Strength and power development in professional rugby union players over a training and playing season

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Abstract

Purpose: To investigate strength and power development in elite rugby players during the different phases of a professional season. Methods: Sixteen professional rugby union athletes from an English premiership team were monitored for measures of lower body peak force, force at 50 ms, force at 100 ms (all isometric squat), and power (explosive hack squat). Athletes were assessed at the start of pre-season (T1), post pre-season (T2), mid-way through the competitive season (T3) and at the end of the competitive season (T4). Effect size statistics with magnitude based inferences were calculated to interpret differences in physical performance between the different stages of the season. Results: Very likely beneficial increases in force at 50 ms (+16%, ES = 0.75 ± 0.4) and 100 ms (+14%, ES = 0.63 ± 0.4) were observed between T1-T2. A likely beneficial increase in power was observed between T2-T3 (+4%, ES = 0.31 ± 0.2). Between T3-T4, decreases in force at 50 ms (-6%, ES = -0.39 ± 0.3) and 100 ms (-9%, ES = -0.52 ± 0.4) occurred whilst peak force and power were maintained. Over the full season (T1-T4) clear beneficial increases in all measures of strength and power were identified. Conclusions: Meaningful increases in strength and power can be achieved in professional English premiership rugby players over a full playing season. The greatest opportunity for strength and power development occurs during pre to mid-season phases whilst these measures are maintained or decrease slightly during the latter stages of a season.

Keywords: Strength – Power – Rugby – Resistance Training – Peak Force
Introduction

Rugby union players require maximum and explosive force production capabilities for both contact (e.g. scrummaging, rucking and mauling) and sprinting aspects of the game.\(^1,2\) Maximizing long-term adaptation of muscular force via resistance training is therefore one of the main goals of professional rugby players’ conditioning programmes. Most evidence on training adaptation arises from short-term studies (6-12 weeks) with sub-elite athletes, where improvements in muscular strength and power are achieved with relative ease.\(^3\) These studies may not reflect the adaptation potential of well-trained rugby players where the concurrent training environment, the principle of diminished return, and the time limited nature of a competitive season make athletic development harder to achieve.\(^4-6\)

Currently, there is limited information regarding long-term changes in physical performance in elite rugby union athletes. A 13 week in-season monitoring study reported moderate increases in lower body strength (9%) and maintenance of upper body strength (-1%), with small decreases in lower and upper body power (both -3%).\(^4\) Over a two season period in elite Australian rugby union players, which comprised an 8-10 week pre-season and 14 week in-season period, strength capacity increased by 7 and 12% in upper and lower limbs respectively.\(^7\) Similar findings have been reported in highly trained rugby league players, where two years of resistance training lead to a 6% increase in upper limb strength,\(^8\) whilst lower limb strength increased by 14% over a four-year period.\(^8\) Elite rugby athletes may not demonstrate extreme changes in physical performance capacity, but evidence does suggest that meaningful improvements in strength and power can be achieved when monitored over long-term training periods.

The structure of the training and playing season is very different in southern and northern hemisphere rugby union, with 14 weeks of competition per season in the southern hemisphere,\(^4,7\) compared with 34 weeks in the English premiership with the longer in-season periods due to the number of matches played (approximately one per week). Average weekly pre-season training loads of 4211 intensity-minutes have been reported in New Zealand\(^4\) compared with 2175 in England,\(^9\) with in-season values of approximately 1700 and 1581 respectively. Clear differences in pre-season load exist and whilst in-season load is similar the longer competitive duration of the English premiership may impact athlete recovery potential and influence the treatment effects of strength and power training.\(^10\) These differences may alter the force development, retention and decay potential of rugby athletes competing in the northern hemisphere. Applying the limited long-term training research available from southern hemisphere structures may not therefore reflect adaptive physiological capacities in athletes competing during pre and in-season phases during a full season in the English premiership.

To date, there is no literature examining the effects of a full season of English professional rugby union on changes in strength and power. Hence, the purpose of this study was to describe changes in strength and power over the pre and in-season phases of a professional competitive season of rugby union in the English premier division. It was hypothesised that strength and power would improve over the pre-season period and that these levels would be maintained throughout the competitive season.

Methodology

Participants

Twenty two professional male rugby union athletes from an English premiership professional rugby team volunteered to take part in this study. The participants competed in both the
English premiership and European cup competitions from September 2013 to May 2014. Three of the participants also performed at senior international level. Each athlete had at least two years of resistance training experience. Each participant was over the age of 18 and provided written informed consent. Six participants were removed from analysis due to match related injury. Data for sixteen participants (age, 23 ± 4 years; height, 1.89 ± 0.10 m; body mass, 109.0 ± 11.4 kg) was subsequently analysed. Study procedures were approved by an institutional ethics committee (Research Ethics Advisory Committee for Health, University of Bath) and complied with the regulations set out in the 2008 Declaration of Helsinki.

**Design**

This longitudinal tracking study investigated markers of strength and power in professional rugby union athletes over 45-weeks. Athletes were assessed on four separate occasions: initial testing (weeks 1-3; [T1]) which represented the start of the pre-season period, at the end of the pre-season period (weeks 10-12; [T2]), mid-way through the competitive season (weeks 31-33; [T3]), and at the end of the competitive season (weeks 43-45; [T4]). All testing sessions were performed in the morning between 08:00 and 10:00 hours, prior to the athletes’ first training session of the day. During each testing session an explosive hack squat (power) was performed first followed, after a 5-minute recovery period, by an isometric squat (strength). Neither the isometric squat nor explosive hack squat formed part of the athletes’ training programme.

**Training**

The nature of the training programme was dependent on the training phase as outlined in Table 1. The strength training programme was periodised and was designed to develop maximal and explosive force production qualities. Strength training programmes were prescribed to individual athletes’ based on their physical limitations, positional requirements and injury history. Strength training performed throughout the season was characterised as: i) hypertrophy-strength isotonic (i.e., 75-89% of 1 repetition maximum [1RM], 4-6 working sets, 4-10 reps per set), ii) hypertrophy-strength eccentric (i.e., 110-130% 1RM, 4-6 working sets, 3-6 reps per set), and iii) maximal-strength (89-95% 1RM, 4-6 working sets, 2-4 reps per set).

During the pre-season phase (weeks 1-12), the first six weeks were characterised by a greater frequency and volume load of hypertrophy-strength training, while the last six weeks were characterised by a greater volume load of maximal-strength training. During the first competition phase (weeks 13-33), hypertrophy-strength and maximal-strength training sessions were cycled in five week blocks, whilst frequency decreased training intensity remained high and total volume load was reduced. The second competition phase (week 34-45) was characterised as physical maintenance, and was periodised via short cycles of reduced total volume load hypertrophy-strength and maximal-strength training.

Typical multi-joint lower body strength exercises used during training sessions included squat variants, deadlifts, supine and incline leg press and hip extensions. Typical power and speed exercises included weighted jumps, horizontal jumps, sled sprints, flat sprints and change of direction drills. Supplementary isolation exercises for the calf, hamstring and gluteal muscle groups were prescribed after the completion of multi-joint exercises. Each multi-joint lower body exercise began with three sets of progressively increasing load prior to three to six maximal intensity sets at the load prescribed for the specific strength training session.
Rugby training involved full team training with match simulation. These sessions incorporated varying levels of contact from tackle/static exertion simulation, to pads, to full contact. Position specific unit training was also performed weekly whereby skills, technique and tactics were practiced (i.e. scrum, lineout, backline play) based on each individual’s positional demands. Energy system conditioning consisted of two high-intensity interval training (HIT) sessions per week during the pre-season period (i.e. 15-30 minute total duration, repeated efforts of 5 to 20 second work periods, 1:2-4 work to rest ratio). Athletes were prescribed exercise intensities that corresponded to approximately 110-130% of their maximal aerobic speed. Conditioning sessions comprised predominantly running with changes of direction (e.g. 180°), however bike sessions were also used. Athletes also performed two sessions per week of small-sided games (30 minute duration). Due to the high running conditioning component of rugby training, conditioning sessions were reduced to one per week during the last 4 weeks of pre-season. During the first and second competition phases conditioning sessions were delivered on an individual basis dependent on weekly training and match play volume.

Test battery

**Explosive hack squat**

Lower body power was monitored using an explosive hack squat exercise. The explosive hack squat used a plate-loaded sled with padded shoulder supports positioned on a steel constructed frame with rails inclined at 24° (Figure 1). The sled was mounted on the rails on low friction steel rollers. The starting position of the sled was adjustable to the nearest 50 mm and the foot platform was gridded to ensure lower limb joint angles and starting foot positions were standardised. An optical encoder analysis system (Gymaware, Kinetic Performance Technology, Canberra, Australia), which has been reported to provide valid measures of kinetics during explosive bilateral lower limb movements¹¹ and has built-in correction for non-vertical movements, was attached to the sled to record concentric mean power. The explosive hack squat was performed with a load which represented 177% (193 kg) of the group’s mean body mass taking into consideration the effect of gravity on the incline plane. This load was based on the mean percentage of body mass by which maximal average mechanical power was attained during pilot work. Five repetitions were performed on the explosive hack squat to ensure maximal power was achieved,¹² with the best repetition used for analysis. During each repetition, participants were instructed to perform a triple extension movement with the intent to generate maximum velocity of the sled. Before each of the five repetitions, participants reset into their standardised starting positions. Analysis of reliability was conducted with data from the five consecutive explosive hack squat trials performed during initial testing (T1). The intraclass correlation coefficient (ICC) was 0.97, and the typical error (TE) for the explosive hack squat was 2.3%.

**Isometric squats**

Isometric squats were completed on a squat rig consisting of a horizontal barbell above a portable force platform (AMTI ACCUGAIT 0341, USA). Ground reaction forces were recorded at the highest sample rate available from the portable force platform (200 Hz). The portable force platform was selected due to the practicalities of performing the tests within the applied rugby training environment. Zero force was defined as the participant’s body weight. Peak force has been reported to occur at knee flexion angles of 130-170° during the concentric phase of a squat, therefore a knee angle of approximately 140° was used.³ Participants stood on the force platform in a back squat position and bar height was fixed using metal stops. Average knee flexion angle was 137.6 ± 3.7° as measured by a
goniometer. Foot position was recorded for each participant and replicated on subsequent testing. During all squat trials, participants were instructed to adopt a neutral spine position and maintain a stable posture throughout each contraction period. Participants performed two warm up trials, one at 60% and one at 80% of their perceived maximal exertion. They then performed three maximal isometric efforts where they followed a simple 5 second countdown, followed by “go, 1, 2, 3, 4, stop”. During the contraction, each participant was instructed to push against the bar as fast and as hard as possible for the entire count, with 3 minutes of rest separating each trial. Knee angles and body alignment was checked before each trial and verbal encouragement, which was standardised for each participant, was given to increase participant motivation.

Force data collected via the AMTI portable force platform were exported to Microsoft Office Excel. The vertical ground reaction force data was smoothed via a 10 point moving average. The greatest peak vertical ground reaction force of the three maximal squats was defined as peak force. As force production during the early phase of isometric squatting (<100 ms) has been reported to be associated with athletic performance in elite rugby players,² force at 50 ms and 100 ms intervals from the onset of force application was identified. Onset of force application was defined as the first value to exceed three standard deviations above the mean quiet resting value. Peak force, force at 50 ms and force at 100 ms was normalised to body mass by allometrically scaling with an appropriate power value (i.e., N.kg⁻⁰.⁶⁶).¹³ Analysis of reliability was conducted with data from the three consecutive isometric squat trials performed during initial testing (T1). For measures of peak force, the ICC was 0.95, and the typical error was 2.4%. The measure of force at 50 ms reported an ICC of 0.53 and a TE of 9.6%, whilst force at 100 ms reported an ICC of 0.51 and a TE of 11.2%. It was not possible to assess between-session reliability for early force measures in the current study. However, past studies have reported between-session reliability measures of force at 50 ms (ICC = 0.80; CV = 16.6%) and force at 100 ms (ICC = 0.91; CV = 6.4%).¹⁴

Statistical analysis
All training session data, force and power values are represented as Mean ± SD. A one-way ANOVA with repeated measures was used to identify if significant differences existed over the three training phases between the training session data collected (Table 1). All training session data was tested for sphericity and paired t-tests were used for post hoc analysis. Changes in measures of force and power were analysed according to the concept of smallest worthwhile change through effect size (ES) statistics.¹⁵ The smallest worthwhile change is a reference value (calculated as 0.2 of the pooled between participant standard deviation) that permits the calculation of the probability that an observed change in performance is large enough to have an important effect on performance in team sport athletes.¹⁵ This statistical methodology has been advocated as a more appropriate strategy for identifying meaningfulness of change in elite athletes since well-trained individuals display smaller alterations in performance than typical or less trained populations.¹⁵,¹⁶

Effect size statistics were calculated for the magnitude of difference in the force and power scores between three different stages of the season (T1-T2, T2-T3 and T3-T4) and between the start and end of season measures (T1-T4). Changes in force and power were categorised as trivial (ES <0.2), small (ES 0.2-0.6), moderate (ES 0.6-1.2), large (ES 1.2-2.0) and very large (ES >2.0).¹⁵ In order to identify the uncertainty around the true value of the reported effect size statistics, 90% confidence intervals around each effect size were reported based on the methods of Hopkins.¹⁷ Subsequently, magnitude based inferences were attached to each effect size and reported as the percentage chance, with descriptor, that the true effect was
beneficial, trivial or harmful. For an effect size to be clear, the odds of benefit relative to odds of harm (odds ratio) had to be > 66.

Results
Between initial testing to post pre-season (T1-T2), the change in peak force was unclear (+2.7%, ES = 0.21 ± 0.30, Table 2), whilst very likely beneficial increases in force at 50 ms (+16.0%, ES = 0.75 ± 0.40, Table 2) and 100 ms (+13.9%, ES = 0.63 ± 0.40, Table 2) were observed. The change in power was likely trivial (+0.2%, ES = 0.02 ± 0.20, Table 2) (Figure 2A).

Between post pre-season to mid-season (T2-T3) there was an unclear change in peak force (+1.9%, ES = 0.20 ± 0.40, Table 2), and a likely beneficial increase in power (+3.6%, ES = 0.31 ± 0.20, Table 2). Changes in force at 50 ms (+1.6%, ES = 0.09 ± 0.40, Table 2) and 100 ms (+2.8%, ES = 0.16 ± 0.40, Table 2) were unclear (Figure 2B).

Mid-season to end of season (T3-T4) there was a likely harmful decrease in force at 50 ms (-6.3%, ES = -0.39 ± 0.30, Table 2) and 100 ms (-8.8%, ES = -0.52 ± 0.40, Table 2). Changes in peak force (-0.6%, ES = -0.07 ± 0.50, Table 2) and power (-0.8%, ES = -0.08 ± 0.50, Table 2) were trivial (Figure 2C).

When performance was analysed between initial testing and end of season testing (T1-T4), increases in peak force (+4.1%, ES = 0.32 ± 0.40, Table 2), power (+3.0%, ES = 0.29 ± 0.30, Table 2) and force at 100 ms (+6.9%, ES = 0.32 ± 0.40, Table 2) were possibly beneficial, whilst force at 50 ms (+10.5%, ES = 0.55 ± 0.40, Table 2) was likely beneficial (Figure 2D).

Discussion
This investigation tracked strength and power characteristics in professional rugby union athletes during a full competitive playing season. Beneficial improvements in early force production occurred during the pre-season training period, whilst beneficial increases in power were observed at mid-season testing. Peak force and power characteristics were maintained during the latter stages of the season. Over the 45 week training and playing period, beneficial increases in peak and early force production as well as power were identified, suggesting improvements in muscular performance can be achieved over a season of concurrent training and match play.

The 12-week pre-season period (T1-T2) resulted in greater increases in strength than other periods in the season. This finding supports previous evidence demonstrating the positive effects of a pre-season training block on measures of lower body strength in professional rugby union athletes and reflects the greater opportunity pre-season presents in team sports for physical preparation. In the present study, significantly greater lower limb resistance training volume loads were recorded during the pre-season when compared to mid and end of season phases whilst a significantly greater frequency of resistance training was completed during this period in comparison to the end of season phase (Table 1). Pre-season training also facilitates the implementation of more effective periodisation strategies. For example, strength training was a prioritised training goal and sessions were planned to avoid interference effects of concurrent training (i.e. strength and endurance training were performed on separate days). The pre-season period also involved significantly fewer matches which may have reduced the likelihood of injury and limited fatigue which has been reported to decrease the potential for strength adaptation.
Power did not improve during pre-season training (T1-T2). Similarly, Argus et al.\textsuperscript{18} reported small declines in lower-body power over a four week pre-season training cycle to be associated with the greater total training volumes accumulated during this period. Consequently, the elevated resistance training volume load during pre-season (Table 1) may have compromised the development of power. Power did however increase between the end of pre-season and mid-season testing (T2-T3), which was characterised by a reduction in total resistance training volume load. Long-term changes in power have also been reported to be heavily reliant on changes in strength and multi-joint isometric peak force is a strong predictor of multi-joint dynamic performance.\textsuperscript{21,22} At mid-season testing, values for peak force were at their highest of the study period (Table 3) and there was a significant association between peak force and power ($r = 0.50$, $p = 0.02$).

From mid to end of season testing (T3-T4) peak force and power remained unchanged. These findings support previous long-term analysis suggesting physical qualities such as strength and power can be maintained throughout in-season periods.\textsuperscript{4,10,23} This training phase resulted in small decreases in force at 50 and 100 ms. The maintenance of force and power and the decline in early force production may reflect the diminishing scope for positive physical adaptation during this period.\textsuperscript{21} Weekly rugby training volume, running distance and high intensity running/sprinting volume was not statistically different throughout each season phase, whilst match play frequency was significantly higher during the final phase of the season in comparison to pre and mid-season phases (Table 1). Consequently, the limited effectiveness of strength and power training during this period may be associated with the effects of residual fatigue which may have built up over the course of the season combined with inadequate recovery time between weekly competition and rugby training demands.

The most robust training responses were identified when changes in strength and power were analysed over the entire 45-week season, with clear beneficial but small effect sizes (ES range = 0.29-0.55) for all the performance measures. This supports evidence that strength and power appear to be trainable in elite-football code athletes over competition periods.\textsuperscript{7,24} In particular, the 4.1\% (ES = 0.32) increase in peak force in the present study is comparable to the 11\% (ES = 0.50)\textsuperscript{7} increase in back squat 1 RM performance and is greater than the 1\% (ES = 0.07)\textsuperscript{7,25} increase in front squat 1 RM performance observed over one year in southern hemisphere rugby union athletes. Lower limb extension power also demonstrated a beneficial 3.0\% (ES = 0.29) increase at the end of season which is in contrast to a study by Argus, Gill, Keogh, Hopkins, Beaven\textsuperscript{4} who identified a decrease (-3\%, ES = <0.20) in jump squat power.

The discrepancies in long-term strength and power development within elite rugby research may reflect differences in the testing measures used (i.e., isometric force vs. maximum dynamic strength) and the weekly prescription of training loads, volumes, frequencies and exercise patterns (i.e., jumps vs. Olympic lifting). However, in contrast to previous southern hemisphere tracking analysis,\textsuperscript{4} both strength and power appeared adaptable at different phases over the longer in-season competition period of the English premiership.

This is the first study to identify long-term changes in markers of peak and early force capacity in an elite applied environment since muscular performance tracking has typically been used in short-term non-elite training studies.\textsuperscript{3,26} In particular, Tillin, Folland\textsuperscript{27} demonstrated significant increases in maximum voluntary isometric force production (21 ± 12\%), force at 50 ms (70 ± 77\%) and force at 100 ms (16 ± 14\%) in response to four weeks of strength training in recreationally active participants. The present study observed smaller increases in these values over longer training periods which may reflect the diminished central nervous system and hypertrophic adaptation potential of already elite athletes.\textsuperscript{5,28}
must be acknowledged, however, that interpretation of the change in force at 50 ms and 100 ms had relatively poor within-session reliability and has previously been shown to have only moderate between session reliability.\textsuperscript{14} This may, in part be a function of the low sampling frequency of the portable force platform, and the findings regarding training induced changes in early force measures should be considered cautiously in this context. It is recommended that future research tracking longitudinal changes in early force be taken in duplicate, at greater sampling rates (i.e., 1000 Hz).

We also recognise that the reported changes in strength and power characteristics may differ with alternative periodisation and exercise prescription, that these changes may not be indicative of the upper body as these measures were not included in the current study, and that the interpretation of the association between anthropometric and performance variables would have benefitted from regular body composition measurements.

Nevertheless, beneficial increases in lower body isometric peak force combined with enhanced isotonic power may contribute to better performance in dynamic rugby tasks. For example, the ability to explosively utilise high peak ground reaction forces is important for the development of stride length during acceleration.\textsuperscript{25,29,30} High rates of power development across a multitude of contraction time scales are also a critical component for contact situations such as scrum engagements, collision effectiveness and rucking and mauling tasks.\textsuperscript{31-33}

**Practical Applications**

Approximately 1-2 lower body strength and power training sessions per week can induce meaningful adaptation in these qualities despite the concurrent training loads which characterise a competitive season of English premiership rugby. If further gains in strength and power are to be achieved during the final stages of a season, then a reduction in external rugby training load and match play is likely needed to limit the potential effects of residual fatigue and to maximise resistance and power training response pathways.

**Conclusions**

The net effect of an entire training and playing season on markers of strength and power in senior English premiership rugby players appears positive. The greatest opportunity for physical development occurs during pre to mid-season phases whilst maintenance or slight decreases in these qualities appears to define the latter stages of a season. Meaningful increases in these measures over a competitive season could support functional improvements in dynamic rugby tasks such as initial acceleration and contact events.

**Acknowledgements**

The authors would like to acknowledge the assistance of Dr Sean Williams (University of Bath) in relation to the presentation of the statistical analyses.
References


Figure Captions

**Figure 1.** Photograph of the custom built explosive hack squat showing; A) participant positioning at the start of the movement, B) participant at extension during the jump.

**Figure 2.** Effect sizes (with 90% CI) for the differences in each performance measures at; A) initial testing vs. end of pre-season (T1-T2), B) end of pre-season vs. mid-season (T2-T3), C) mid-season vs. end of season (T3-T4), and D) initial testing vs. end of season (T1-T4). Data labels give likelihoods that effect is substantially harmful | trivial | beneficial.
**Table 1.** Average weekly total volume load for lower limb resistance training, average number per week of lower limb resistance training, speed and power training, rugby training sessions and matches played as well as average weekly running volumes, high intensity running and sprinting volume (i.e. all running volumes $>5$ m/s)\(^1\) and the average number of total weekly collisions (mean ± SD).

<table>
<thead>
<tr>
<th>Training phase</th>
<th>T1-T2 (weeks 1-12)</th>
<th>T2-T3 (weeks 13-33)</th>
<th>T3-T4 (weeks 34-45)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower limb resistance training</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>volume load (kg)</td>
<td>9110 ± 2335(^*#)</td>
<td>5737 ± 2475</td>
<td>5662 ± 224</td>
</tr>
<tr>
<td><strong>Lower limb resistance training</strong></td>
<td>1.6 ± 0.1(^*)</td>
<td>1.4 ± 0.6</td>
<td>1.3 ± 0.4</td>
</tr>
<tr>
<td><strong>Speed-power training</strong></td>
<td>1.1 ± 0.1(^*#)</td>
<td>0.4 ± 0.1</td>
<td>0.4 ± 0.2</td>
</tr>
<tr>
<td><strong>Rugby training</strong></td>
<td>4.1 ± 0.8</td>
<td>4.2 ± 0.2</td>
<td>4.3 ± 0.4</td>
</tr>
<tr>
<td><strong>Matches</strong></td>
<td>0.2 ± 0.1(^*)</td>
<td>0.5 ± 0.1</td>
<td>0.7 ± 0.1(^*)</td>
</tr>
<tr>
<td><strong>Running volume (m)</strong></td>
<td>13201 ± 2924</td>
<td>11852 ± 3023</td>
<td>10384 ± 3570</td>
</tr>
<tr>
<td><strong>High intensity running &amp; sprinting volume (m)</strong></td>
<td>513.9 ± 200</td>
<td>519.7 ± 248</td>
<td>526.7 ± 235</td>
</tr>
<tr>
<td><strong>Collision volume</strong></td>
<td>36.8 ± 29.3</td>
<td>40.8 ± 22.7(^*)</td>
<td>26.7 ± 12.6</td>
</tr>
</tbody>
</table>

\(^*\)T1-T2 significantly different to T2-T3 p < 0.001
\(^#\)T1-T2 significantly different to T3-T4 p < 0.001
\(^*\)T3-T4 significantly different to T2-T3 p < 0.05
\(^*\)T2-T3 significantly different to T3-T4 p < 0.05

Note: volume load (kg) = number of sets × number of repetitions × weight lifted (kg)\(^1\)
Table 2. Percentage change with 90% confidence intervals (CI) in early and peak force and power between each test during the 45 week season. T1 = baseline; T2 = post pre-season, T3 = mid-season, T4 = end of season.

<table>
<thead>
<tr>
<th></th>
<th>T1-T2</th>
<th>T2-T3</th>
<th>T3-T4</th>
<th>T1-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean % Change ± 90% CI</td>
<td>Mean % Change ± 90% CI</td>
<td>Mean % Change ± 90% CI</td>
<td>Mean % Change ± 90% CI</td>
</tr>
<tr>
<td>PF (N.kg⁻⁰.⁶⁶)</td>
<td>2.7 ± 1.1</td>
<td>1.9 ± 1.1</td>
<td>-0.6 ± 1.0</td>
<td>4.1 ± 1.0</td>
</tr>
<tr>
<td>Power (W)</td>
<td>0.2 ± 1.0</td>
<td>3.6 ± 1.1</td>
<td>-0.8 ± 1.0</td>
<td>3.0 ± 1.1</td>
</tr>
<tr>
<td>F50 (N.kg⁻⁰.⁶⁶)</td>
<td>16.0 ± 1.3</td>
<td>1.6 ± 1.1</td>
<td>-6.3 ± 1.0</td>
<td>10.5 ± 1.2</td>
</tr>
<tr>
<td>F100 (N.kg⁻⁰.⁶⁶)</td>
<td>13.9 ± 1.2</td>
<td>2.8 ± 1.1</td>
<td>-8.8 ± 1.0</td>
<td>6.9 ± 1.2</td>
</tr>
</tbody>
</table>

PF = Peak force, F50 = force at 50 ms, F100 = force at 100 ms
Table 3. Values of early and peak force, power and body mass (mean ± SD) at each of the four testing periods over the competitive season. T1 = baseline; T2 = post pre-season, T3 = mid-season, T4 = end of season.

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak force (N.kg^{-0.66})</td>
<td>158.5 ± 23.0</td>
<td>162.8 ± 17.0</td>
<td>165.9 ± 13.0</td>
<td>164.9 ± 17.0</td>
</tr>
<tr>
<td>Power (W)</td>
<td>1197.2 ± 134.0</td>
<td>1200.1 ± 153.2</td>
<td>1243.2 ± 126.2</td>
<td>1233.4 ± 117.6</td>
</tr>
<tr>
<td>F50 (N.kg^{-0.66})</td>
<td>81.2 ± 14.9</td>
<td>94.2 ± 19.5</td>
<td>95.7 ± 14.6</td>
<td>89.7 ± 16.2</td>
</tr>
<tr>
<td>F100 (N.kg^{-0.66})</td>
<td>95.6 ± 22.6</td>
<td>109.0 ± 19.7</td>
<td>112.1 ± 19.3</td>
<td>102.2 ± 18.7</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>109.0 ± 11.4</td>
<td>109.9 ± 10.7</td>
<td>110.3 ± 10.9</td>
<td>110.3 ± 11.1</td>
</tr>
</tbody>
</table>

PF = Peak force, F50 = force at 50 ms, F100 = force at 100 ms
Figure 1.
Figure 2.