Peak power output in the bench pull is maximised after 4 weeks of specific power training

Russell I Jolley[1,2], Jon E Goodwin[1], and Daniel J Cleather[1]

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[1]School of Sport, Health and Applied Science, St. Mary's University, Twickenham, UK

[2]The Conditioning Centre, Poole, UK

Corresponding author

Daniel Cleather,

St. Mary's University, Waldegrave Road, Twickenham. TW1 4SX United Kingdom

Tel: +44 7973 873 516

Email: dancleather@hotmail.com / daniel.cleather@stmarys.ac.uk

ABSTRACT

Maximal power production has been shown to be a differentiating factor between playing levels in many sports and is thus a focus of many strength and conditioning programmes. We sought to evaluate the duration for which a strategy of training with the optimal load (that maximises power output) will be effective in producing improvements in power output in the bench pull. The optimal load that produced the maximum power output in the bench pull was determined for twenty-one male university athletes who were randomly assigned to a group that trained with their optimal load or a load 10% of their one repetition maximum below the optimal load. Both groups completed two sessions per week for 4 weeks, after which their power output capabilities were reassessed. They then trained for a further 3 weeks with a load that was modified to reflect changes in their optimal load. The cohort as a whole had improved their peak power output by 4.6% (p = 0.002, d = 0.290) after 4 weeks of training, but experienced no further increase after another 3 weeks of training. There were no significant differences in the response to training between the two groups. This study suggests that improvements in power output can be realised within a few weeks when training with the optimal load, but training in such a way for a longer duration may be ineffective. Strength and conditioning coaches should consider periodizing power training to maximise gains in power output capabilities.

Key search terms: optimal load, periodization, peaking, power-load curve, power profile, diminishing returns

INTRODUCTION

Muscular power has been shown to correlate with performance in athletic movements such as jumping, sprinting and agility tests, and with playing level in a number of sports (3,10,17,32,34). Therefore the efficient development of muscular power is a high priority for strength and conditioning programmes. It has been widely suggested that an effective method for increasing power output is to train with the load that permits the highest power output in a particular lift or movement, that is the optimal load (12,14,23,24,40). It should be noted however, that training with the optimal load alone may not be the most effective method for increasing power, and the most effective strategy may be dependent on the training status of the athlete or the sport they are involved in (12,24). Equally, the relative magnitude of the optimal load also appears to be dependent on factors including the relative strength of the athlete, the sex of the athlete, and the type of lift performed (12,24). It has also been suggested that training at the optimal load may be effective over a short period of 8-12 weeks but may not be the best strategy over a longer period of time (12). Equally, Baker (4) has suggested that training with the optimal load should be confined to the last few weeks of a training programme where it would function effectively as a "peaking" strategy. In order to ascertain the veracity of these recommendations it is necessary to evaluate the length of time that such a power training strategy will continue to deliver improvements in power output capacity.

Although it is widely assumed that training at the optimal load will have the greatest effect on power output improvements (12,14,23,24,40) other commentators have suggested that training slightly below the optimal load during in-season training is the best way to increase power output due to the effects of fatigue limiting power production (4). However, there is a lack of research exploring the effect of power training with loads above or below the optimal load.

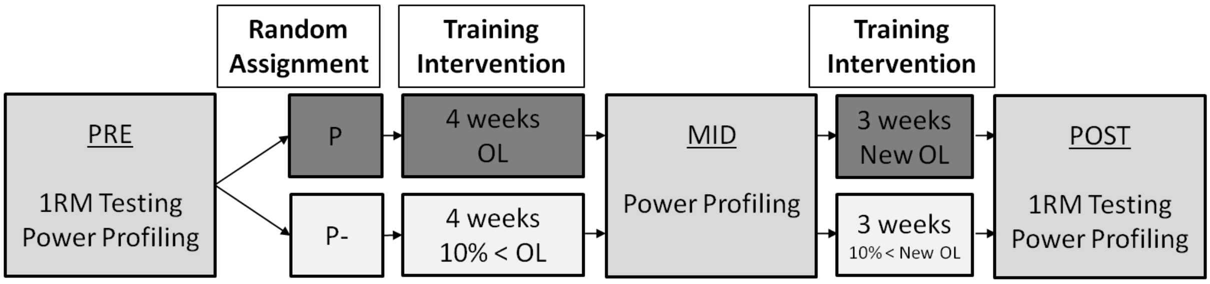
The purposes of this study were therefore twofold. Firstly, the study aimed to evaluate the time period for which a standard power training protocol would yield improvements in power output. Secondly, the study sought to ascertain if training at the optimal load would lead to greater gains in power production than training with a load just below the optimal load.

METHODS

Experimental Approach to the Problem

Twenty-one resistance trained men were tested for their 1 repetition maximum (1RM) and maximum power output at loads from 30-80% of their 1RM (i.e. their power profile) in the bench pull (BP). Their peak power output and the load at which it was achieved (i.e. the optimal load) was identified from the power profile. Subjects were then randomly assigned to two groups and performed 5 sets of 3 repetitions at either their optimal load or at 10% of their 1RM below their optimal load twice per week for 7 weeks. The subjects' power profiles were reassessed after 4 weeks of the training programme and the training loads adjusted to ensure that the subjects were still training at the designated load for the final 3 weeks of the training programme. Finally, the subjects were retested for their 1RM and power profile at the end of the training intervention. The experimental design is depicted in Figure 1.

Figure 1. The experimental design used in this study.



The BP exercise was chosen for this study as it is easy to perform and removes questions about including bodyweight in the calculations that arise in exercises like loaded jumping (35). It also allows the subject to accelerate the load throughout the whole lift, thereby removing the potential variance associated with the deceleration or projection of the load at the end of the concentric phase (9). Finally, the BP is a commonly used testing and training exercise across a range of different sports (1,15,16,21,27).

Subjects

Twenty-five male university athletes with at least 1 year of resistance training experience were recruited to take part in this study. The inclusion criteria stipulated that all subjects reported no upper body injuries or pathology in the 12 months prior to data collection. Subjects were randomly divided into a group that trained at their optimal load (P) and a group that trained with a weight 10% of their 1RM below their optimal load (P-). In addition, subjects had to complete 85% of the training sessions to be included in the final analysis and 4 subjects were excluded for not meeting this criterion (thus for P $n = 9$, and for P- $n = 12$). There were no significant ($p \leq 0.05$) differences in the subject characteristics at the start of the study (Table 1). Ethical clearance was granted by the institutional review board of St Mary's University College and subjects provided written informed consent.

Table 1. Subject characteristics given as mean ± standard deviation. There were no significant differences between the groups ($p \leq 0.05$).

	P	P-
n	9	12
Age (years)	21.7 ± 2.1	21.8 ± 1.5
Height (m)	1.84 ± 0.07	1.84 ± 0.08
Weight (kg)	83.9 ± 14.2	88.3 ± 11.7
1RM (kg)	73.1 ± 14.2	83.5 ± 10.0
Peak power output (W)	602 ± 128	672 ± 69
Optimal load (%1RM)	64.4 ± 7.3	64.2 ± 10.0

Sample Size Determination

The appropriate sample size was determined by considering the power of the study to detect differences in the peak power output between the two groups across the 3 time points. In particular, we determined the sample size necessary to achieve a power of 0.80 with a significance criterion of $\alpha = 0.05$. In order to calculate the sample size we employed the equation of Overall and Doyle (31) for longitudinal designs, assuming that the increase in power output would be linear across the course of the study, and that there would be no difference between the two groups at the start of the study. In addition we assumed that the correlation of the repeated measures was $\rho = 0.6$ (18). We assumed that the variation (i.e. the standard deviation) in the peak power output of the participants would be 35W. This was based on the results of Baker (5) who found the standard deviation of power output scores in the bench throw to range from 19-32W depending on the ability and age level of the subjects (in particular, the 36 university aged athletes who would be most similar to our cohort had a standard deviation of 32W). We also assumed that the average increase in power output over the course of the study for the cohort as a whole would be 10%, based upon the consideration of several short term upper body power training studies (19,20,28). Our experience with this cohort of athletes lead us to estimate that the initial mean peak power output would be 650W, thus we estimated that the average increase in power output for the cohort as a whole would be 65W. We therefore defined the minimum expected difference between the two groups to be half this value – that is 32.5W. These values lead to a required sample size of 14.6 subjects in each group, which we rounded up to 15. We thus aimed to recruit 30 total subjects however, unfortunately we fell a little short of this number.

Instrumentation

A linear force transducer (TENDO Weightlifting Analyser, TENDO Sports Machines, Slovak Republic) was used to record the maximum power output during each repetition. The TENDO unit has been previously assessed and shown to be accurate and reliable in the measurement of power in explosive movements (22,36). The unit was attached to the centre of the bar and placed directly beneath it to ensure a vertical cable alignment.

Procedures

Subjects completed initial testing in the 1st week (PRE; 1RM test followed by a day's rest then power profiling). They then trained for 4 weeks using either the optimal load identified from the power profile (P) or a load 10% of their 1RM below their optimal load (P-). Following this the subjects' power profiles were retested (MID) and training loads adjusted to ensure subjects continued to train at the appropriate load for their intervention group. They then trained for a further 3 weeks and then in the 10th week final testing took place (POST; 1RM test followed by a day's rest then power profiling).

For each testing session the subjects performed a standardised full body general warm up followed by a specific bar warm up (Table 2). They then performed the BP testing protocol for the day. Each lift started with the bar stationary beneath the bench with the bar supported at a height such that the subject's arms were straight. The subject then pulled the bar until it contacted the bench and lowered it under control whilst maintaining contact of their chest, hips and feet with the bench. For the 1RM testing the weight was increased in increments of 10kg then 2.5kg and subjects were permitted a maximum of 3 attempts at each load with 2-4 minutes rest between attempts (1). For the power profiling, subjects performed 2 repetitions at each of 30%, 40%, 50%, 60%, 70% and 80% of their 1RM (in ascending order) with 2-4 minutes rest between sets. The TENDO unit was used to determine the maximum power output for each load and then the load which permitted the greatest power output (the peak power) was taken to be the optimal load.

Table 2. The warm up protocol used prior to testing.

Exercise	Duration
General Warm Up	
Jog	5 mins
Skip	2 × 20m
Sidestep	2 × 20m
Carioca	2 × 20m
High Knee	2 × 20m
Heel Flick	2 × 20m
Sumo Squat	1 × 20m
Lunge Complex	1 × 20m
Inchworm	5 reps
Specific Bench Pull Warm Up	
Bar (20 kg)	10 reps
40 kg	5 reps
50 kg	3 reps

The training intervention involved the subjects performing 5 sets of 3 reps in the BP (using the appropriate load for their intervention group) with 3 minutes rest between sets on two separate occasions each week. The frequency and volume of the BP training programme were based upon the resistance guidelines of Baechle et al. (2). When performing the BP training subjects were continually supervised and instructed to lift the bar as fast as possible and to hit the pad on the bench apparatus as hard as possible to ensure there was no unnecessary deceleration of the bar. The BP training was incorporated within a full body strength and conditioning programme (consisting of 2 sessions each week) which utilised lower body strength and power exercises, upper body pressing and trunk stability training. The content of each subject's programme was individualised based upon their sporting needs, however upper body pulling exercises were standardised between the subjects. An example training programme is depicted in Table 3.

Table 3. An example of a typical programme completed by the subjects.

Exercise	Sets × Reps	Rest (s)
Session 1		
Stretch, Warm Up (Table 2)		
1. Bench Hip Lift	3×8	30
2a. Hang Clean	4×4	60
2b. Box Jump	4×3	90
3. Front Squat	1×10, 1×8, 1×6	120
4. Bench Pull	5×3	180
5a. Bench Press	3×8	30
5b. Plank March	3×8	30
5c. Side Plank Plus	3×8	30
Stretch		
Session 2		
Stretch, Warm Up (Table 2)		
1. Squat Circuit	3×1	30
2a. Hang Clean	4×4	60
2b. Tuck Jump	4×3	90
3. Trap Bar Deadlift	3×5	120
4. Bench Pull	5×3	180
5a. Military Press	3×5	30
5b. Chin Up	3×8	30
5c. Dumbbell Half Get Up	3×10	30
Stretch		

Statistical Analysis

Statistical procedures were performed using SPSS (Version 21, IBM). Repeated measures ANOVA was used to test for differences in power outputs at each load, peak power output, optimal load and 1RMs across the course of the study (the assumption of sphericity was tested with Mauchly's Test of Sphericity, and the Greenhouse Geisser adjustment employed if the assumption of sphericity was violated – this was only the case for power output at 50% of 1RM). Post hoc pairwise comparisons were Bonferroni adjusted to account for multiple comparisons. PRE to POST effect sizes were calculated using Cohen's *d* following the recommendations and interpretations of Rhea (33). Independent samples T-tests where used to test for differences between the two groups at PRE. Significance was determined *a priori* ($\alpha = 0.05$).

RESULTS

Subjects experienced a modest improvement in their 1RM BP across the course of the study (i.e. a significant main effect of time; $F(1,19) = 9.806$, $p = 0.005$, $d = 0.270$; Figure 2). There was a significant effect of time on peak power output for the cohort as a whole ($F(2,38) = 8.991$, $p = 0.001$). Post hoc testing suggested that the cohort significantly increased their peak power output from PRE to MID ($p = 0.002$, $d = 0.290$), but there was no further increase by POST (Figure 3a). The cohort as a whole also experienced a decrease in the optimal load (as a percentage of 1RM) across the course of the study which approached significance (i.e. a main effect of time; $F(2,38) = 3.188$, $p = 0.052$, $d = 0.590$; Figure 3b). This decrease was a result of both the increased 1RM (Figure 2) and also a decrease in the absolute load at which peak power was expressed (which fell from 64.2% of PRE 1RM to 61.4% of PRE 1RM at POST; see also the frequency of peak power loads in Table 4).

Figure 2. PRE and POST bench pull 1RM performance (kg) for each group (* = significant difference from PRE to POST for the cohort as a whole, p = 0.005).

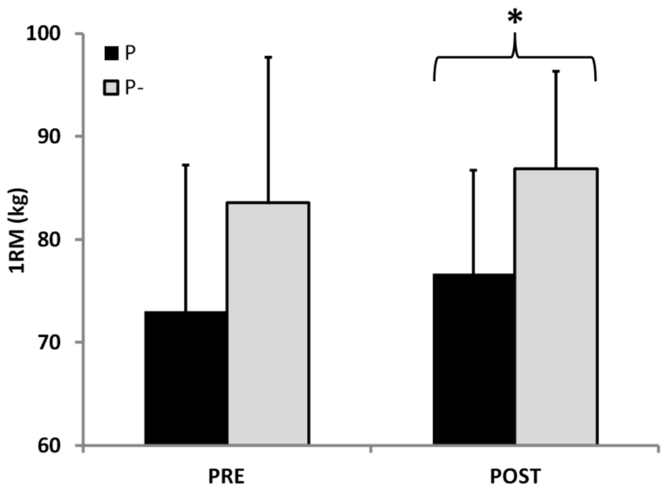


Figure 3. Results of power profile testing for the cohort as a whole: a) mean peak power output (* = significantly different to PRE, p = 0.002; † = significantly different to PRE, p = 0.015); b) mean load at which peak power was expressed (optimal load). Note that optimal load is expressed as a percentage of the 1RM at PRE for PRE and MID, and the 1RM at POST for POST.

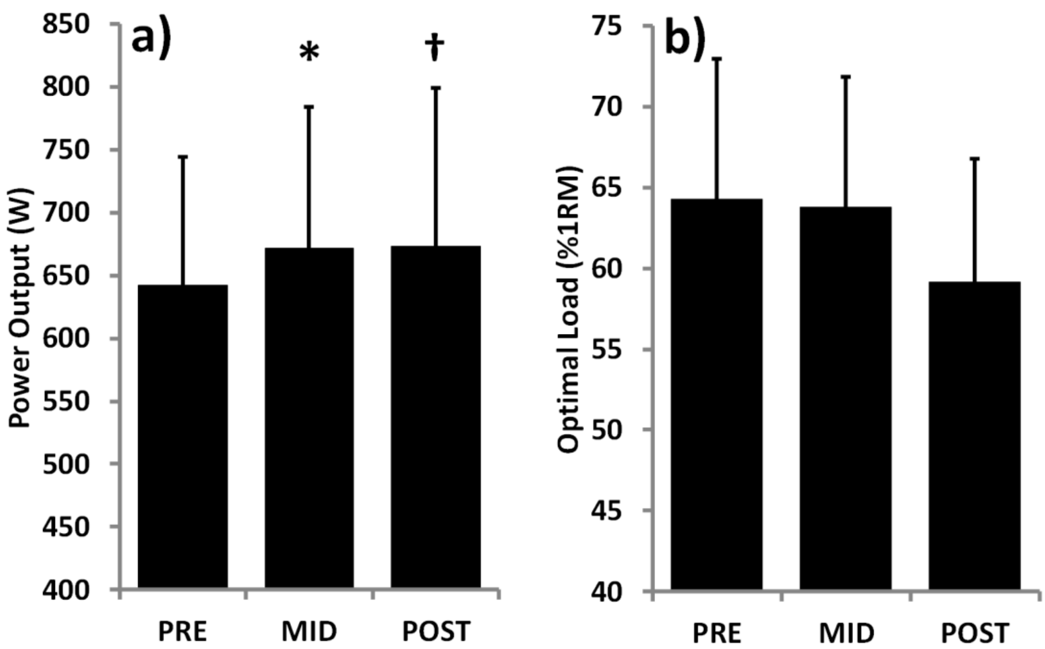
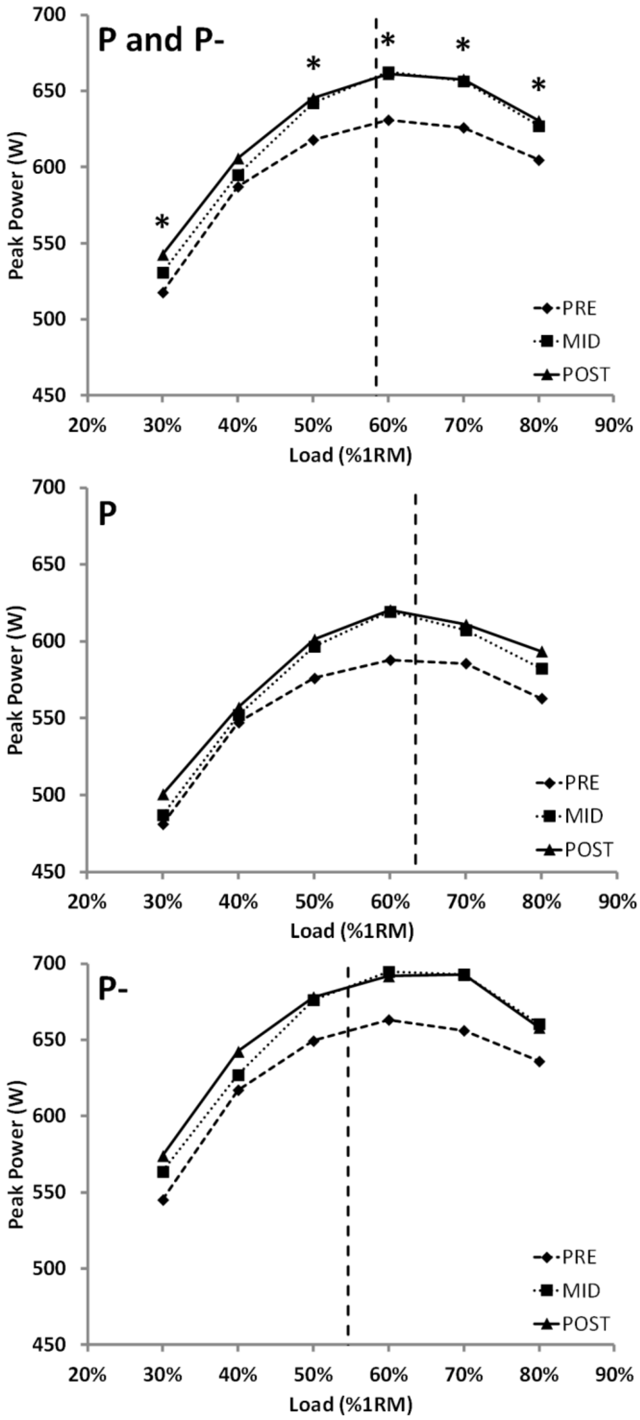


Table 4. Frequency of the loads at which peak power was produced (all values are given as a percentage of the PRE 1RM).

	30%	40%	50%	60%	70%	80%
PRE	0	0	3	8	8	2
MID	0	0	2	11	6	2
POST	0	0	5	9	6	1

Subjects significantly increased their power outputs at all loads apart from 40% of 1RM (30%: $F(2,38) = 4.889$, $p = 0.013$; 40%: $F(2,38) = 2.436$, $p = 0.101$; 50%: $F(1.497,28.449) = 5.269$, $p = 0.018$; 60%: $F(2,38) = 10.819$, $p < 0.001$; 70%: $F(2,38) = 6.484$, $p = 0.004$; 80%: $F(2,38) = 3.703$, $p = 0.034$; Figure 4). There were no differences for the main effect of group or the interaction effect for any of the variables considered.

Figure 4. Power profiles for each group (* = significant difference from PRE to POST for the cohort as a whole, $p \leq 0.05$). The vertical dashed line represents the mean load that was used for power training during the course of the study for each group.



DISCUSSION

The subjects who participated in this study (when considered as a whole) experienced a small significant (p = 0.002) increase in peak power output of 4.6% (d = 0.290) after 4 weeks of training (which is representative of an upwards shift of the complete power-load curve). These results are in broad agreement with other studies that have shown an increase in power output following specific power training (25,26,29). However, a further 3 weeks of the same training failed to provide further increases in power output, despite the fact that the training load was modified to ensure that subjects were training at the desired load. This observation is consistent with other previous power training studies that have demonstrated diminishing returns in terms of improvements in power from 5 weeks onwards (10,11).

Cormie et al. (11) found significant ($p \leq 0.05$) increases in the peak power produced in the vertical jump after 5 weeks of training but no further increase at 10 weeks in a group of stronger subjects (able to squat 1.97 × body weight; the weaker subjects experienced a modest further increase at 10 weeks). It was suggested that one explanation for this was the decrease in the absolute strength of the stronger subjects across the course of their study. In contrast, in this study the subjects experienced a modest increase in their absolute strength in the bench pull but despite this did not increase their power output beyond 4 weeks of training.

This study therefore suggests that a significant increase in power output in the BP can be obtained in a reasonably short amount of time by training at, or just below the optimal load (although the effect size of this increase was small). However, these gains will be exhausted in a short amount of time. This study then further emphasizes the importance of periodisation and progressive overload to prevent accommodation and stagnation (37–39) and supports

Baker's (4) suggestion that training at the optimal load be reserved for the last few weeks of a training cycle. One idea that was untested within this study, and that should be the focus of future research, is the effect of varying the percentage of 1RM used for power training and whether this is a strategy that can prolong the period of power output improvements leading to greater overall increases in power output.

The secondary aim of this study was to evaluate if there was any difference between training at the optimal load (P), or just below it (P-). Our results suggest that there was no difference between P and P-. One reason for this could be the fact there are only small differences in power output when using loads close to the optimal load. For instance, Baker and Newton (8) showed how an athlete who trained with 84% of the optimal load could produce 96% of their peak power output. Equally, Baker et al. (7) reported that there was a similarity in the power produced in the range of loads (48-63% of 1RM) surrounding the optimal load (55-59% of 1RM) in the jump squat and Newton et al. (30) found that the greatest mean power was produced at 30% and 45% of 1RM in the bench press throw. These results support the idea that there is a plateau in power outputs when using loads around the optimal load (8; a plateau that was also seen in our results). This in turn suggests that both groups would exhibit similar power outputs relative to their potential maximums during training thus making the training stimulus markedly similar.

A further interesting result in this study was the decrease in optimal load (as a percentage of 1RM) across the course of study (a decrease that approached significance; p = 0.052). In addition, the effect size of this decrease was the largest seen in this study (d = 0.590). This decrease was not simply the result of the increased 1RM of the subjects as the absolute value of the optimal load also decreased during the study (Table 4). In contrast to the peak power outputs which did not exhibit a change in the latter half of the study, the optimal load fell throughout the course of the study. This provides tentative support for the notion that the power profile did not remain static in the final 3 weeks of the study, but rather experienced a left shift. It can then be speculatively suggested that training around the optimal load may result in both an upwards and leftwards shift of the power-load curve. There is some disagreement within the literature as to whether the optimal load of stronger athletes is at a higher or lower percentage of 1RM than for weaker athletes (4,12,24). These results allow us to speculatively suggest that the ability to produce peak power outputs at a relatively lower load is a specific adaptation to training (and in particular to training at or just below the optimal load).

The optimal load for the subjects in this study ranged between 50% and 80% of 1RM with a mean of 64.3% ± 9.7 and 59.1% ± 7.6 of 1RM at PRE and POST respectively. To our knowledge there is no research in the bench pull to support this finding, but similar values for optimal load of between 50% and 70% of 1RM have been found in other upper body exercises (6,13). This information will be of value to strength and conditioning coaches particularly if they don't have the required equipment to perform an individualised assessment of their athletes' power profile in the bench pull.

In this study we endeavoured to recognise the limitations of previous research in this area (14). In particular there have been weaknesses in the load selection in previous training intervention studies with a number of studies not assessing the actual optimal load of the subjects involved for the movement studied (14). A strength of this study is therefore that the training load used by each subject was individualised based on their personal power profile. In addition, it is also possible for the optimal load to vary over the length of the study (25), thus we adjusted the training loads used by the subjects in this study based on the MID results in order to ensure that subjects continued to train at the desired load. A potential limitation of this study is the uneven group numbers due to the exclusion of four subjects from the study for not meeting the training threshold requirements (3 of the excluded subjects being from the P group). However, a sensitivity analysis showed that if the group numbers were balanced by including the 3 subjects excluded from the P group and if their peak power increased by 20% (the maximum increase seen by any subject in the study) there would still have been no significant differences in the increase in peak power between P and P-.

PRACTICAL APPLICATIONS

The results of this study suggest that small but significant improvements in power output can be realised in only a few weeks of specific power training with the optimal load, but that there is no benefit in prolonging this type of training. Thus the results of this study tend to support Baker's (4) recommendation that power training with the optimal load only be performed in the last few weeks of a training cycle. In addition, these results also support the idea that similar improvements in power output can be realised by training with loads that are below the optimal load (8). A further finding of this study was a relative decrease in optimal load across the course of the study. Strength and conditioning coaches should be cognisant of the fact that power training with the optimal load may also cause a left shift of the power-load curve towards peak power being expressed at relatively lighter loads and ensure that this is a desired training effect. Finally, this study also supports previous studies that suggest that the optimal load for upper body exercises is in the range of 50% to 70% of 1RM. This information will be of use to strength and conditioning coaches and especially to those who do not have the facility to evaluate the individual power profiles of their athletes.

REFERENCES

1. Appleby, B, Newton, RU, and Cormie, P. Changes in strength over a 2-year period in professional rugby union players. *J Strength Cond Res* 26: 2538–2546, 2012.

2. Baechle, TR, Earle, RW, and Wathen, D. Resistance training. In: Essentials of Strength Training and Conditioning,.Champaign, IL, Human Kinetics, 2nd ed., 2000. pp. 395–426

3. Baker, D. Comparison of upper-body strength and power between professional and college-aged rugby league players. *J Strength Cond Res Natl Strength Cond Assoc* 15: 30–35, 2001.

4. Baker, D. A series of studies on the training of high-intensity muscle power in rugby league football players. *J Strength Cond Res Natl Strength Cond Assoc* 15: 198–209, 2001.

5. Baker, D. Differences in strength and power among junior-high, senior-high, college-aged, and elite professional rugby league players. *J Strength Cond Res Natl Strength Cond Assoc* 16: 581–585, 2002.

6. Baker, D, Nance, S, and Moore, M. The load that maximizes the average mechanical power output during explosive bench press throws in highly trained athletes. *J Strength Cond Res* 15: 20–24, 2001.

7. Baker, D, Nance, S, and Moore, M. The load that maximizes the average mechanical power output during jump squats in power-trained athletes. *J Strength Cond Res* 15: 92–97, 2001.

8. Baker, D and Newton, RU. Methods to Increase the Effectiveness of Maximal Power Training for the Upper Body. *Strength Cond J* 27: 24–32, 2005.

9. Clark, RA, Bryant, AL, and Humphries, B. A comparison of force curve profiles between the bench press and ballistic bench throws. *J Strength Cond Res Natl Strength Cond Assoc* 22: 1755–1759, 2008.

10. Cormie, P, Mcguigan, MR, and Newton, RU. Adaptations in Athletic Performance after Ballistic Power versus Strength Training: *Med Sci Sports Exerc* 42: 1582–1598, 2010.

11. Cormie, P, McGuigan, MR, and Newton, RU. Influence of strength on magnitude and mechanisms of adaptation to power training. *Med Sci Sports Exerc* 42: 1566–1581,

2010.

12. Cormie, P, McGuigan, MR, and Newton, RU. Developing maximal neuromuscular power: part 2 - training considerations for improving maximal power production. *Sports Med Auckl NZ* 41: 125–146, 2011.

13. Cronin, J, McNair, PJ, and Marshall, RN. Velocity specificity, combination training and sport specific tasks. *J Sci Med Sport* 4: 168–178, 2001.

14. Cronin, J and Sleivert, G. Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Med Auckl NZ* 35: 213–234, 2005.

15. García-Pallarés, J, Sánchez-Medina, L, Carrasco, L, Díaz, A, and Izquierdo, M. Endurance and neuromuscular changes in world-class level kayakers during a periodized training cycle. *Eur J Appl Physiol* 106: 629–638, 2009.

16. Garthe, I, Raastad, T, Sundgot-Borgen, J, and others. Long-term effect of weight loss on body composition and performance in elite athletes. *Int J Sport Nutr AndExercise Metab* 21: 426, 2011.

17. Hansen, KT, Cronin, JB, Pickering, SL, and Douglas, L. Do force-time and power-time measures in a loaded jump squat differentiate between speed performance and playing level in elite and elite junior rugby union players? *J Strength Cond Res Natl Strength Cond Assoc* 25: 2382–2391, 2011.

18. Hedeker, D, Gibbons, RD, and Waternaux, C. Sample size estimation for longitudinal designs with attrition: comparing time-related contrasts between two groups. *J Educ Behav Stat* 24: 70–93, 1999.

19. Hermassi, S, Chelly, MS, Fathloun, M, and Shephard, RJ. The effect of heavy-vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *J Strength Cond Res* 24: 2408–2418, 2010.

20. Hermassi, S, Chelly, MS, Tabka, Z, Shephard, RJ, and Chamari, K. Effects of 8-week in-season upper and lower limb heavy resistance training on the peak power, throwing velocity, and sprint performance of elite male handball players. *J Strength Cond Res* 25: 2424–2433, 2011.

21. Ivey, PMe, Oakley, JMe, and Hagerman, PE. Strength Training for the Preparatory Phase in Collegiate Women's Rowing. *ET J* 26: 10–15, 2004.

22. Jennings, CL, Viljoen, W, Durandt, J, and Lambert, MI. The reliability of the FitroDyne as a measure of muscle power. *J Strength Cond Res Natl Strength Cond Assoc* 19: 859–863, 2005.

23. Kaneko, M, Fuchimoto, T, Toji, H, and Suei, K. Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. *Scand J Sports Sci* 5: 50–55, 1983.

24. Kawamori, N and Haff, GG. The optimal training load for the development of muscular power. *J Strength Cond Res Natl Strength Cond Assoc* 18: 675–684, 2004.

25. Mayhew, JL, Ware, JS, Johns, RA, and Bemben, MG. Changes in upper body power following heavy-resistance strength training in college men. *Int J Sports Med* 18: 516–520, 1997.

26. McBride, JM, Triplett-McBride, T, Davie, A, and Newton, RU. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res Natl Strength Cond Assoc* 16: 75–82, 2002.

27. McNeely, E, Sandler, D, and Bamel, S. Strength and Power Goals for Competitive Rowers. *Strength Cond J* 27: 10–15, 2005.

28. Naclerio, F, Faigenbaum, AD, Larumbe-Zabala, E, Perez-Bibao, T, Kang, J, Ratamess, NA, et al. Effects of Different Resistance Training Volumes on Strength and Power in Team Sport Athletes. *J Strength* 27: 1832–1840, 2013.

29. Newton, RU, Kraemer, WJ, and Häkkinen, K. Effects of ballistic training on preseason preparation of elite volleyball players. *Med Sci Sports Exerc* 31: 323–330, 1999.

30. Newton, RU, Murphy, AJ, Humphries, BJ, Wilson, GJ, Kraemer, WJ, and Häkkinen, K. Influence of load and stretch shortening cycle on the kinematics, kinetics and muscle activation that occurs during explosive upper-body movements. *Eur J Appl Physiol* 75: 333–342, 1997.

31. Overall, JE and Doyle, SR. Estimating sample sizes for repeated measurement designs. *Control Clin Trials* 15: 100–123, 1994.

32. Requena, B, García, I, Requena, F, de Villarreal, ES-S, and Cronin, JB. Relationship between traditional and ballistic squat exercise with vertical jumping and maximal sprinting. *J Strength Cond Res Natl Strength Cond Assoc* 25: 2193–2204, 2011.

33. Rhea, MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength* 18: 918–920, 2004.

34. Sleivert, G and Taingahue, M. The relationship between maximal jump-squat power and sprint acceleration in athletes. *Eur J Appl Physiol* 91: 46–52, 2004.

35. Smilios, I, Sotiropoulos, K, Christou, M, Douda, H, Spaias, A, and Tokmakidis, SP. Maximum power training load determination and its effects on load-power relationship, maximum strength, and vertical jump performance. *J Strength Cond Res Natl Strength Cond Assoc* 27: 1223–1233, 2013.

36. Stock, MS, Beck, TW, DeFreitas, JM, and Dillon, MA. Test-retest reliability of barbell velocity during the free-weight bench-press exercise. *J Strength Cond Res Natl Strength Cond Assoc* 25: 171–177, 2011.

37. Stone, MH, Keith, RE, Kearney, JT, Fleck, SJ, Wilson, GD, and Triplett, NT. Overtraining: a review of the signs, symptoms and possible causes. *J Strength Cond Res* 5: 35–50, 1991.

38. Stone, MH, O'Bryant, H, and Garhammer, J. A hypothetical model for strength training. *J Sports Med Phys Fitness* 21: 342, 1981.

39. Stowers, T, McMillan, J, Scala, D, Davis, V, Wilson, D, and Stone, M. The Short-Term Effects of Three Different Strength-Power Training Methods. *Strength Cond J* 5: 24–27, 1983.

40. Wilson, GJ, Newton, RU, Murphy, AJ, and Humphries, BJ. The optimal training load for the development of dynamic athletic performance. *Med Sci Sports Exerc* 25: 1279–1286, 1993.

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