The Relation Between Strength and Power in Professional Rugby League Players

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ABSTRACT

The purpose of this investigation was to analyze the relation between measures of maximal strength and maximal power generated during exercises with similar movement patterns. Twenty professional rugby league players were examined for maximal strength in a 3 repetition maximum (RM) full squat and 3RM bench press exercise and for maximal power during a jump squat and incline bench press throw exercise. A 3RM power clean from the hang was also examined to determine if this exercise was related to lower or upper strength and power. The results indicate that maximal strength is highly related to maximal power in all the tests performed ($r = 0.55-0.89$, $p \leq 0.05$). The power clean from the hang was related more to lower-body squat strength and jump squat power ($r = 0.79$) than to upper-body bench press strength or incline bench throw power ($r = 0.51-0.55$). The practical application of this data suggests that while strength and power are highly related, a large degree of variance still exists. This may imply that further specific power training may be warranted to maximize power development, especially for the upper body.

Key words: squat, jump squat, bench press, incline bench throw


Introduction

Strength can be defined as the maximum force produced by a muscle or muscles at any given speed (18). Power is the product of force (strength) and velocity (speed). A number of sports would appear to be dependent upon high levels of strength and muscular power for athletic success. Consequently the use of various methods of resistance training can be seen as a way of improving strength and power, leading to an improvement in sporting performance.

Schmidtbleicher (25) has stated that maximal strength is the overall most important factor in power output when the movement duration is longer than 250 milliseconds. This belief is based upon the rationale that strength and movement speed are in a hierarchical relation to power. The greater the external load that power must be produced against, the greater the relative relation of maximal strength to that power output (20). Consequently, it is thought that any increase in strength brought about by maximal strength training methods will be reflected in a change in power and speed, possibly due to favorable neural adaptations (4, 26).

However, research has shown that the transfer effect between exercises or at different resistances or speeds may be limited, as suggested by the limited strength of the statistical relation between strength and power (2, 14). In a hierarchical relation, a strong correlation should exist between strength and power in exercises with the same or a similar movement pattern. Biomechanical profiles of selected resistance training exercises have shown that certain exercises used for maximal strength training produce high levels of force (strength) but low levels of power, presumably due to lower movement speeds (11, 13, 27). Other exercises, typically the lifts taken from Olympic-style weightlifting, are characterized by higher levels of power and faster movement speeds (8, 10, 11, 13).

Given this disparity between strength and power, various authors have suggested that certain resistance training exercises be utilized as predominantly strength or power exercises, presumably depending upon the kinetic profiles of the exercise (1, 9, 21). This may imply a more limited relation between various measures of strength and power, possibly due to mechanical, neural, and structural differences between the exercises (2). Thus an investigation of the relationship between strength and power measures in exercises with similar movement patterns in well-trained athletes is of considerable interest.

If a strong or weak relation exists between measures of strength and power it may be assumed that this would also be reflected in the relation between various measures of power. Newton and Kraemer (21)
suggested that the only chances for muscle power to be generalized across different movement patterns would be through either hypertrophy or contractile changes toward more powerful contractions occurring within the muscle. If, as a result of extensive training, there was a gravitation towards more inherently powerful contraction characteristics, then possibly the relation between different tests of power may be stronger for a homogeneous group of athletes.

For example, of interest is the relation between the power clean exercise, which uses lower- and upper-body musculature, and various tests of upper- and lower-body strength and power. However, unless the power clean performance is measured on a force plate, with a potentiometer (7) or filmed at high speed for later analysis (10), the only data available to the strength coach is the mass of the barbell that is lifted, rather than the power output. Would performance in a power clean exercise be strongly related to the lower- or upper-body maximal power capabilities of an athlete?

The purpose of this paper is to investigate the relation between measures of maximal strength and maximal power in professional rugby league players conditioned to high levels of maximal strength, speed, and power. Furthermore, the interrelation between various tests of power will be investigated. This information would be of benefit to researchers and coaches attempting to understand the relation between strength and power in elite athletes.

**Methods**

**Subjects**

Twenty professional rugby league players gave informed consent and were tested as part of their athletic training program at the completion of their preseason training program. Their mean body mass, height, and age (±SD) were 93.4 ± 11.7 kg, 181.9 ± 7.0 cm, and 24.2 ± 3.8 years, respectively. All the subjects had been involved in intensive resistance training for a minimum of 4 years and were considered to be in peak condition at the time of testing.

**Testing**

Testing was carried out over 1 week, at the completion of preseason training, with all the subjects being in a highly trained state. All the subjects were familiar with the testing procedures and exercises, which they had been performing as part of their training routine. Maximal strength and maximal power tests were separated by a 3-day period, with the 3 repetition maximum (RM) tests performed on the first day.

**3RM Testing.** A 3RM measure of maximal strength was assessed in the full squat, bench press, and power clean from the hang exercises. A 3RM was used in this instance, as this was the standard test for the subjects at this stage of their athletic program (23).

For all 3RM tests the following procedures were observed. Warm-up consisted of stretching and then the performance of 4–5 submaximal sets of 5–1 repetitions with progressively larger loads, finishing 10–15 kg less than the individually prescribed goal 3RM. The athletes then attempted a 3RM load that had been predetermined by their strength coach, based upon recent training history and previous maximum test results. If the athletes were successful with this load, they were allowed to attempt another load or loads until both the athlete and the strength coach were confident that a 3RM had been attained, usually within one extra attempt.

For the bench press exercise, 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.

For the full squat, the athlete descended until the top of the thigh was below parallel with the floor. This depth was visually assessed by the strength coach, a national level powerlifting coach. During the squat lift, a powerlifting belt was worn, but no knee wraps or other supportive garments were allowed.

For the 3RM power clean from the hang, the athlete stood straight with the barbell, then lowered the barbell to the hang position, approximating knee level. From this hang position, the athletes immediately thrust upwards, finishing with the barbell in the catch position for the power clean. The athletes were allowed to wear a lifting belt and wrist straps if so desired.

**Power Testing.** Maximal power was assessed during an incline bench press throw activity and a jump squat. Jump squats with loaded barbells have been extensively used to assess lower-body power (15–17). Explosive bench press (3, 19) and bench press throws (22) have also been used extensively to assess upper-body power. The incline bench press throw, rather than the flat bench press throw, was used in this study in a bid to further isolate the upper-body musculature.

Both tests were performed using the Plyometric Power System (PPS), which has been described elsewhere (22, 28). 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 produced 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. From this data, the PPS software calculated the power output during jump squats and incline bench press throws.

For the power testing, absolute resistances (e.g., 40, 60, 80, 100 kg), rather than percentages of each indi-
individual’s maximum strength score (e.g., 30, 45, 60, 75%) were used, as previously it has been illustrated that strength and power training adaptations are predominantly manifested in the improved ability to overcome absolute, rather than relative, loads (3, 15, 16, 19).

In the incline bench press throw, the athlete performed 3 consecutive stretch-shorten cycle (SSC) movements against absolute loads of 20, 30, 40, 50, 60, and 70 kg. The average mechanical power output for the concentric phase of each load was determined by the software of the PPS, and the highest score for each load was recorded.

In the jump squat, the athlete performed 3 consecutive SSC movements against absolute loads of 40, 60, 80, and 100 kg (15, 16). The average mechanical power output for the concentric flight phase of each jump squat for each load was determined by the software of the PPS, and the highest score for each load was recorded.

Before testing, the athletes performed their prescribed preseason strength and power training. This entailed resistance training 4 times per week (2 × upper and lower body). In the weeks immediately before testing, the athletes performed the maximal strength and power phase of their periodized training cycle. This included maximal strength exercises such as full squat and bench press; various assistance strength exercises; special power exercises such as jump squat and incline bench throw; Olympic lifts such as power clean from hang, power shrug, push press, and split jerk; and various plyometric exercises. Consequently all the athletes were in their peak condition for strength and power and were familiar with all the testing exercises, which they had been performing regularly as part of training.

**Statistical Analysis**
The relation between the various tests of maximal strength and maximal power was determined using a Pearson’s product moment correlation. The coefficient of determination, used for interpreting the meaningfulness of the relation, was developed by squaring the correlation, multiplying by 100, and expressing as a percentage. Statistical significance was set at \( p \leq 0.05 \) for all measured variables.

**Results**
The results for the 3RM tests and the maximal power tests are outlined in Table 1. The relation between the strength and power exercises and between different power exercises are outlined in Table 2. All the measured relations were positive and statistically significant.

**Discussion**
The results for the 3RM tests indicate that the current subject group is far stronger than that previously reported for professional rugby league players (23). Certainly the strength test results from this study are more in line with those reported for American football players of similar body mass (6).

Although it could be argued that 3RM tests are not truly indicative of the full maximum strength, as per a 1RM test, it was not possible to test the 1RM of these athletes as their training program specified a 3RM test at that particular stage of their preparation. However, the 3RM scores were compared with 1RMs determined at other stages of their training cycle. The relation between the 3RM bench press recorded during this study and the 1RM bench press was assessed on 2 other occasions, with the same relation recorded both times (\( r = 0.92, n = 18, \) and \( n = 17 \)). For the squat and power clean from the hang, the relation between the 3RM score and a previous 1RM was also quite high (\( r = 0.96, n = 15, \) and \( r = 0.87, n = 14, \) respectively). These figures suggest that in these highly trained athletes, the 3RM and 1RM scores were highly related and somewhat stable. Based upon the extent of these relations, it is not thought that our results would be impaired considerably because of the use of a 3RM as opposed to a 1RM. The basic finding

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**Table 1.** Results for the various measures of strength and power in professional rugby league players (values are mean ± SD).

<table>
<thead>
<tr>
<th>Exercise</th>
<th>3RM (kg)</th>
<th></th>
<th>Maximum power (W)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3RM bench press</td>
<td>3RM full squat vs. jump squat</td>
<td>3RM full squat vs. 3RM power clean (hang)</td>
</tr>
<tr>
<td>Bench press</td>
<td>124.0 ± 13.0</td>
<td></td>
<td>0.81 ± 0.65</td>
<td>0.79 ± 0.62</td>
</tr>
<tr>
<td>Full squat</td>
<td>157.9 ± 18.8</td>
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<td></td>
<td></td>
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<tr>
<td>Power clean (hang)</td>
<td>102.2 ± 13.4</td>
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</tbody>
</table>

**Table 2.** Relationship between strength exercises and power exercises. All relationships were significant \( (p \leq 0.05) \).

<table>
<thead>
<tr>
<th>Exercise</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>3RM bench press vs. incline bench throw</td>
<td>0.89</td>
<td>0.8</td>
</tr>
<tr>
<td>3RM bench press vs. 3RM power clean (hang)</td>
<td>0.51</td>
<td>0.26</td>
</tr>
<tr>
<td>3RM full squat vs. jump squat</td>
<td>0.58</td>
<td>0.34</td>
</tr>
<tr>
<td>3RM full squat vs. 3RM power clean (hang)</td>
<td>0.79</td>
<td>0.62</td>
</tr>
<tr>
<td>3RM full squat vs. 3RM power clean (hang)</td>
<td>0.71</td>
<td>0.5</td>
</tr>
<tr>
<td>3RM full squat vs. 3RM power clean (hang)</td>
<td>0.55</td>
<td>0.3</td>
</tr>
</tbody>
</table>
of this study is that strength, as measured here, is highly correlated to maximal power output.

The incline bench throw score of 569 W is similar to the score of 595 W reported by Newton et al. (22) for the maximal power output for weight-trained men performing a flat bench press throw. No other data has been found concerning the maximal power output during an incline or flat bench press throw activity. However, Santa Maria et al. (24) reported power outputs of 481 W during free-weight bench pressing with submaximal loads. Mayhew et al. (19) and Bemben et al. (3) tested maximal bench press power, but did not report the power scores.

The athletes in the present study had a much higher bench press score and body mass than those reported in Newton et al. (22), so the fact that a difference may have existed between the groups in maximal power output, given the strong relation between bench press strength and bench throw power, may be partially ascribed to the fact that the athletes in the present study utilized an incline, rather than a flat bench, for the throw activity.

The inclined angle, as compared with a flat bench used in the study of Newton et al. (22), could conceivably reduce the work and power capabilities of the involved musculature. Thus, whereas the athletes in the present study were stronger than those from the study of Newton et al. (22) in terms of bench press strength, their power output during the upper-body movement may be lower because of the mechanics of the test, rather than from inherent muscular differences.

Limited data is available concerning the power output of athletes derived during a jump squat exercise. Hakkinen and Komi (15, 16) reported similar power outputs, given differences in body mass, of 1722 and 1693 W recorded during a jump squat with a 100-kg barbell by athletes trained with heavy and explosive resistance training methods, respectively.

The strong relation between the 3RM tests of strength and the respective tests of power with a similar movement pattern suggest that the factors contributing to maximal strength are also the predominant factors involved in maximal power output. The correlation between bench press and incline bench throw would indicate that 80% of the power output could be attributed to bench press performance. This result partially supports the findings of Burhle and Schmidtbleicher (4), who, for different groups of athletes, reported correlations of $r = -0.88$, $-0.86$, and $-0.87$ for isometric strength and for speed lifting a 2.5-kg load in a one-arm bench press–type activity. Similarly, Moss et al. (20) also recently demonstrated that maximal strength and maximal power are very highly correlated ($r = 0.93$). Furthermore, Moss et al. (20) demonstrated that the relation between strength and power diminishes as the external load is reduced (i.e., maximal strength vs. submaximal power, $r = 0.73$).

Consequently it would appear that upper-body maximal power is heavily dependent upon upper-body maximal strength. Nonetheless, around 20% of the upper-body power performance remains explained by strength performance. This could be an area for future research.

For the 3RM squat and the power exercises of jump squat and power clean from the hang, the relation suggests that over 62% of the power performance could be related to the strength performance. The strength of the relations between strength exercises and power exercises with similar movement patterns implies that strength is the predominant factor influencing power output in highly trained professional rugby league players. However, although strength may be in a hierarchical position to power, a large portion (25–40%) of the power performance still remains to be clarified.

This result is in partial agreement with the results of Haff et al. (14), who reported a nonsignificant relation of $r = 0.70$ between peak force and peak power in the clean pull exercise. Of interest is the fact that the significant relations between peak force and dynamic rate of force development ($r = 0.84–0.88$) in that study were of a similar magnitude to those of strength and power in the current study.

Importantly, the two lower-body power exercises (jump squat and power clean from the hang) were also strongly correlated. Hakkinen et al. (17) reported relations of $r = 0.72–0.75$ between the jump squat with loads of 100 and 140 kg, respectively, and performance in the full Olympic clean. This statistic suggests that the jump squat and clean (and presumably the power clean from the hang) exercises are basically measuring the same capabilities of the neuromuscular system in trained athletes. This is not unexpected, given the similar biomechanics involved in the thrust portion of Olympic lifts and jumping exercises (5, 12).

The unexplained variance between the jump squat and the power clean from the hang may be due to factors such as the more difficult technique involved in the power clean, as compared with the jump squat, and also the contribution of some upper-body musculature. Given the difficulties in coaching and performing the power clean-type exercises, it may be prudent to substitute the jump squat in a Smith machine as a training and testing exercise for the lower-body power for some athletes. A jump squat in a Smith machine reduces the need for balance, which may be a prudent consideration for low-level athletes. However, it could also be argued that free-weight power exercises that require greater balance and coordination may provide a greater overall training stimulus for more advanced athletes than do jump squats in a linear supported device such as a Smith machine. Consequently strength and conditioning coaches will need
to determine the use of such exercises for athletes of different levels of training adaptation, given that the finding of this study is that both exercises are similarly related to each other and to the full squat.

It would appear that strength and power capabilities may be specific between the lower- and upper-body areas. The relation of \( r = 0.71 \) between the jump squat and the incline bench throw suggests that, at most, only 50% of the respective power outputs could be related to common factors. The relevant relation for the strength exercises, squat and bench press, indicates that only one-third of their variance is common. The figures are virtually the same for the relation between the power clean from hang and both the bench press and the incline bench throw. Consequently there would not appear to be a transfer of strength or power capabilities between the lower- and upper-body areas. Thus an athlete may be powerful in the lower body, but not necessarily in the upper body and vice versa.

The authors have found from experience that most strength coaches train both the upper and lower body for strength, but very few prescribe adequate upper-body power training. Power training has typically meant Olympic-style lifts and plyometrics, both of which emphasize the lower body, or low-load upper-body plyometric training with medicine balls. Given that the power transfer of Olympic lifts to the upper body may be quite low, the findings of this study may indicate that specific upper-body power training with much greater loads than medicine balls may be warranted to ensure the transfer of strength capabilities to power capabilities.

The use of a regular Smith machine-type of weight-training device could allow the strength coach to perform bench press and incline bench press throw exercises, which would allow for greater overload in the training of upper-body power. The authors have used such devices to train hundreds of athletes ranging from college-aged athletes to elite professional rugby players and have witnessed no injuries in athletes despite there being no braking mechanism for the downward phase of the movement, as is the case with the PPS. Even in the present study and during the training that occurred leading up to the testing, the braking mechanism of the PPS purposely was not used to allow for a more ballistic muscular performance. On the basis of the authors’ experience, if the application of overload is gradual and progressive, then there should be minimal incidence of injury performing these power exercises for the upper body.

On the basis of the descriptive results of this study, future research may focus upon the transfer of effects of different resistance training exercises during a qualitative study. Of interest would be the relation between changes in performance in any of the tests consequent to a 8–12-week training cycle. This could provide data pertaining to the usefulness of different resistance exercises upon power output.

**Practical Application**

The present findings suggest that maximal strength is the most important factor influencing maximal power output in highly trained professional rugby league players when using exercises with similar movement patterns. This exposure to strength and power exercises may then lead to contractile changes occurring within the muscle(s), tending the muscle toward more inherently powerful contractions. As a result, this could lead to an increased ability to manifest maximal strength into maximal power and presumably into improved power during sport-specific movement patterns.

For the upper body, strength and power are very strongly related. For the lower body, the special power exercises of power clean from the hang and jump squat share a relation of similar magnitude with the full squat strength exercise and with each other. This would indicate that both lower-body power exercises are similarly capable of predicting lower-body power output. Jump squats in a Smith machine may prove a useful lower-body power training alternative for athletes who may not be able to perform the Olympic-style lifts.

However, a large degree of variance between strength and power still remains unexplained. Therefore, to maximize power adaptations, further specific power training may be warranted. Merely training for maximal strength may limit the possible gains in power.

Power adaptations appear specific to the body area being trained. As most strength coaches would prescribe Olympic lifts and plyometrics for power training, predominantly affecting the lower body, this may lead to less than optimal power adaptations in the upper body. It is therefore recommended that more specific upper-body power training be performed, such as bench press throws in a Smith machine or other modified exercises that may entail greater acceleration or lifting speeds.

**References**

5. **Canavan, P., G. Garrett, and L. Armstrong.** Kinematic and