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Changes in Muscular Strength Over Two Consecutive Professional Rugby League Seasons

Kellyanne J. Redman[1,2]*, Ryan Whitley[2], Mark J. Connick[3], Vincent G. Kelly[3] and Emma M. Beckman[1]

[1]School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Australia; [2]Performance Science Department, Brisbane Broncos Rugby League Club, Brisbane, Australia; [3]School of Exercise and Nutrition Sciences, Queensland University of Technology, Brisbane, Australia.

**Corresponding Author: kellyannejredman@outlook.com*

ABSTRACT

Rugby league is a contact team sport that requires players to exert large forces to gain or maintain control of the opposition during contact. Therefore, developing and maintaining strength long-term is a key objective for strength and conditioning coaches. The aim of this study was to investigate the long-term strength training adaptations in professional rugby league across two consecutive seasons. Further, this study aimed to examine any differences between players that demonstrated an increase in maximal strength (responders) and players that demonstrated a decrease or no improvement in maximal strength (non-responders) training experience and resistance training load. Maximal strength was assessed via one-repetition maximum (1RM) back squat and bench press (n = 14). Training loads were quantified using volume load and training intensity. There were small significant increases in lower (ES = 0.49, $p = 0.017$) and upper body (ES = 0.59, $p < 0.001$) maximal strength over successive seasons. Bench press responders had significantly less training experience ($U = 3.000$, $p = 0.044$) than non-responders. These results demonstrate players were able to improve lower body strength over consecutive seasons. The findings from this study indicate that players with less training experience have a greater capacity for upper, but not lower, body strength improvements than players with more training experience.

Keywords: Football, Resistance, Training, Experience, Responder.

INTRODUCTION

Rugby league is a contact team sport that requires players to develop and express high levels of strength and power in order to tolerate and compete in intense physical collisions throughout a match. On average players collide 0.68 times per minute, while generally travelling 90 to 100 m per min, 300 – 500 m of this at high-speed and completing an average number of accelerations 1.10 ± 0.56 per min throughout competition[1-4]. During matches, players exert large forces to push and pull their opponents to gain control and wrestle them to the ground while defending. While in attack, players will attempt to evade the opposition by sidestepping or pushing the opposition away, or by pulling away from the opposition during a tackle to quickly stand up and play-the-ball. Superior muscular strength has been associated with match-related performance and with a number of match-related qualities including; tackle ability, proportion of dominant tackles, metres conceded during defence, play-the-ball speed, fewer defensive errors and team selection[5-9]. Moreover, previous research has reported stronger players cover greater total distance, complete a higher number of repeated high-intensity efforts in competition, recover faster post-match and are more likely to be selected for competition[6,10,11]. Overall, these studies indicate developing, and subsequently maintaining, muscular strength is a fundamental component of rugby league training.

Developing maximal strength is a key objective during the pre-season, while during competitive season it is important that this physical attribute

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is maintained[12,13]. Typically, professional rugby league players complete two to four resistance training sessions, three or four field sessions and two wrestling sessions per week for the duration (four months) of the pre-season[14,15]. Previous research has shown increases (9.2–17.7%) in lower body strength, assessed via 1RM back squat in professional rugby league players, over three-to eight-week periods (comprised of 3–16 sessions) during the specific preparation phase of a pre-season[12,14,16,17]. The competitive season is a considerably long time to maintain peak strength, with competition on a weekly basis for 24–32 weeks. Resistance training load declines to one or two resistance training sessions per week to allow for an increase in the volume of technical and tactical skill training and recovery from matches[18,19]. This reduction in training volume may make it challenging to develop and/or maintain muscular strength throughout the competition phase and long-term (over multiple seasons)[15,20]. Previously, American football players have demonstrated significant decreases in bench press following the competitive seasons[21,22]. This inability to maintain strength may be related to training age, resistance training load or concurrent energy system training[23]. It is important to understand the training adaptations of professional rugby league players over multiple seasons to optimise prescription of training longitudinally.

Throughout a season, strength and conditioning coaches encounter several challenges in attempting to develop and maintain muscular strength long-term. Concurrent energy system and resistance training may have interfering effects on the development of strength due to conflicting neuromuscular recruitment patterns, alterations in hormonal output, activation or repression of anabolic or catabolic processes and muscle fibre recruitment[24]. Players' previous concurrent training experience (specifically in the professional rugby league training environment) along with the duration, frequency and mode of training may also affect the muscles' ability to adapt to the concurrent training stimulus[24,25]. The varied training experience of players may also result in different frequency, volume and intensity of resistance training to meet their individual needs. The scope for improvement in strength may therefore potentially be limited for players with greater resistance training experience, and presumably superior maximal strength[26]. These constraints may affect a professional rugby league player's ability to develop and maintain strength long-term.

Currently, there is limited evidence examining the magnitude of change in strength over multiple seasons in professional rugby league[15,27,28]. Further, minimal research is available investigating potential factors that may influence the magnitude of change in strength in professional rugby league. Therefore, the purpose of this study was to investigate the long-term muscular strength training adaptations in professional rugby league across two consecutive seasons. Further, this study aimed to examine any differences between players that demonstrated an increase in maximal strength (responders) and players that demonstrated a decrease or no improvement in maximal strength (non-responders) training experience and resistance training load.

METHODS

This study examined changes in professional rugby league players' muscular strength over a two-year period to examine long-term adaptations to resistance training. Additionally, the study investigated the influence of training experience and resistance training load on responders (players that exceeded the smallest worthwhile change (SWC) in maximal strength) and non-responders (players that failed to meet the SWC in maximal strength) in professional rugby league. All participants completed maximal strength testing at the completion of pre-season training. Throughout the study, resistance training loads were recorded. All participants completed regular strength training sessions.

Subjects

Fourteen professional rugby league players participated in this study (mean ± SD age 22.2 ± 4.1 yrs; mass 101.6 ± 10.8 kg; stature 184.7 ± 6.0 cm; National Rugby League (NRL) training experience 3.6 ± 4.2 yrs). All players were contracted with a professional rugby league club for the 2018, 2019 and 2020 NRL seasons. All procedures in this study were approved by the local institutional human research ethics committee and were conducted in accordance with the Declaration of Helsinki. All players provided written consent following an explanation of the procedures, purpose, benefits and associated risks of the study.

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Procedures

Training Program

The training program was prescribed and implemented by the NRL club coaching staff throughout the study (Table 1). The nature of the training program was dependent on the phase of competition in addition to individual and positional requirements. A periodised, game-specific training programme was implemented during skills sessions including small-sided games, skills, energy-system conditioning and speed. The skills sessions were approximately 60–90 mins during pre-season and reduced to approximately 60 mins during the competitive phase of the season. Players completed high-intensity contact wrestle sessions that were approximately 60 mins in duration throughout the pre-season period.

Resistance Training Program

An observational approach was utilised for this study and no changes were made to the strength training program by the researchers. All programs were delivered by NRL club strength and conditioning staff (UK Strength and Conditioning Association and Australian Strength and Conditioning Association accredited). The nature of the training program was dependent on the phase of competition in addition to individual and positional requirements. The strength training program was designed to develop maximal strength and power. Furthermore, the strength training program catered to individual requirements including exercise modifications due to physical limitations (e.g., injuries). Two key multi-joint exercises, one lower and one upper body, were monitored over the season: back squat and bench press.

During pre-season, strength training sessions were more frequent (3–4 days per week) to enable the development of physical attributes. Training sessions in weeks 1–8 (Pre-season 1) were aimed at developing muscular strength and hypertrophy; therefore exercise prescription was comprised of high volume and moderate intensity (5–8 sets × 2–8 reps at 50–83% 1RM). Subsequently, training sessions during weeks 9–12 (Pre-season 2) were designed to develop optimal strength and power and were characterized by a reduction of volume and increase in intensity (6–8 sets × 2–9 reps at 50–90% 1RM)[15]. A wave-like strength training model was implemented during the competitive season, aimed at maintaining power, hypertrophy and consequently maximal strength[20]. Training mesocycles were typically four weeks long; week one was an introduction to the new stimulus, week two increased in volume, week three involved a reduction of volume and increase in intensity and week four was a deload week[18]. In line with typical NRL scheduling practices, field-based conditioning and skills sessions were generally completed earlier in the day, with resistance training sessions undertaken afterwards.

A number of strength training methods were utilized throughout the season including cluster sets, tempo reps (accentuated eccentric) and paused reps (each rep for all of these methods was counted as a normal rep for analysis of training load). The frequency of strength training sessions was subject to the number of days between matches, but sessions were generally performed twice per week.

Resistance Training Loads

Throughout the resistance training sessions, all players manually entered their training loads on a hard copy of their training program, which was given to strength and conditioning staff following each session. At this time, staff followed up with all players to ensure that data were filled in correctly. At the completion of each training week, resistance training loads were manually entered into Microsoft Excel. All players completed regular strength training sessions. Only players who completed all training blocks were included in the study.

The two following equations were used to determine

Table 1. Average duration and number of sessions per week throughout the study.

Phase of season	Duration (weeks)	Resistance training sessions	Conditioning sessions	Skills sessions	Wrestle sessions	Matches
Pre-season 1	1–6	3–4	4	4	2	0
Christmas break	2	0	0	0	0	0
Pre-season 2	9	3–4	4	4	1–2	3
Competition	26	1–2	1–2	1–3	0	24
Off-season	6–12	0	0	0	0	0

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the strength training loads for the two multi-joint exercises:

1. Volume load: the workload of a resistance training session

Number of sets × number of reps per set × load lifted[29].

2. Training intensity: the average intensity: Volume load/ total reps[29].

Muscular Strength

Maximal strength was assessed at the completion of each pre-season (via 1RM) on the back squat and bench press. Players were familiar with testing and training of the back squat and bench press prior to completing 1RM testing. Previous research has reported high reliability of the back squat and bench press 1RM testing[30]. Prior to testing, players completed a warm-up consisting of dynamic stretching and then five reps at ~50% estimated 1RM before performing increasingly heavier loads pre-determined by the NRL strength coach (3–1 reps at 60, 72, 80 and 90% estimated 1RM). Players used a 20 kg Olympic barbell, with ~2 mins recovery between sets, until they attempted a load that they could only lift once with appropriate technique. During the back squat, only trials in which players reached a relative knee angle (i.e., the angle between the midline of the lower leg and the midline of the thigh) ≤90° of flexion were considered successful. During the bench press, players were required to lower the bar-to-chest and were not allowed to bounce the bar off the chest; their feet remained in contact with the floor and buttocks remained in contact with the bench. All attempts were assessed using 2-dimensional motion analysis, captured with a tablet camera at 30 frames per second, and inspected immediately following each attempt to verify players had met specific criteria for a successful lift. Players were permitted one additional attempt if the lift was unsuccessful in meeting the specified criteria.

Maximal strength values of the back squat and bench press were selected for analysis due to their significant associations with tackle outcomes[31].

Statistical Analyses

Statistical analyses were completed using IBM SPSS Statistics (Version 26, SPSS Inc., Chicago, US). The Shapiro-Wilk Normality Test was applied to assess normality of distribution. Firstly, due to the maximal strength data being normally distributed, a repeated-measures analysis of variance followed by Bonferroni post hoc tests was used to examine changes in maximal strength over multiple seasons. Secondly, percentage change of maximal strength between seasons was calculated and paired t-tests were completed to examine changes throughout the study. Effect size (ES) statistics were then completed to determine the magnitude of any differences between maximal strength and percentage changes over the two seasons. The strength of the effect was classified based on Hopkins, which suggests ES magnitudes: <0.2 trivial; ≥0.2 and <0.6 small; ≥0.6 and <1.2 moderate; ≥1.2 and <2.0 large; ≥2.0 and <4.0 very large[32]. A paired t-test was completed to examine resistance training loads completed throughout the study. The SWC for maximal strength was calculated as 0.2 x between-player SD[33]. Finally, characteristics of responders (players who exceeded the SWC in maximal strength) and non-responders (players who failed to meet the SWC in maximal strength) are presented, and a Mann–Whitney U test was conducted to assess differences between the groups. Statistical significance for all analyses was defined by $p \leq 0.05$.

RESULTS

Maximal strength throughout the study is shown in Table 2. Body mass differed significantly between time points ($F = 19.433$, $p < 0.001$). Post hoc tests revealed body mass significantly increased in 2020 from 2018 ($p = 0.002$) and 2019 ($p < 0.001$). Further, the back squat 1RM demonstrated a significant difference throughout the study ($F = 4.809$, $p = 0.017$), and 2020 showed a significant increase from 2018 ($p = 0.007$). Further evaluation of back squat relative to body mass revealed no significant differences over the seasons ($F = 2.983$, $p = 0.068$). The bench press 1RM significantly differed between time points ($F = 26.163$, $p < 0.001$), with post hoc analysis revealing significant increases in 2019 ($p < 0.001$) and 2020 ($p = 0.001$) when compared to 2018. Finally, bench press relative to body mass was significantly different between years ($F = 32.384$, $p < 0.001$), with 2019 ($p < 0.001$) and 2020 ($p = 0.007$) demonstrating significant increases when compared to 2018, and 2020 ($p = 0.021$) showing a significant decrease from 2019.

Figure 1 shows the percentage change in players' body mass and maximal strength from season one and season two. Body mass percentage change had a significant and large (ES = 1.22, $p < 0.001$) increase in season two in comparison to season

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Table 2. Participants' characteristics throughout the study.

	2018	2019	2018-2019 Effect Size		2020	2019-2020 Effect Size	
Body mass (kg)	101.2 ± 10.8	101.4 ± 10.9	0.02	Trivial	103.9 ± 10.7*†	0.25	Small
Back squat (kg) n = 14	177.86 ± 19.19	186.43 ± 20.70	0.43	Small	187.86 ± 21.10*	0.49	Small
Back squat (kg·BM^{-1}) n = 14	1.77 ± 0.17	1.85 ± 0.17	0.46	Small	1.80 ± 0.19	0.28	Small
Bench press (kg) n = 12	137.29 ± 16.29	149.38 ± 17.26*	0.69	Moderate	147.08 ± 15.88*	0.59	Small
Bench press (kg·BM^{-1}) n = 12	1.34 ± 0.12	1.46 ± 0.12*	0.87	Moderate	1.40 ± 0.12*†	0.50	Small

** $p < 0.05$ significant difference from 2018; † $p < 0.05$ significant difference from 2019.*

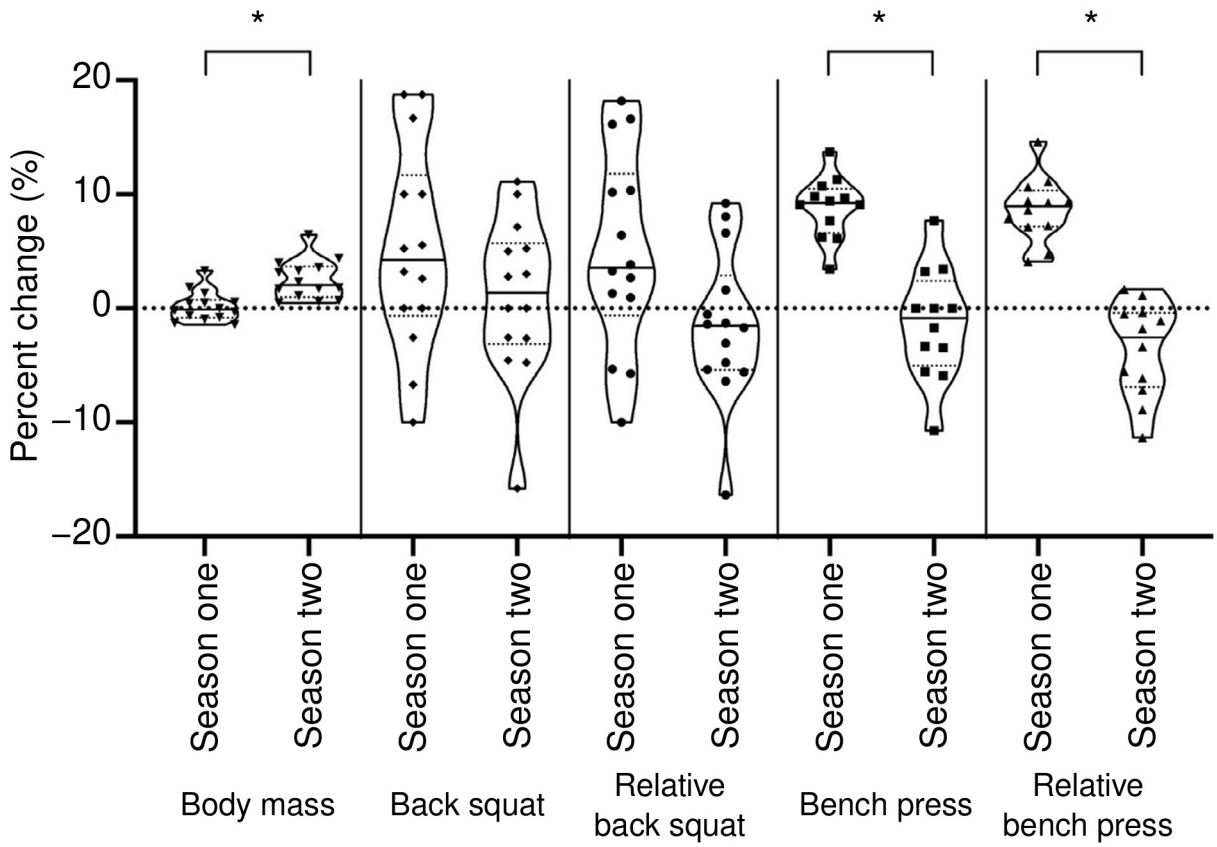


Figure 1. Violin plot including individual data points for percentage change in body mass and maximal strength between season one and season two: minimum, Q1, median, Q3 and maximum. * denotes significant difference ($p \leq 0.05$) between season one and season two.

one. Maximal back squat (ES = -0.50, p = 0.325) and back squat relative to body mass (ES = -0.78, p = 0.120) percentage change demonstrated small and moderate decreases, respectively, from season one to season two. Further, maximal bench press and bench press relative to body mass showed a significant large (ES = -1.57, $p < 0.001$ and ES = -1.71, $p < 0.001$, respectively) decrease in percentage change from season one to season two.

Resistance training loads completed for back squat and bench press throughout the study are shown in Figure 2. Back squat volume load was significantly greater (p = 0.012) in season two when compared to season one. Back squat training intensity and bench press volume load showed no significant difference between seasons (p = 0.846 and p = 0.095, respectively). Players' bench press training intensity was significantly less (p = < 0.001) in season two than season one.

Following season one, nine players were classified as responders and five as non-responders for the back squat. Responders demonstrated a significantly higher absolute and relative change score than non-responders ((U = 0.000, p = 0.010), (U = 0.000, p = 0.010)). Additionally, back squat responders had significantly greater training

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experience (five years) (U = 7.500, p = 0.045) than the non-responders (one year). All players were categorized as responders for bench press following season one.

Following season two, seven players exceeded their SWC in maximal back squat and were classified as responders. Subsequently, significant differences were observed between responders and non-responders in terms of absolute (U = 0.000, p = 0.002) and relative strength changes (U = 0.005, p = 0.002). Similarly, following season two, three players were classified as responders in the bench press. Absolute (U = 0.000, p = 0.011) and relative strength changes (U = 0.000, p = 0.012) were significantly higher in responders than non-responders. Additionally, bench press responders (one year) had significantly less training experience (U = 3.000, p = 0.044) than non-responders (five years).

DISCUSSION

This study aimed examined the long-term muscular strength training adaptations across two consecutive seasons and to explore whether training experience and resistance training load were associated with responder and non-responder classification in professional rugby league players. The primary findings were that maximal lower body strength improved across successive seasons, while upper body strength significantly increased following the first season and training adaptations were maintained throughout the remainder of the study. Additionally, players with less experience appeared more likely to demonstrate a greater likelihood of improving upper, but not lower, body strength improvements than players with more NRL training experience. Importantly, resistance training load measured from selected exercises was not significantly different between players who increased (responders) or decreased (non-responders) maximal strength (response)[26].

The upper body strength values observed in the present study are similar to those previously reported in professional rugby league[15]. Moreover, the results align with previous observations suggesting highly trained rugby league players continue to develop strength over multiple seasons[15,28]. These long-term improvements are likely associated with chronic neuromuscular adaptation commonly observed with resistance training, including increased muscle fibre hypertrophy, increased myofibrillar cross-sectional area, preferential hypertrophy of type II muscle fibres, alterations to muscle architecture, increased musculotendinous stiffness and tendon thickness[34]. While these mechanisms were not directly measured in the present study, they are widely recognised contributors to strength development following prolonged resistance training exposures[34].

All players demonstrated increases in upper body strength following the first season, while only three players exceeded the SWC after the second season. Players classified as non-responders following the second season had significantly

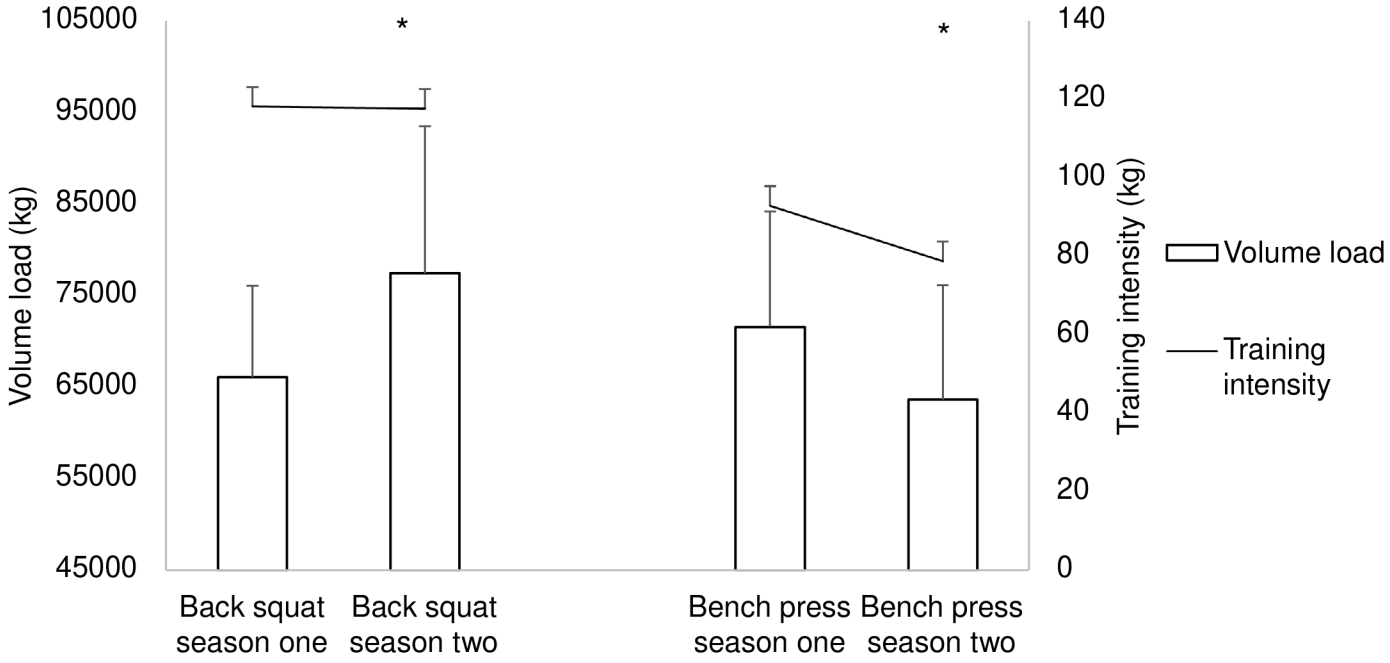


Figure 2. Volume load and training intensity associated with changes in maximal strength across two seasons. *denotes significant difference ($p \leq 0.05$) from season one.

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greater training experience than the responders. This observation is consistent with the concept that as training experience and strength levels increase, the potential magnitude of further improvement may diminish over successive seasons[15,28]. Additionally, bench press training intensity was significantly lower in season two, when compared to season one, which may have influenced the proportion of players demonstrating further improvements (Figure 2). It should be noted that although bench press training load was monitored in this study, other upper body exercises were prescribed within the program. For example, dumbbell bench press was prescribed more frequently during the second season to increase exercise variation and reduce monotony. Given the principle of specificity, this modification may have influenced the magnitudes observed in bench press. Therefore, interpretations regarding the relationship between resistance training load and strength adaptation should be considered within the context of the specific exercises monitored rather than the entirety of the resistance training programme.

The magnitude of lower body strength improvements following the first season is comparable to previous longitudinal observations in professional rugby league players[28]. Changes in competitive demands of the sport and evolving training practices may influence the magnitude of strength adaptations observed across seasons[35,36]. In the present study, nine players were classified as responders following the first season of back squat testing, and these players demonstrated greater professional rugby league training experience than the non-responders. This finding may reflect differences in the ability of players to tolerate the combined physical demands of rugby league training. Previous research in rugby league populations has suggested that concurrent exposure to high volumes of running, contact training and resistance training may influence strength development, particularly in athletes with lower levels of training experience[24]. However, as running loads and match demands were not quantified in this study, these interpretations should be considered cautiously.

Across the two seasons, players demonstrated non-significant percentage changes in lower body strength between seasons (Figure 1). One possible contextual factor may relate to changes in coaching strategies or training priorities. For example, an increased emphasis on high-speed, game-specific field training may alter the distribution of training stress across the week. Although these factors were not directly quantified in the present study ,and therefore any relationship between these contextual changes and strength adaptations should be interpreted as associative rather than causal. Nevertheless, these findings suggest that professional rugby league players can develop and maintain lower body strength across multiple seasons despite complex training demands.

Strength development in highly trained athletes is typically associated with both morphological and neurological adaptations[37]. Long-term resistance training is commonly accompanied by increases in muscle cross-sectional area, improved neural drive and enhanced coordination of motor unit recruitment[37]. In the present study, body mass significantly increased over the monitoring period alongside significant increases in maximal strength. Although body composition was not assessed, this increase in body mass may partially reflect hypertrophic adaptations. Previous work in professional rugby union players has similarly reported that upper body strength improvements were positively associated with increases in lean mass index (an indicator of hypertrophy)[38]. Collectively, these findings suggest that strength development in highly trained team sport athletes may benefit from programming that targets hypertrophy and maximal strength qualities.

The present study is not without limitations. It is important to note that these findings were observed in a single team; therefore, the variability between players is specific to this club. Although key exercises, back squat and bench press, resistance training loads provides a strong indication of the resistance training completed throughout the duration of the study, this data does not capture all exercises. Further, the influence of other aspects of training and competition (e.g., running loads, physical collisions) was not examined. Finally, the small sample size in this study reflects the realities of conducting research within elite professional sport environments.

In conclusion, this study has demonstrated that professional rugby league players can maintain and modestly improve maximal strength over consecutive seasons. The findings also suggest that training experience and exercise selection may be associated with upper body strength adaptations over time. Although resistance training loads were monitored for key exercises, strength adaptations likely reflect the interaction of multiple training stimuli within the professional rugby league environment.

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These results provide useful longitudinal reference data for strength and conditioning coaches of highly trained team sport athletes.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

No funding was received for this study to be completed.

ETHICAL APPROVAL

All procedures in this study were approved by the local institutional human research ethics committee and were conducted in accordance with the Declaration of Helsinki. All players provided written consent following an explanation of the procedures, purpose, benefits and associated risks of the study.

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