Discriminative Analyses of Various Upper Body Tests in Professional Rugby-League Players

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Purpose: To examine the upper body strength, speed, power, and strength-endurance of rugby-league players of different ranks. These data could provide information pertinent to the importance of these factors for different grades of rugby league and for positional groups in those different grades. Methods: Sixty rugby-league players, 20 participants each in the elite, national first-division league (NRL), state-based second-division league (SRL), and intracity third-division league (CRL), served as subjects. Maximal upper body strength, power, speed, and muscle endurance were assessed using the bench-press exercise. Results: The NRL players were significantly stronger (141.4 ± 15.4 kg) than SRL (126.6 ± 13.1 kg, ES = 1.033) and CRL (108.1 kg ± 11.6, ES = 2.458) and more powerful (NRL = 680 ± 99 W) than SRL (591 ± 72 W, ES = 1.037) and CRL players (521 ± 71 W, ES = 1.867). The differences in speed (NRL = 345 ± 31 W, SRL = 319 ± 29 W, CRL = 303 ± 29 W; ES = 0.884 and 1.409, respectively) and strength-endurance (NRL = 36 ± 7 reps, SRL = 32 reps ± 7, CRL = 24 ± 5 reps; ES = 0.521 and 1.984, respectively) were not as pronounced. Conclusions: Of the tests undertaken, maximal strength best describes players who attain NRL ranking. Maximum power and strength-endurance were also strong descriptors of attainment of NRL level. Upper body speed appears less likely to strongly discriminate between players who attain NRL level and those who do not. These results tended to hold true across the different team positional groupings.

Key Words: athletic training, training, strength, sport, resistance training, physical performance, speed, power, endurance, football

Rugby league is a collision sport played worldwide that is particularly popular in Australia, New Zealand, and Great Britain. A rugby-league team consists of 13 players participating on the field (6 forward-line and 7 back-line), as well as up to 4 interchange players (of mixed positional groupings). At the professional level, the game is typically played over two 40-minute halves separated by a 10-minute
rest interval. Success in rugby-league football appears heavily reliant on the players’ possessing an adequate degree of various physical-fitness qualities such as strength, power, speed, and endurance, as well as individual skill and team tactical abilities. In particular, upper body strength, power, speed, and endurance would appear to be important because of the large amount of tackling and grappling that occurs in both attack and defense during an 80-minute game. It has previously been established that maximum strength and power levels could distinguish between players participating in the elite national first-division league and those participating in second- and third-division leagues. Furthermore, a test of upper body speed distinguished between players participating in these professional leagues from younger high school players. Other previous work has also illustrated differences in strength between high school and college-age (17 to 21 years) rugby-union and rugby-league players.

There has been scant research investigating upper body endurance in rugby-league players. The studies cited previously illustrated the importance of maximum strength and power but did not investigate strength-endurance as an outcome measure. Recent changes in referee interpretations, coaching strategies, and game play have conceivably increased the importance of upper body strength-endurance. For example, previously only 1 to 2 defending players would generally commit to a tackle and then, as stipulated by the rules, quickly move away from the tackled player. This meant that a high level of maximum strength and power would be required by those 1 to 2 defending players to quickly halt the forward momentum of the attacking player. Since about 2001 the concept of a “dominant tackle” has been promoted by some coaches and commentators and is now interpreted by referees throughout the game. This has had the effect of increasing “gang tackles” and “grapple tackles” whereby 4 to 5 defenders attempt to take extra time to halt the forward momentum of the attacker and “wrap up” the ball to prevent the attacker from unloading the ball to further promote the attack. This has had the effect of increasing the number of tackles each player might be involved in during a game, but these tackles might require less strength and power effort per tackle than before 2001. This situation has led many commentators in the popular media and coaches to subscribe to the theory that high levels of upper body strength-endurance and lower body running endurance (elite rugby-league players can cover distances of up to 10 km in an 80-min game) are now the main physical requirements needed by rugby-league players who aspire to reach the highest levels of competition.

The purpose of this study was to compare the upper body strength, speed, power, and strength-endurance of selected rugby-league players participating in the elite, national first-division (NRL); state-based second-division (SRL); and intracity third-division (CRL) rugby-league competitions. In addition, a further analysis by positional grouping was performed, similar to that of Meir et al. These data and analyses would provide information pertinent to the importance of upper body strength, power, speed, and strength-endurance for different grades of rugby league and for positional groups within those different grades. Whether upper body strength-endurance, as measured in this investigation, had become the dominant upper body physical quality (rather than maximum strength or power) that separates NRL players from SRL and CRL players was of particular interest.
Methods

Subjects

Sixty rugby-league players, comprising 20 full-time professionals participating in the elite first-division National Rugby League competition (NRL), 20 semiprofessionals participating in a second-division state league (SRL), and 20 players in a third-division intracity league (CRL) served as participants in this investigation. All were members of the same football club and performed the same resistance training relative to their different playing positions and individual strength levels under the same resistance-training coach to ensure that homogeneous exercise-technique development occurred across the different squads. Irrespective of which team a player was on, his entire resistance-training program was prescribed according to his positional grouping, which was the same throughout all 3 squads. The bench-press portion of the training was exactly the same for each individual in terms of training volume (Sets × Repetitions) and relative intensity (percent 1-repetition-maximum [1RM]) for at least 8 weeks before testing. Therefore, the players in each positional grouping were resistance trained in a homogeneous manner, and each player performed exactly the same bench-press training for the 8 weeks before testing, irrespective of his position or squad. Although the full-time professional NRL players performed additional training sessions (fitness, skill, tactics), they performed no additional resistance training. All subjects were aware of the methods and nature of the testing and voluntarily participated in the testing sessions, which were a regular part of their testing and conditioning regime. This study conformed to the policy statement of the Declaration of Helsinki regarding research involving human subjects. All of the athletes had performed a preseason resistance-training cycle immediately before testing. Descriptive data for the various player groupings are contained in Table 1.

Experimental Design

Tests of strength, power, speed, and high-intensity strength-endurance during upper body pressing movements were measured in rugby-league players participating in 3 different playing grades. Scores on these tests were analyzed to determine whether there were differences between the different grades. A further analysis by positional

Table 1  Description of Subjects as Participants in Different Levels of Rugby-League Competition, Mean (SD)

<table>
<thead>
<tr>
<th>Rugby-league level</th>
<th>Body mass (kg)</th>
<th>Height (cm)</th>
<th>Age (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>96.8 (10.4)</td>
<td>183.6 (5.4)</td>
<td>25.3 (3.1)</td>
</tr>
<tr>
<td>Intrastate</td>
<td>94.2 (8.1)</td>
<td>184.6 (4.9)</td>
<td>20.7 (2.5)</td>
</tr>
<tr>
<td>Intracity</td>
<td>88.7 (7.7)*</td>
<td>182.0 (5.4)</td>
<td>18.6 (0.9)*</td>
</tr>
</tbody>
</table>

*All groups different, \( P \leq .05 \).
†Intracity different from national, \( P \leq .05 \).
grouping was also performed to determine whether upper body strength, power, speed, or strength-endurance is more important for players in different positions in rugby league.

**Methodology**

Four tests were chosen to measure the strength, power, speed, and strength-endurance of the upper body musculature. All tests entailed the exact same movement pattern, in which weights were lowered to the chest and then forcefully and rapidly pressed away from the body (bench-press movement). Individuals can exhibit differences in performance in strength and power between different test movements for the same muscles. By using the same test movement to assess all 4 physical qualities it was presumed that if differences occur they could be ascribed to the level of performance in the 4 physical qualities rather than intertest differences. The bench press is a very common exercise in the training regimen of many athletes and is commonly used to assess strength and other upper body physical qualities in rugby-league players because it replicates pushing away an opponent, a fundamental task in both attack and defense. Each player, irrespective of position or squad, performed the same bench-press training routine for 8 weeks before testing. The tests of maximum strength and strength-endurance were performed on day 1, with the maximum-strength test performed first. Both of these tests were performed using the free-weight bench-press exercise.

The tests of upper body maximum power and speed were performed 4 days later, with the speed test performed first. Both of these tests entailed the use of the Plyometric Power System (PPS), which has been described previously. 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. A rotary encoder attached to the machine produced pulses indicating the displacement of the barbell. The number of pulses and the time of the barbell movement were measured by a counter timer board installed in a computer. The PPS software calculated the average mechanical power output of the concentric phase of bench-press throws based on the displacement, time, and mass data.

**Strength Testing.** Maximum upper body strength was assessed by the 1RM bench press (BP) using free weights and according to methods previously outlined.

**Strength-Endurance Testing.** The strength-endurance test was devised based on the results of pilot work and entailed the athlete’s attempting to bench press a free-weight resistance of 60 kg for as many repetitions as possible till fatigue (RTF BP60). This absolute resistance was chosen because it complied with the American College of Sports Medicine (ACSM) position stand for progression models in resistance training for healthy adults concerning strength-endurance. Specifically, the absolute resistance was 30% to 80% for all subjects and allowed for the completion of at least 10 to 25 repetitions or more as recommended by the ACSM guidelines. Recent research has illustrated that absolute resistances, for example 40 kg during bench throws, are reliable indicators of training-based changes. Thus, players who can perform more repetitions with this absolute mass are performing more absolute work, a factor that rugby-league coaches believe is more important than measures relative to body mass or 1RM. A resistance of 60 kg was also only
marginally different between groups in terms of relative percentage of body mass; it represented 62%, 63.7%, and 67.6% of the NRL, SRL, and CRL groups’ body masses, respectively. Test–retest reliability was $r = .94$ (n = 19).

**Speed Testing.** Upper body speed testing was conducted using the PPS and a resistance of 20 kg (the empty barbell representing the lightest resistance that could be used in the PPS) via methods described previously. After warming up, the athlete performed 5 repetitions of the bench-press-throw exercise, with the highest power output generated during the concentric phase recorded as the speed capability of the upper body (BT P20).

**Power Testing.** Maximum power output (BT Pmax) was assessed for the upper body during the concentric phase of bench-press throws with resistances ranging from 40 to 80 kg using methods described previously. Briefly, this entailed the subjects’ performing 3 repetitions of bench throws with resistances of 40, 50, 60, 70, and 80 kg, with the highest power output at any of the resistances deemed the Pmax.

**Player Groupings**

Players were analyzed according to a method modified from Meir et al, in which the front row and back-rowers were defined as the hit-up forwards and the centers and wingers were defined as outside backs. The hookers, halves, fullbacks, and utility players were defined as the ball players because their primary role in a game is setting up plays, distributing the ball, and generally organizing attack. These were the groupings determined by the club coaches based on contemporary trends and practices, and the players’ training was organized in such groupings to a large degree.

**Statistical Analyses**

Means and SDs for each measured variable were calculated for both playing-level and team-position groupings. The Levene test was used to assess homogeneity of variance, and age and body mass were the only variables that did not pass this test. Multivariate ANOVA was used to determine whether there were differences between the groups or positional subgroups in age, body mass, height, 1RM BP, BT Pmax, BT P20, or RTF BP60. In the event of a significant $F$ ratio, Bonferroni post hoc comparisons were used to determine where these differences existed, except for age and body mass, for which Dunnett T3 was used to account for lack of homogeneity of variance for these 2 variables. Spearman rank correlations were calculated between individual test scores and progression from CRL to NRL level. Pearson product–moment correlations were calculated to examine the interrelationships between performances in the different tests. Significance was accepted at a criterion alpha level of $P \leq .05$.

**Results**

Summary data for age, height, and body mass are contained in Table 1. Age was significantly different between all groups ($P < .001$, $df = 2$, $ES = 0.598$), but height was not ($P = .308$, $df = 2$, $ES = 0.040$). Body mass was not different between NRL
and SRL players \((P = 1.000, df = 38, ES = 0.283)\) or SRL and CRL \((P = .163, df = 38, ES = 0.693)\); however, NRL players were significantly heavier than CRL players \((9.1\%, P = .016, df = 38, ES = 0.896)\). Results for the strength, power, speed, and strength-endurance tests are contained in Table 2. Maximum strength and power were significantly different between all groups. NRL players were stronger than SRL \((11.6\%, P = .003, df = 38, ES = 1.033)\) and CRL players \((30.8\%, P < .001, df = 38, ES = 2.458)\), and SRL players were stronger than CRL players \((17.1\%, P < .001, df = 38, ES = 1.497)\). In terms of upper body power output, BT Pmax was higher for the NRL players than for the SRL players \((15.0\%, P = .003, df = 38, ES = 1.037)\) and CRL players \((30.6\%, P < .001, df = 38, ES = 1.867)\). In addition, SRL players produced more power than CRL players did \((13.6\%, P = .025, df = 38, ES = 0.987)\). Strength-endurance was not different between the NRL and SRL groups \((P = .250, df = 38, ES = 0.521)\), but both groups were significantly different from the CRL group \((49.3\%, P < .001, df = 38, ES = 1.984, and 34.6\%, P < .001, df = 38, ES = 1.356, respectively)\). The NRL group was significantly different from both other groups in upper body speed. That is, BT P20 was higher for the NRL players than for the SRL players \((8.4\%, P = .019, df = 38, ES = 0.884)\) and CRL players \((13.9\%, P < .001, df = 38, ES = 1.409)\), but there was no difference between SRL players and CRL players \((P = .310, df = 38, ES = 0.536)\). The relations of the 4 physical factors to progression to NRL level were \(r = .75, .63, .63, \) and \(.55\) for strength, power, strength-endurance, and speed, respectively. Body weight alone exhibited a much lower relation to progression to NRL rank \((r = .34)\). This analysis indicated that maximum strength displays the highest correlation to playing level. Differences in the performance data according to 3 broad positional groupings for the players of different ranking are depicted in Tables 3 to 5. In the main, these results reflected those of the team group data.

### Discussion

The aim of this study was to assess and compare upper body strength, speed, power, and endurance in rugby-league players across 3 competition levels and by

### Table 2  Comparison of Strength, Power, Strength-Endurance, and Speed Between Rugby-League Players Participating in Different Levels of Competition, Mean (SD)*

<table>
<thead>
<tr>
<th>Rugby-league level</th>
<th>1 RM BP (kg)</th>
<th>BT Pmax (W)</th>
<th>BT P20 (W)</th>
<th>RTF BP60</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>141.4 (15.4)</td>
<td>680 (99)</td>
<td>345 (31)‡</td>
<td>35.6 (6.6)</td>
</tr>
<tr>
<td>Intrastate</td>
<td>126.6 (13.1)</td>
<td>591 (72)</td>
<td>319 (29)</td>
<td>32.1 (6.9)</td>
</tr>
<tr>
<td>Intracity</td>
<td>108.1 (11.6)†</td>
<td>521 (71)†</td>
<td>303 (29)</td>
<td>23.8 (5.3)‖</td>
</tr>
</tbody>
</table>

*1RM BP indicates 1-repetition-maximum bench press; BT Pmax, maximum power generated during bench throws with 40 to 80 kg; BT P20, power generated during bench throws with empty 20-kg barbell; RTF BP60, maximum number of repetitions performed till fatigue while bench-pressing 60 kg.

†All groups different from each other, \(P \leq .05\).
‡National different from both other groups, \(P \leq .05\).
‖Intracity different from both other groups, \(P \leq .05\).
Table 3  Comparison of Upper Body Strength, Power, Speed, and Strength-Endurance Between Rugby-League Hit-Up Forwards Participating in Different Levels of Competition, Mean (SD)

<table>
<thead>
<tr>
<th>Rugby-league level</th>
<th>1 RM BP (kg)</th>
<th>BT Pmax (W)</th>
<th>BT P20 (W)</th>
<th>RTF BP60</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National (n = 8)</td>
<td>150.0</td>
<td>740</td>
<td>362</td>
<td>36.6</td>
<td>107.6</td>
</tr>
<tr>
<td></td>
<td>(19.3)‡</td>
<td>(86)‡</td>
<td>(29)‡</td>
<td>(8.5)‡</td>
<td>(2.9)‡</td>
</tr>
<tr>
<td>Intrastate (n = 9)</td>
<td>126.9</td>
<td>596</td>
<td>322</td>
<td>32.3</td>
<td>99.4</td>
</tr>
<tr>
<td></td>
<td>(5.6)‡</td>
<td>(41)‡</td>
<td>(26)‡</td>
<td>(4.5)‡</td>
<td>(5.2)‡</td>
</tr>
<tr>
<td>Intracity (n = 6)</td>
<td>112.5</td>
<td>536</td>
<td>305</td>
<td>25.3</td>
<td>93.7</td>
</tr>
<tr>
<td></td>
<td>(10.0)‡</td>
<td>(70)‡</td>
<td>(32)‡</td>
<td>(4.4)‡</td>
<td>(5.2)‡</td>
</tr>
</tbody>
</table>

*1RM BP indicates 1-repetition-maximum bench press; BT Pmax, maximum power generated during bench throws with 40 to 80 kg; BT P20, power generated during bench throws with empty 20-kg barbell; RTF BP60, maximum number of repetitions performed till fatigue while bench-pressing 60 kg.
†Denotes all groups different from each other, \( P \leq .05 \).
‡National different from both other groups, \( P \leq .05 \).
||Intracity different from both other groups, \( P \leq .05 \).

Table 4  Comparison of Upper Body Strength, Power, Speed, and Strength-Endurance Between Rugby-League Outside Backs Participating in Different Levels of Competition, Mean (SD)

<table>
<thead>
<tr>
<th>Rugby-league level</th>
<th>1 RM BP (kg)</th>
<th>BT Pmax (W)</th>
<th>BT P20 (W)</th>
<th>RTF BP60</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National (n = 5)</td>
<td>141.0</td>
<td>698</td>
<td>351</td>
<td>37.4</td>
<td>94.9</td>
</tr>
<tr>
<td></td>
<td>(4.2)‡</td>
<td>(41)‡</td>
<td>(11)‡</td>
<td>(4.0)‡</td>
<td>(6.2)‡</td>
</tr>
<tr>
<td>Intrastate (n = 7)</td>
<td>125.0</td>
<td>604</td>
<td>325</td>
<td>31.0</td>
<td>93.4</td>
</tr>
<tr>
<td></td>
<td>(13.0)‡</td>
<td>(105)‡</td>
<td>(29)‡</td>
<td>(6.7)‡</td>
<td>(7.3)‡</td>
</tr>
<tr>
<td>Intracity (n = 7)</td>
<td>109.3</td>
<td>535</td>
<td>308</td>
<td>22.7</td>
<td>87.3</td>
</tr>
<tr>
<td></td>
<td>(14.2)‡</td>
<td>(93)‡</td>
<td>(31)‡</td>
<td>(5.6)§</td>
<td>(7.1)§</td>
</tr>
</tbody>
</table>

*1RM BP indicates 1-repetition-maximum bench press; BT Pmax, maximum power generated during bench throws with 40 to 80 kg; BT P20, power generated during bench throws with empty 20-kg barbell; RTF BP60, maximum number of repetitions performed till fatigue while bench-pressing 60 kg.
†All groups different from each other, \( P \leq .05 \).
‡National different from both other groups, \( P \leq .05 \).
§Intracity different from both other groups, \( P \leq .05 \).

playing position. Before testing, all players performed exactly the same bench-press routine. Therefore, the differences exhibited are not a result of the NRL players’ training more often or relatively harder before testing but must reflect long-term adaptations garnered from multiyear training, as well as some possible genetic influences that are beyond the scope of this article. The results illustrate that all the measured variables tend to discriminate between rugby-league players of
different grades or achievement levels to some degree. This is understandable given the intense physical nature of rugby-league football and the need to forcefully push away opponents.

First, overall maximum strength appears the most potent descriptor for the 3 different grades of rugby-league players, as has been reported previously.\textsuperscript{5-7,11} Upper body pressing strength, as assessed by the 1RM BP, was different by about 15% between grades. Thus, the NRL squad was 30% stronger than the CRL and about 15% stronger than the SRL squad. The magnitude of the relationship between strength and progression to NRL ranking (\(r = .75\)) can be defined as very large according to Hopkins’ scaling and interpretation of correlations and effect sizes (\(r > .7 = \) very large).\textsuperscript{16} Although the ES differences between the NRL and SRL squads could be deemed to be moderate according to Hopkins’ analysis,\textsuperscript{16} the differences between NRL and CRL and SRL and CRL can be described as either large (ES = 1.2 to 2) or very large (ES > 2). Thus, the relationship between strength and NRL ranking and the magnitude of ES differences between the squads mean that of the variables in this investigation, strength is the most distinguishing between rugby-league players of different ranking.

This difference cannot be explained solely by differences in body mass because there was no significant difference in body mass between the SRL and NRL groups (but differences with the CRL group). If results for 1RM BP are scaled relative to body mass, the scores of 1.46, 1.34, and 1.22 kg/kg BM for the NRL, SRL, and CRL groups, respectively, are still significantly different from one another. Even if an allometric method of scaling such as the “two-thirds” formula is used, \((1\text{RM BP})/(\text{BM} \times 0.67)\),\textsuperscript{17} the scores of 2.18, 2.00, and 1.82 for the NRL, SRL, and CRL groups, respectively, are still significantly different from one another. Therefore, issues other than simple measures of total body mass or even fat-free mass must explain these differences in strength. Consequently,

<table>
<thead>
<tr>
<th>Rugby-league level</th>
<th>1 RM BP (kg)</th>
<th>BT Pmax (W)</th>
<th>BT P20 (W)</th>
<th>RTF BP60</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National (n = 7)</td>
<td>131.8</td>
<td>597</td>
<td>321</td>
<td>33.1</td>
<td>86.0</td>
</tr>
<tr>
<td>(n = 7)</td>
<td>(10.2)</td>
<td>(91)‡</td>
<td>(30)</td>
<td>(5.5)‡</td>
<td>(8.9)</td>
</tr>
<tr>
<td>Intrastate (n = 4)</td>
<td>128.8</td>
<td>558</td>
<td>299</td>
<td>33.5</td>
<td>84.0</td>
</tr>
<tr>
<td>(n = 4)</td>
<td>(25.6)</td>
<td>(62)</td>
<td>(35)</td>
<td>(12.3)</td>
<td>(4.2)</td>
</tr>
<tr>
<td>Intracity (n = 7)</td>
<td>103.0</td>
<td>493</td>
<td>296</td>
<td>23.7</td>
<td>86.0</td>
</tr>
<tr>
<td>(n = 7)</td>
<td>(9.6)†</td>
<td>(46)</td>
<td>(26)</td>
<td>(6.2)</td>
<td>(3.5)</td>
</tr>
</tbody>
</table>

\*1RM BP indicates 1-repetition-maximum bench press; BT Pmax, maximum power generated during bench throws with 40 to 80 kg; BT P20, power generated during bench throws with empty 20-kg barbell; RTF BP60, maximum number of repetitions performed till fatigue while bench-pressing 60 kg.

\†Intracity different from both other groups, \(P \leq .05\).

\‡National different from intracity only, \(P \leq .05\).
various neural, tissue/morphological, or maturation (the NRL players were older) adaptations must explain this result. It has been shown that increased neural activity occurs in muscles, perhaps because of increased rate coding and signal intensity, in the first 8 to 12 weeks of strength training. It has been postulated that other neural adaptations that occur with long-term periodized strength and power training would be more efficient neural patterning of the skill of the strength exercises, diminished levels of unwarranted antagonist cocontraction, synchronous firing of motor units (especially during the initial concentric phases of ballistic power exercises), and reduced inhibitory feedback from force receptors or regulators such as the Golgi tendon organs and Renshaw cells. The extent to which these adaptations occur and the time frame for their occurrence are yet to be fully determined. Qualitative muscle-tissue adaptations such as changes to the fiber type or myosin heavy-chain expression could also presumably occur with increased training experience. Further discussion of the type, extent, and nature of these adaptations is beyond the nature of this article, but they have been reviewed extensively elsewhere.

Maximum upper body pressing power, as assessed by the BT Pmax, also clearly differentiated between the 3 groups. The NRL and SRL groups were 30% and 15% more powerful, respectively, than the CRL group. The extent of the relation of power to NRL ranking was large according to the Hopkins interpretation. Effect-size differences were quite large between NRL and CRL players and moderate between NRL and SRL players and SRL and CRL players. The outcome mirrors almost exactly the result for maximum strength, which is understandable given the very strong correlation between maximum strength and power. Thus, maximum power would appear to be a potent descriptor of which athletes progress from CRL to SRL to NRL level, a finding verifying previous research.

Movement speed, as assessed by the BT P20, illustrated a difference between the NRL group and the other 2 groups but no difference between the lower 2 groups. Overall, the percentage differences between the groups, magnitude of the relation of speed to NRL progression, and ES were about half compared with strength and power. There was no significant difference in upper body speed between the CRL and SRL groups; however, the apparent 5% difference in scores might have a practical significance for elite athletes. A previous report on this type of testing also demonstrated that the movement-speed test was not as strong a discriminator of rugby-league playing level as a test of maximum strength. This finding might indicate that upper-body-movement speed, as assessed while athletes lift a light resistance, is less important to rugby-league success than absolute strength and maximum power.

Strength-endurance, as assessed by the RTF BP60 test, has not been assessed in this manner before in rugby-league players, and this article is the first to report on its suitability for this athlete population. Our preliminary pilot work attempted to analyze the ability of a common test of high-intensity strength-endurance used in the American football system to describe and compare rugby-league players of different grades. It was felt, however, that the resistance used in the test (RTF while bench pressing 102.5 kg, a test known as the NFL 225-lb test) was inappropriately heavy for a large number of subjects who either could not lift this resistance at all or could for only a few repetitions. As a result, the test became a feat of maximum strength, rather than strength-endurance, for a large proportion of the subjects. It was concluded that a lighter absolute resistance of 60 kg be used during
bench-press RTF testing to determine the relative importance of strength-endurance for success in rugby league.

The repetitions to fatigue performed while bench-pressing 60 kg in the current study ranged from 16 to 50, clearly indicating that this was a valid test of strength-endurance in terms of repetitions completed and the relative %1RM used, according to the ACSM guidelines.14 This test of strength-endurance differentiated between CRL players and the other higher-ranking groups, with the relation to NRL ranking and ES indicating a large difference. Between the NRL and SRL groups, however, the differences were not significant, and the ES could be deemed to be small. So although there was clearly a significant difference between the lower-ranked CRL group and the higher-ranked groups in the performance of this test, it would be appear not to be as potent a descriptor of rugby-league playing ability as the upper body test of maximum strength and power between athletes already at state-league level. Given that the NRL players are substantially stronger than SRL players and that there is a strong relationship between 1RM strength and the number of repetitions performed with submaximal resistances,22-24 it is not fully understood how the strength-endurance test failed to be different between these 2 groups. Further research is required in the area of high-intensity strength-endurance to determine its relevance to rugby league.

The relative importance of these tests to whether a player attained NRL, SRL, and CRL ranking and interpretation to Hopkins’ scale16 is interesting. By assigning numbers 3, 2, and 1, respectively, to the players in the NRL, SRL, and CRL squads and then rank-correlating these numbers to the different test scores for an individual, the relationship of these absolute test scores to the player ranking can be determined. For example, body mass was significantly related to attainment of NRL level ($r = .34$), but the very moderate extent of this relationship suggests that it is not as strongly related as the performance factors of strength (very large), power, speed, or strength-endurance (large). Thus, merely being a rugby-league player with a large body mass is far less important than being a strong rugby-league player, irrespective of body mass.

As rugby-league football entails players with different positional tasks, it could be expected that the different upper-body-muscle qualities might be more or less desirable in these different positions.2 To discern whether this was true, further analyses were implemented along the positional groupings that were determined by their club coaches according to contemporary practices and trends. Conceivably, the upper body strength, power, speed, and strength-endurance needs for these 3 different positional groups could differ substantially.

Tables 3 to 5 describe the differences in these 4 qualities of upper-body-muscle performance for each of the 3 positional groupings. As is the case for the squad data, maximum strength and power again tend to be the best descriptors of rugby-league playing ability. For the hit-up forwards, maximum strength and power clearly distinguish the NRL players from the SRL players (11% to 13%, ES = 1.855 to 2.267) and the CRL players (33% to 38%, ES = 2.6). Upper-body-speed results are less markedly different, and muscle endurance only separated the NRL and SRL hit-up forwards from their CRL counterparts (ES ≥ 1.5), not from each other. For the more robust physical tasks confronting the larger hit-up forwards during a game of rugby league, maximum strength, power, and body mass (ES = 1.75 to
3.39, large to very large differences) appear more highly desirable and better able to describe those who progress to NRL level from those who do not.

The results for the outside backs are similar to those for the hit-up forwards, with the NRL outside backs being 13% to 14% stronger (ES = 1.86, large, and 3.44, very large, differences) and 29% to 30% (ES = 1.2 to 1.98, large differences) more powerful than their SRL and CRL counterparts, respectively, despite no significant difference in body mass. Although strength was significantly different between all 3 team levels, power and speed were similar between the SRL and CRL players. Strength-endurance was different between the CRL and both the NRL (ES = 2.854) and SRL groups, who were statistically similar. Based on the magnitude of the percentage differences and the ES, clearly the outside backs at NRL level are much stronger and more powerful than lower-ranked counterparts. Most important, they do not rely on differences in body mass to provide those advantages.

The magnitude of differences in the muscle-performance tests for the ball players was less pronounced. There were differences in strength, strength-endurance, and power between CRL players and the SRL and NRL players (ES = 1.46 to 2.909, designating large to very large differences) but not between the latter 2 groups. Because the ball players are deemed to be the most skillful players, it is probable that the factors separating the SRL and NRL players in this positional grouping are not upper body strength or power but might be more related to other attributes such as ball skills, organizational ability, and game-related decision making.

Although the Positional Grouping × Team Ranking analysis is hampered by lower numbers of subjects, we think that this is unavoidable when dealing with elite and subelite athletes. In this case-study approach we wanted subjects with a recent homogeneous training background but who were ranked differently by their coaches. This allowed us to investigate whether their performance in strength, power, speed, and endurance in 1 simple test motion (bench press) could largely distinguish their different team rankings. Thus, this was a performance-oriented approach to determining the relative importance of upper body strength, power, speed, and strength-endurance in a real-world setting with elite and subelite athletes, rather than a controlled mechanistic study of the underlying factors affecting strength, power, speed, and strength-endurance. Thus, we rated performance as team ranking, as determined by the professional coaches, and attempted to ascertain how the upper body factors affected this measure of “performance.” Using the descriptors linked to the correlation coefficients and effect sizes proposed by Hopkins, the overall team analyses show that strength “very largely” and the other factors “largely” do distinguish team ranking. This is especially so for both the hit-up forwards and the outside backs and to a lesser degree for the ball players.

The interrelations between various muscle-performance factors are also of interest and are detailed in Table 6. First, body mass exhibits only moderate relationships between maximum strength, power, speed, and strength-endurance (r [95% confidence interval] = .48 [.22 to .74], .58 [.32 to .84], .51 [.25 to .77], and .40 [.14 to .66], respectively). Maximum power, strength, and speed were very highly interrelated, a finding that has been reported numerous times before in rugby-league players, as well as other athletes.21
A pathway in upper body strength, power, speed, and strength-endurance for professional rugby-league players in different positions and team rankings has been illustrated in this article. Strength-and-conditioning specialists and players must devote considerable training time to increasing these aspects if they are to maximize their playing level. The preparation of elite rugby-league athletes will include a long training history of hypertrophy-oriented training (to increase body mass to the levels of SRL and NRL players), heavy resistance training to maximize strength development, and exercises to develop upper body power output. Strength-endurance training also appears to be important to NRL attainment and should be stressed in the resistance-training regime of rugby-league players. Players should initiate resistance training during adolescence and gradually increase its volume and intensity as they mature and rise in playing level if they are to be successful in elite competition.

**Conclusions**

Despite recent rule changes, referee interpretations, and coaching strategies and ploys that have conceivably increased the upper body strength-endurance demands on the players, strength-endurance, as assessed in this investigation, was not found to be the most dominant upper body descriptor of NRL playing rank. Of the 4 upper body tests assessed in this article, maximum strength appears the most highly related to success in rugby league and displays the highest percentage differences between different teams. Maximum power and strength-endurance, which were both strongly related to maximum strength, were also strongly and similarly indicative of successful attainment of NRL level. Upper-body-movement speed, while still significant, tends to describe team ranking less readily than the other measures of upper-body-muscle function. When analyzed according to positional groupings, the results are similar. Based on these results, younger rugby-league players who desire to attain higher playing levels should strive to increase upper body maximum strength, which appears to underpin performance in other key muscle-performance factors such as maximum power and strength-endurance.

**Table 6**  Intercorrelations Between Tests of Upper Body Strength, Power, Speed, and Strength-Endurance Between Rugby-League Players in National, Intrastate, and Intracity Leagues

<table>
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<tr>
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<th>BT Pmax</th>
<th>BT P20</th>
<th>RTF BP60</th>
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<tr>
<td>1RM BP</td>
<td>.84</td>
<td>.71</td>
<td>.83</td>
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<tr>
<td>BT P20</td>
<td>.84</td>
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<td>.55</td>
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*All relationships are \( P \leq .0001 \). BT Pmax indicates maximum power generated during bench throws with 40 to 80 kg; BT P20, power generated during bench throws with empty 20-kg barbell; RTF BP60, maximum number of repetitions performed till fatigue while bench-pressing 60 kg; 1RM BP, 1-repetition-maximum bench press.

Practical Applications
References

