antagonist musculature may also prove fruitful for enhancing power output. In support of this theory, Burke et al. (8) recently reported that a high-speed antagonist muscle contraction immediately preceding an agonist muscle contraction resulted in increased torque during the agonist contraction (isokinetic seated bench press and pull movements). As yet, it has not been determined if the effect they reported would transfer between alternating sets of agonist and antagonist muscle exercises in typical isoinertial resistance training.

The purpose of this study was to examine the acute effect on power output of alternating agonist and antagonist muscle exercises during typical isoinertial complex power training.

Methods

Experimental Approach to the Problem

An intervention study was implemented to determine if power output generated during an exercise could be

TABLE 1. Description of subjects (mean ± *SD*).*

Group	Age (y)	Height (cm)	Body mass (kg)	1RM BP (kg)	BT Pmax (W)
Antag (n = 12)	18.7 ± 0.65	184.5 ± 6.0	87.6 ± 6.8	111.2 ± 6.9	522 ± 43
Con (n = 12)	19.0 ± 1.0	184.1 ± 5.3	93.0 ± 9.3	115.8 ± 15.1	554 ± 84

* 1RM BP = 1 repetition maximum bench press; BT Pmax = bench press throw maximal power output; Antag = experimental; Con = control.

acutely affected by the subsequent performance of an antagonist muscle exercise. This entailed 2 groups of athletes performing a pretest of power output during bench press throws with a standard resistance. The control group (Con) would then repeat this test 3 minutes later to provide data pertinent to whether power output could be acutely affected without some form of active intervention. The experimental group (Antag) would perform the same tests; however, an intervention strategy of performing a set of an antagonist muscle exercise of bench pulls between power tests would be implemented to determine whether power output could be acutely affected.

TABLE 2. The acute effect on power output of imposing a set of antagonist prone bench pulls between sets of bench press throws with a 40-kg resistance (mean ± *SD*).†

Group	Power output (W)	
	Pretest	Posttest
Antag	468 ± 31	490 ± 38*
Con	508 ± 54	505 ± 59

* Significantly different from pretest occasion, $p < 0.05$.
† Antag = experimental; Con = control.

Subjects

Twenty-four college-aged rugby league players who had at least 1 year of resistance-training experience and specifically at least 6 months of contrast and 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 they were equally assigned to the Con or Antag group. A description of the subjects is contained in Table 1.

Testing Procedures

Power output was tested during explosive bench press–style throws with an absolute resistance of 40 kg (BT P40) with the Plyometric Power System (PPS; Norsearch, Lismore, Australia), which has been described extensively elsewhere by various authors (4–6, 18–22). 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 that indicate the displacement of the barbell. In this study, the number of pulses 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 output in watts (W) of the concentric phase of the bench press throws based upon the displacement of the barbell, time of displacement, and mass of barbell (×gravity) data (m × g × d / t = W, where G = acceleration due to gravity). Test-retest reliability of r = 0.92 was previously established with a group of 12 subjects.

Before pretesting, subjects warmed up by performing 5 repetitions of both the bench press (60 kg) and bench throw exercise (20 kg). After 3 minutes of rest, the subjects performed the pretest, which consisted of 5 consecutive repetitions with the investigated resistance (pre–BT P40). Only the repetition with the highest concentric average power output was chosen and recorded for analysis. The Con subjects were posttested after 3 minutes of rest. This provided data pertinent as to whether any augmentation to power output may occur without active intervention.

The Antag group performed the intervention strategy of a set of a moderately heavy-resistance antagonist muscle action exercise. In this case, the prone bench pull with a free-weight barbell was used. For this exercise, the subjects lay prone on a special high bench with the barbell placed upon the floor directly under their chest. The subjects were instructed to pull the barbell as forcefully as possible toward their chest-abdomen region for 8 repetitions. The construction of the bench prevented any impact of the barbell with a subject's body. The subjects were allowed to virtually drop the bar to the floor to lessen any potential effect of fatigue that may have arisen from the slow or careful eccentric lowering of the barbell. This meant about a 1- to 2-second rest was between consecutive repetitions as the subjects regripped the bar. These strategies were implemented to ensure the subjects performed the bench pulls in a manner similar to the bench throws (i.e., explosively and with loss of hand contact with the bar). The resistance of the barbell for the bench pull was set at 50% of each subject's 1 repetition maximum bench press. This meant the subjects were bench throwing a mass of 40 kg and prone bench pulling a mean barbell mass of 56.2 kg (±3.8 kg). The Antag group was then retested for BT P40 3 minutes after completing the intervention strategy of bench pulls.

Statistical Analyses

To determine the effect of the intervention on test occasion, a repeated-measures analysis of variance was used. Significance was accepted at an alpha level of $p \leq 0.05$ for all comparisons.

RESULTS

The results are presented in Table 2. The 4.7% increase in the posttest BT P40 as a result of the intervention strategy of heavy antagonist muscle bench pulls for the Antag group was statistically significant. The power output for the BT P40 remained unchanged in the Con group between test occasions.

Discussion

The Antag group increased power output as a result of the intervention of a set of antagonist muscle bench pulls between sets of the power exercise, whereas the power output for the Con group remained unaltered. The acute increase in power output as a result of the contrasting contraction strategy supports the effect reported by Burke et al (8). If this augmentation to power output was due to a neural strategy of enhanced reciprocal inhibition of the antagonist musculature, then the nature of these strategies might need to be discussed to provoke further research in this area.

During some rapid, ballistic movements of the limbs, a particular neural pattern of motor-unit firing known as the triphasic or "ABC" pattern becomes evident (16). This pattern is characterized by a large *action* burst of activity by the agonist musculature followed by a shorter *braking* burst of activity by the antagonist musculature of the limb and finally a short *clamping* burst again by the agonist muscles to complete the movement. Because the net force produced during a movement is a trade-off between the force of the agonist muscles and the counteracting force of the antagonist muscles (7, 9), the interaction between these bursts of myoelectrical activity warrants interest. Strength training reduces the interfering effect of cocontraction between agonist and antagonist muscles in rapid movements (16). Therefore, a more efficient control of the ABC pattern may benefit the power athlete.

For example, the "maximal resistance" theory of myoelectrical augmentation (10, 11, 13, 14, 23) in agonist muscle complex training (e.g., alternating very heavy squats and light jump squats) would rely on an increase in the action burst of activity in the agonist muscles, caused by enhanced neural stimulation resulting from the very heavy squats, to facilitate the increase in power during the ensuing exercise. This would be the "posttetanic potentiation" advocated by Gulich and Schmidtbleicher (14). However, in this study a contrasting antagonist muscle contraction was alternated with the power exercise; hence, it is not readily conceivable how this strategy could directly affect the amount of activity of the action burst of the agonists. It is conceivable that the heavy bench pull set altered the timing of the braking burst of the antagonist muscles during the agonist muscle power exercise. A shorter, more succinct braking phase would mean that the agonist muscle action burst could be continued longer into the total contraction time (16). Given that the total concentric contraction time during bench throws with this sort of resistance is only around 500–650 milliseconds (19), any significant increase in action time and reduction in braking time could be beneficial. Indeed, Jaric et al. (16) demonstrated that increased strength of the antagonist muscles as a result of training resulted in increased speed during ballistic elbow flexion movements. They demonstrated that the increased strength allowed for a shorter braking period, a greater relative acceleration period, and favorable alterations in the ABC myoelectrical patterns. Some evidence also suggests that increased power output could result without increased agonist or antagonist muscle strength if a more synchronous firing of motor units within a muscle occurred within the first 60–100 milliseconds of the contraction (18). Conceivably, complexes of agonist and antagonist muscle exercises may aid in these situations.

Although this study illustrates the acute effect on power output of alternating agonist and antagonist muscle exercises during complex training, it is unknown if this effect would transfer to greater increases in power output over long-term periods. Researchers need to perform longitudinal studies of many months duration that compare the development of power through various intervention strategies used in complex training with the more traditional straight-sets method of power training. Conceivably, this agonist-antagonist strategy could also be used as a specific warm-up strategy to acutely increase power output for sports activities. For example, baseball pitchers and tennis players could alternate antagonist shoulder external rotation exercises (e.g., with rubber tubing) with their agonist pitching and serving drills.

When selecting antagonist muscle power-training exercises, it may be even more appropriate to choose exercises that allow acceleration for the entire range of movement. For rapid upper-limb movements, this could mean throwing movements alternated with rapid pulling movements, such as the top pulls and power cleans from hang or boxes. The alternating of agonist and antagonist muscle power exercises may be an area for future exploration for strength scientists and coaches.

Practical Applications

Although traditional contrasting resistance and complex training recommendations have focused on the alternating of heavier and lighter resistances in exercises of similar agonist muscle movement patterns, the alternating of agonist and antagonist muscle movement patterns may be useful in ballistic power training. The effect of directly stimulating the antagonist musculature in a power-training complex may be to reduce the time necessary for the braking phase that occurs about halfway through the ballistic limb movement in the ensuing agonist muscle movement. In turn, this may increase resultant force, speed, and power. Practical combinations of agonist and antagonist muscle exercises for the upper body would be bench press throws and bench pulls; bench press throws and power clean from hang; or various forms of explosive medicine ball throwing alternated with explosive pulling, shoulder external rotation, and elbow flexion exercises (with resistance provided by dumbbells, rubber tubing, medicine balls, or sports implements in some cases).

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