The Load That Maximizes the Average Mechanical Power Output During Explosive Bench Press Throws in Highly Trained Athletes

DANIEL BAKER,1 STEVEN NANCE,2 AND MICHAEL MOORE2

1Department of Sport and Exercise Science, Sunshine Coast University, QLD, Australia; 2Brisbane Broncos Rugby League Club, Red Hill, QLD, Australia.

ABSTRACT

The power output generated with different barbell loads and which resistance generated the maximum mechanical power output (Pmax) during explosive bench press-type throws (BT) in a smith machine device were investigated in power-trained athletes. Thirty-one rugby league players were tested for 1 repetition maximum (1RM) free-weight bench press strength (1RM BP). Maximal power output was assessed by the Plyometric Power System during BT using resistances of 40, 50, 60, 70, and 80 kg (BT P40, BT P50, BT P60, BT P70, and BT P80). It was found that BT Pmax occurred with resistance of 70.1 ± 7.9 kg, representing 55 ± 5.3% of 1RM BP of 129.7 ± 14.3 kg. The power output with all loads except the BT P70 were different from the BT Pmax. The BT P70 and BT P80 were not different from each other. Furthermore, the BT P60 and BT P80 were not different from each other. This suggests that although resistances of 55% 1RM BP may maximize power output during explosive BT, loads in the range of 46±62% also allow for high power outputs. Resistances of 31±45% of 1RM BP resulted in significantly lower power outputs. Compared with previous research of BT in strength-trained athletes, the results of this investigation suggest that power-trained athletes may generate their Pmax at higher percentages of 1RM.

Key Words: percentage of 1RM, strength, Pmax


Introduction

The use of resistance training methods to increase muscle strength, speed, and power for improving sports performance would appear widespread. Since most sports require movements performed with both force and velocity, the product of force and velocity, power, is of considerable interest to strength and conditioning coaches.

Power may be affected by force- or velocity-orientated training methods. Thus, considerable debate exists concerning not only methods to produce power adaptations but also the “optimal” resistances for power adaptations (29). Some research advocates low-resistance (<30% of 1 repetition maximum [1RM]), high-velocity (speed-oriented) training (12) or high-resistance (>80% of 1RM), low-velocity (strength-oriented) training to produce power adaptations (6, 23).

Thus, training with either strength- or speed-oriented methods may lead to an improvement in muscular function through specific adaptations rather than through a broad spectrum of power adaptations (26–28).

More recently, research has indicated a combination of methods, through implementing both speed-oriented and strength-oriented training strategies (1, 14) or through a specific maximum mechanical power output (Pmax) training method (28), may develop power and various performance measures more efficiently. The Pmax load method of training may lead to a broader range of adaptations than the specific adaptations, which appear to occur through either strength-oriented or speed-oriented training alone (26, 28). This may be rationalized as due to favorable neural and muscle fiber adaptations (24).

For Pmax training, debate exists regarding which range of resistances allows power to be maximized during resistance exercises. A number of studies support the use of loads of 30–50% of 1RM (4, 5, 12, 15–17, 20). These studies have all used college men who were either untrained or strength trained. Researchers and strength and conditioning coaches dealing with specifically power-trained athletes have advocated slightly higher resistances of 40–70% of 1RM to maximize power output (11, 21, 24). Poprawski (21) stated that stronger athletes use loads that are a higher percentage of 1RM (70%), and conversely less strong athletes use loads representing lower percentage of 1RM (50%) to maximize power training adaptations. Tidow
(24), reviewing a number of non–English-language research papers, stated that most research supported the use of loads within the range of 30–70% of 1RM. He further recommended the use of 40–60% of 1RM for the development of explosive speed strength (power).

The purpose of this article was to investigate whether any difference existed in the power output generated with various barbell loads during an exercise commonly used to develop upper-body power and, therefore, if any differences existed in the resistance (percentage of 1RM) that allowed for the attainment of Pmax.

**Methods**

Thirty-one rugby league players, 18 professional and 13 semiprofessionals, were tested for maximum upper-body strength (1RM bench press [BP]) and power output with various barbell loads to determine if differences existed in power output and, therefore, if any differences existed in the load (percentage of 1RM) that allowed for the attainment of Pmax. These athletes were considered as one group, because previous pilot testing had illustrated no significant differences in body mass, height, 1RM BP, or upper-body Pmax ($p = 0.09$) between the groups.

**Subjects**

Thirty-one rugby league football players with a mean $\pm SD$ age, height, and body mass of $22.2 \pm 3.5$ years, $181.1 \pm 7.9$ cm, and $92.0 \pm 11.1$ kg, respectively, were studied. All subjects were members of the same football club and gave informed consent to participate in the testing, which was implemented as part of their scheduled program. All subjects had been in current training, which had entailed the heavy resistance BP and explosive bench press throw (BT) exercises, for a continuous period of at least 6 months before testing.

**Testing**

All testing was completed at the end of a periodized strength and power training cycle to ensure that all athletes would be in a state of maximal strength and power. To control for order effect, the order of testing was altered. Thirteen subjects completed testing with the order being 1RM BP performed first and BT testing following. Seven of the subjects performed the BT testing first followed by the 1RM BP. A 10-minute rest was allowed between testing. Eleven of the subjects completed their testing on separate days (48 hours apart), with the 1RM BP being performed on the first day.

Maximum strength was assessed by a 1RM BP performed with a free-weight Olympic-style barbell using the methods outlined by Baker et al. (3). After warming up with progressively heavier loads, the athletes attempted a 1RM load that had been predetermined by their strength coach based on recent training history and previous maximum test results. If the athlete was successful with this load, he was allowed to attempt another load(s) until both the athlete and the strength coach were confident that a 1RM had been attained. This usually entailed only one more attempt.

For the 1RM BP, the bar could not be bounced off the chest, the feet had to remain in contact with the floor, and the buttocks had to remain in contact with the bench.

**Power Testing**

The Pmax was assessed during a flat BT activity performed within the Plyometric Power System, which has been described elsewhere (14, 19, 20, 26, 28). For the BT, the athlete performed 3 consecutive stretch-shorten cycle repetitions against absolute loads of 40, 50, 60, 70, and 80 kg (BT P40, BT P50, BT P60, BT P70, and BT P80), performed in that order, with approximately 5-minute rests between loads. These absolute loads, rather than loads individually predetermined using selected percentages of 1RM, were used following the precedent of Hakkinen and Komi (9, 10) and Mayhew et al. (15). These absolute loads represented approximately 31, 39, 46, 54, and 62% of the group mean 1RM BP. The athlete assumed the same lifting position as for the bench press, with the feet placed on the floor and a self-selected grip that they had been constantly using in training for this exercise. The average mechanical power output for the concentric phase of each load was determined by the software of the Plyometric Power System based on the mass of the barbell, the displacement of the barbell, and the time taken for the displacement of the barbell. The highest score for each load was recorded and used for analysis.

**Statistical Analyses**

The mean and SD were determined for the power output for each load, the maximal power output and load, and 1RM and percentage of 1RM that maximized power output. The results for each of the power outputs were compared using a 1-way analysis of variance (ANOVA). If a significant effect of load was found, Fisher Post Least Square Difference (PLSD) post hoc comparisons were performed to determine which loads produced significantly different power outputs. A factorial ANOVA was also used to determine if the testing order affected the percentage of 1RM BP that maximized the power output. Statistical significance was accepted at an $\alpha$ level of $p \leq 0.05$.

**Results**

The mean 1RM BP and BT Pmax were $129.7 \pm 14.3$ kg and $598 \pm 99$ W, respectively. The results for BT P40, BT P50, BT P60, BT P70, and BT P80 are contained in Table 1. The Pmax occurred at a mean load of $70.1 \pm 7.9$ kg, representing $54.9 \pm 5.3\%$ of the 1RM BP. The Pmax output was significantly different to BT P40, BT
Table 1. The power output produced with various barbell loads during explosive bench throws in 31 power-trained rugby league players (mean ± SD).*

<table>
<thead>
<tr>
<th>Power output (W)</th>
<th>BT P40</th>
<th>BT P50</th>
<th>BT P60</th>
<th>BT P70</th>
<th>BT P80</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>482 ± 54</td>
<td>533 ± 70</td>
<td>568 ± 83</td>
<td>588 ± 95</td>
<td>580 ± 112</td>
</tr>
</tbody>
</table>

* BT P40, BT P50, BT P60, BT P70, and BT P80 indicate bench press throws using resistances of 40, 50, 60, 70, and 80 kg, respectively.

P50, BT P60, and BT P80 but not BT P70. The BT P70 and BT P80 were not different than each other. Furthermore, the BT P60 and BT P80 were not different than each other. Both the BT P40 and BT P50 were different than all other test results.

There was no significant effect of the order of testing on the percentage of 1RM BP that maximized power output (55, 55.5, and 54.5% of 1RM BP, respectively, for the orders described above).

Discussion

The basic finding of this study is that there is a significant difference in the power outputs generated during BT with barbell loads of 40–80 kg (31–62% of 1RM BP). Furthermore, the Pmax was achieved with a mean resistance of 55 ± 5% of 1RM BP, which is slightly higher than for previous studies. Therefore, BT performed with a resistance of 31–46% of 1RM BP resulted in lower power outputs than BT performed with 54 or 62% of 1RM BP. These results would have implications for those athletes who perform Pmax training or for athletes who perform explosive BT during their upper-body power training.

There was no difference between the power output achieved with 70- and 80-kg loads (54–62% of 1RM BP) and little difference between 60 and 80 kg (46 vs. 62% of 1RM BP) (Figure 1). Consequently, the optimal resistance for Pmax should in reality be considered to be an optimal range of resistances (about 50–60% of 1RM BP). Resistances close to the Pmax resistance (e.g., 46% of 1RM BP) also allowed for high, although not maximal (~3–4%), power outputs. This may also be of interest to athletes and coaches who perform power training.

This result is in general agreement with the hypothesis of a number of researchers and strength coaches (2, 11, 21, 24). The fact that resistances of 54–62% of 1RM results in higher power outputs than lighter resistances of 31–46% of 1RM is at odds to some research (4, 5, 12, 15, 17, 20). The possible reasons for this are discussed below.

A number of investigations were performed using the BP and different loads in a bid to ascertain the optimal resistance for Pmax. Bemben et al. (4) reported that Pmax during bench pressing occurred at 50% of the 1RM before and after training with inexperienced college men. In a follow-up study, Mayhew et al. (15) reported Pmax occurred at loads of 40% of 1RM BP. Santa Maria et al. (22) investigated the effect of loads of 100, 85, and 60% of the 2RM on power output during bench pressing. If a 2RM is equivalent to 95–96% of 1RM (13), then these loads would represent circa 95, 80, and 55% of the 1RM, respectively. They reported that the lightest load produced the Pmax for the loads investigated.

These studies used the traditional method of performing the BP exercise for power testing. However, traditionally performed BP with submaximal loads result in large deceleration epochs toward the end of the movement (25). To determine if a BT in a smith machine device would differ from traditionally performed BP, Newton et al. (19) compared power output, kinetic profiles, and muscle activation patterns in athletes who perform BP and BT with a load of 45% of 1RM. The BT resulted in a much larger power output compared with the BP because the traditional BP entailed a large deceleration phase. The deceleration phase was associated with diminished muscle activation, especially toward the end of the movement. These results suggest that Pmax would occur during a BT exercise (performed in a smith machine) rather than a traditional BP. Consequently, it would appear prudent to assess Pmax during the BT rather than the traditional BP. Consequently, this may partially explain some of the differences in results concerning resistances (percentage of 1RM) that allow for Pmax.

In light of this, Newton et al. (20) investigated the effects of loads of 15, 30, 45, 60, 75, and 90% of 1RM on BT Pmax. They reported that loads of 30 and 45% of 1RM BP produced the BT Pmax. The reduction in power output with heavier loads can be ascribed as...
due to a greater decrease in the velocity compared with the proportional increase in force (20).

It is interesting to compare the research of Newton et al. (20), who reported Pmax loads of 30–45% of 1RM BP, to the present research, which illustrated that Pmax occurred at 55 ± 5.3% of 1RM BP.

Although methodological factors may account for some of this difference, it is possible that the greater specific power training experiences of the current group could partially explain this apparent upward trend in the resistance that allowed for the attainment of Pmax. The subjects studied by Newton et al. (20) were experienced in weight training but not specifically experienced in power training exercises. The current subject group was composed of specifically power-trained athletes who performed BT, jump squats, Olympic lifting exercises, and plyometrics during their usual training schedule. This increased exposure to the specific power training may have resulted in adaptations such that the muscles become inherently more powerful in their contractions, possibly through both neural and fiber-related favorable adaptations (18, 24).

Of interest, in a review of the English-language research, Baker (2) hypothesized that the Pmax resistance would depend on the nature of the exercise and the training experience of the athlete. For example, for Olympic lifting exercises (power clean, power snatch, jerks), powerlifts (squat and BP), and special power exercises such as jump squats and BT in a smith machine, the resistances may be 70–90%, 40–60%, and 30–60% of the relevant 1RM, respectively. He stated that athletes may need to train with submaximal power loads for a period before attempting to use Pmax resistances. This may be because of safety and physiological considerations.

Baker (2) further postulated that these ranges offered a window of power development that could be more readily fine-tuned, depending on the individual, the sport-specific time for force application, and the sport-specific degree of resistance to be overcome. Furthermore, the resistances for power training may need to be periodized or adjusted regularly rather than relying on the dogmatic use of one optimal load (e.g., lighter resistance to stress velocity at the beginning of a training cycle). These notions were also proposed by Newton et al. (20). However, very little research has actually been performed to confirm these hypotheses.

Based on this research, it would appear that a range of loads circa 50–60% of 1RM BP may prove useful in maximizing mechanical power output during the BT exercise. Lighter loads resulted in significantly lower power outputs, for example, by about 22% for a 31% of 1RM load. The effect of much higher loads (>80–90% of 1RM), as recommended by Buehrle and Schmidtbleicher (6, 23), was not directly investigated in this study but has also been shown to reduce power output during BP and BT (20, 22).

However, this does not preclude resistances from either end of the force or velocity spectrum from training. Heavy resistances may be necessary to maximize force and lighter resistances necessary to maximize velocity. Power is maximized with resistances in the range of 50–60% of 1RM. Furthermore, the research by Wilson et al. (26, 27) suggested a certain amount of specificity in the adaptations to the amount of resistance and methods of training, which may depend on the strength level of the athlete. A holistic approach to power training may allow for more inherently powerful contractions to occur across different movement patterns, presumably converting to enhanced sporting performance (18). For example, power may be affected by heavy resistance, high-force training for less strong athletes or by light resistance, high-velocity training for strong but less fast athletes, and maximum power training for a wide range of athletes. Certainly, the athletes involved in the present study had been performing a periodized training cycle that used a broad range of resistances (30–80 kg during BT and heavy resistance BT and plyometrics), as recommended by Newton and Kraemer (18).

Practical Applications

The Pmax was achieved with resistances of 55 ± 5.3% of the free-weight 1RM BP. However, loads in the range of 46–62% of 1RM also allow for high power outputs. If maximizing power output is the specific goal of a particular training session, then lighter resistances (30–46% of 1RM or less) and heavier resistances (>70% of 1RM) are not recommended when performing BT. However, this does not preclude resistances from either end of the force or velocity spectrum from training. Training may entail a combination of high-force training, high-velocity training, and maximum power training to improve power or sporting performance measures. However, although heavy and light resistances may aid in the training of power through different avenues, they do not maximize power output.

It may not be prudent to extrapolate these ranges of 1RM to other power training exercises yet because of differences in biomechanics between exercises (2, 7, 8).

When using Pmax loads, only 3–5 repetitions may be possible before there is a fatigue-related decrease of up to 10% in speed and power output (24). Consequently, Pmax training should be performed for few repetitions and possibly not during fatiguing hypertrophy-style training cycles.

References


