Title: Pre-season training responses and their associations with training load in elite rugby league players.

Submission Type: Original Investigation

Authors: Matthew Daniels[1], Jamie Highton[2] & Craig Twist[2]

Affiliation: [1]St Helens RFC, St Helens, UK

[2]Department of Sport and Exercise Science, University of Chester, UK

Corresponding Author: Craig Twist, University of Chester, Parkgate Road, Chester, CH1 4BJ, England.

Work Tel: 01244 513441

Work Email: c.twist@chester.ac.uk

Running Head: Training dose-response relationship in rugby players

Abstract Word Count: 196

Manuscript Word Count: 3616

Tables: 1

Figures: 3

Abstract

Strength, power and endurance characteristics and their association with training load during a 7-week preseason training phase was assessed in elite rugby league players. Twenty-two players (age 23.3 ± 4.4 years) performed bench throw, one repetition maximum (1RM) bench press, squat jumps, three repetition maximum (3RM) squats, prone pull ups and prone Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) before and after the 7-week preseason period. Training was classified into Gym, Field and Wrestle, with training load of each monitored using session rating of perceived exertion (sRPE) multiplied by training duration (sRPE-TL). There were *most likely* improvements in 3RM back squat, prone pull-ups and Yo-Yo IR1 and *likely* improvements in bench press, bench throw and squat jump after the 7-week training programme (ES = 0.3 to 1.2). Accumulated sRPE-TL for Gym, Field and Wrestle sessions was 9176 ± 1187, 10906 ± 2162, and 1072 ± 315 AU, respectively. Relationships between mean weekly sRPE-TL and changes in physical qualities was *trivial to large* (r = -0.67 to 0.34). This study suggests sRPE-TL is unsuitable to detect dose-response relationships between training load and the changes in physical qualities of elite rugby league players during the pre-season period.

Key words: Monitoring, dose-response, team sports

Introduction

To perform the running and collision demands of elite level rugby league, players require well-developed aerobic and anaerobic capacities, muscular strength and power, reactive agility, and speed (Till et al. 2016). Upper- and lower-body maximal strength and aerobic power are associated with a broad range of technical and sport-specific skills such as tackling and sprinting (Gabbett et al. 2011; Gabbett et al. 2013; Speranza et al. 2015; Delaney et al., 2016; Sperenza et al., 2016). For example, better muscular strength and upper-body power contribute to better tackling ability in rugby league players (Speranza et al. 2015; Speranza et al. 2016). Players with a better Yo-Yo intermittent running test performance also covered greater total distance and greater distance in high-speed running during match play (Gabbett & Seibold 2013; Gabbett et al. 2013). Well-developed physical qualities can also minimise post-match fatigue, allow faster recovery after matches (Johnston et al. 2015), lower risk of injury (Gabbett & Domrow 2007), and influence team selection (Gabbett & Siebold 2013; Gabbett et al. 2013). Collectively, these findings reinforce the importance of well-developed physical qualities in rugby league players and the need to train these to optimise performance.

The rugby league pre-season lasts 6–10 weeks and comprises intense physical conditioning to develop fundamental physical qualities in preparation for the impending competition phase (Jeong et al. 2011). Moderate improvements in upper and lower body strength, sprint performance and shuttle running performance during pre-season phases have been reported in professional rugby union players (Argus et al. 2010; Bradley et al. 2015). Similar responses to a pre-season period have been reported in sub-elite rugby league players (Gabbett et al. 2008), with the changes observed in elite rugby league players limited to maximal strength characteristics (Comfort et al. 2011). A deeper understanding of the adaptations in physical qualities of elite rugby league players during this period is needed alongside their associations with the training dose, which currently remains unknown.

The precise control of training loads and individual responses to training is essential for maximizing training adaptations (Borresen & Lambert 2009) and minimising injury risk (Gabbett 2004). The use of the rating of perceived exertion-based method (i.e. sRPE; Foster et al. 2001) is a popular means of estimating training load (sRPE-TL) that has been widely employed in rugby (e.g. Gabbett & Domorw 2007; Waldron et al. 2011; Lovell et al. 2013; Bradley et al. 2015; Williams et al. 2017). The single use of sRPE-TL is understandable given its strong association with measures of external (GPS, accelerometer) and internal (heart rate; HR) load (Coutts et al. 2003; Lovell et al. 2013), and in assessing resistance training load (Day et al. 2004). sRPE-TL as a global measure of training load in rugby league training is also appealing because it does not require expensive equipment and can be a simple and practical method for practitioners to employ. These factors notwithstanding, the validity of sRPE-TL to reflect the training load in team sports remains unclear.

While sRPE-TL is associated with other measures of training load (e.g. Lovell et al., 2013) and can quantify loads that might alter a rugby player's susceptibility to injury risk (Gabbett & Jenkins 2011; Williams et al. 2017), a fundamental characteristic of any measure of training load is its association with the training outcome (Akubat et al. 2012; Campos-Vazquez et al. 2017; Taylor et al. 2017). Improved understanding of the dose-response relationships between training load and fitness is valuable for coaches and practitioners to maximise physical development and improve performance (Sanders et al. 2017). Several studies have reported a dose-response relationship between training load and changes in fitness after a period of training in professional youth soccer players (Akubat et al. 2012), academy rugby (Taylor et al. 2017) and well-trained cyclists (Sanders et al. 2017). Several studies have favoured individualised measures of training load based on HR over sRPE-TL to understand the dose-response relationship (Akubat et al. 2012; Taylor et al. 2017, Sanders et al. 2017). For example, Taylor and colleagues (2017) reported that selected heart rate-derived measures of training load accounted for 55-78% of the variance in changes in VO_{2max} in academy rugby players, with sRPE-TL explaining only 12% of the fitness change. These findings are in contrast to Campos-Vazquez et al. (2017) who reported stronger positive associations between sRPE-TL and changes in high intensity running performance compared to heart rate derived measures of load in professional soccer players. While all of these studies offer insight in to the dose-response relationship, challenges remain. The study of single modality training practices (e.g. cycling; Sanders et al. 2017) and focus on quantifying training load of only field-based activities or matches (Akubat et al. 2012; Taylor et al. 2017) fails to consider the multi-modality training practices of team sports. That sRPE-TL enables the collective quantification of a training programme that comprises several strength and conditioning elements that lead to improvements in physical qualities means this might offer a valid assessment of the dose-response relationship. However, information on the dose-response relationship between training load measured using the widely adopted sRPE-TL method and changes in physical qualities of multicomponent training programmes, such as those used by elite rugby league players, is lacking.

The purpose of this study was to analyse the changes in strength, power and endurance characteristics and their association with training load during a seven-week preseason training phase in elite rugby league players.

Methods

Participants and design

With institutional ethics approval, 21 professional team rugby league players from one club competing in the European Super League were recruited (age 23.3 ± 4.4 years; weight 91.6 ± 8.9 kg, stature = 180.9 ± 6.5 cm). Players and the club provided verbal and written consent for the data to be used. After screening by the club's medical staff, players completed a testing battery at the start and end of a 7-week pre-season training intervention prescribed and delivered by the lead researcher. The testing battery was completed over two days comprising measurements of upper and lower body strength and power, and high intensity intermittent running capacity. All players were familiar with the testing procedures as part of the club's normal monitoring practices, with testing taking place at the club's training facility.

Procedures

Maximal upper and lower body strength measures

Participants' maximum upper and lower body strength was assessed using one repetition maximum (1RM) bench press and three repetition maximum (3RM) squat exercises, respectively. Before each exercise warm-ups comprised 10 repetitions against a load of 60 kg. Thereafter, participants attempted each exercise with incremental loads added between successful attempts until failure, at which point the participants were allowed 2 more attempts at the failed load. For the bench press exercise, the participant held the bar with a prone grip and lowered it to his chest, before maximally pushing it until full elbow extension. For the back squat exercise, with the bar positioned across their shoulders participants descended until their hips were below the knee joint and then ascended as rapidly as possible until their knees were at full extension. All of the lifts where supervised by the same staff member, who ensured correct technique was employed throughout. The final successful load lifted with correct technique was recorded for analysis. These exercises possess high reliability in experienced athletes and offer appropriate measurements of muscle strength (CV = 2.9-4.5%; Weakley et al. 2017)

Upper and lower body power

Participants' peak upper and and lower body power was assessed using bench throw and jump squat exercises, respectively. Before each exercise warm-ups comprised 3 repetitions against a load of 40 kg. Thereafter, participants performed 3 repetitions of each exercise at 60 kg with peak power output (W) recorded using a FitroDyne rotary encoder (Fitronic, Bratislava, Slovakia) attached to the barbell. A fixed load was used based on the work of Baker (2001) and to enable testing of a large number of athletes simultaneously in a real-world setting. The FitroDyne device was placed on the floor and attached via its nylon cord to the bar. For both exercises participants were asked to ensure that the bar, and thus the nylon cord on the rotary encoder, moved in a vertical plane. All lifts where supervised by two members of staff to ensure appropriate technique. The FitroDyne is deemed to provide a reliable marker of moderate changes in peak power during bench press and squat (CV = 1.6-5.8%; Fernandes et al. 2016).

Prone grip pull up

Before testing the players were given a verbal description as well as a demonstration of correct technique for the pull up, which involved starting from a full straight arm hang position and raising to the point where the chin was level with bar. The players then completed 3 repetitions, which was used as a warm up set as well as clarifying technique and appropriate range. Participants then performed a single set of maximum repetitions under the supervision of the same staff member ensuring correct technique throughout with the result recorded for analysis. The pull up test has been shown to provide a reliable measure of muscle function in athletes (CV = 1.7%; Weakley et al. 2017).

Prone Yo-Yo intermittent recovery test level 1

The prone Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) was employed to measure high-intensity intermittent running capacity. The test required the participants to complete as many 40 m shuttles as possible with a 10 s active recovery (10 m walk) between shuttles (Bangsbo et al. 2008). Unlike the traditional Yo-Yo IR1, participants were required to start each shuttle in a prone position with their head behind the start line and legs straight. The starting speed for the test was 10 km/h, increasing 0.5 km/h incrementally approximately every 60 s until the participants were unable to maintain the required running speed. The final distance (m) achieved for each participant was recorded for analysis. The prone Yo-Yo IR 1 is known to provide a valid assessment of match running performance of rugby league players (Dobbin et al., 2018b) and possesses acceptable reliability (CV = 9.9%; Dobbin et al., 2018a).

Training type

During the intervention, the training performed by all players was classified into three categories: Field, Gym and Wrestle. The three categories encompassed all training methods employed during the pre-season period. Field sessions included aerobic and anaerobic conditioning sessions, speed sessions, match-based conditioning and skills sessions (Table 1). Gym sessions included all strength and power sessions undertaken during the period. Wrestle sessions were undertaken within a padded wrestle hall and incorporated both technique and full contact sessions. The lead researcher, who as the club's strength and conditioning coach in consultation with the club's coaching and medical staff, prescribed all training.

***** Insert Table 1 here *****

Quantification of training load

Given the multicomponent nature of the training performed (i.e. Field, Gym and Wrestle), session rating of perceived exertion (sRPE; Foster et al. 2001) was used with training time for each session to calculate training load (sRPE-TL). All participants were familiar with the sRPE method and had used it before as part of daily monitoring procedures. Each session required the participants to score individual sessions using the team's online analytics programme (Rugby Squad, Sports Office, UK), which participants have access to using a mobile phone app. The participants entered a score between 0-10 using Borg's CR-10 scale for each training component (i.e. Field, Gym and Wrestle). The sRPE for each component was then multiplied by the respective session time (minutes), recorded by the lead researcher, to provide an individual's load value (sRPE-TL, AU) for each component. This method was employed for all training components on an individual player basis and was reported ~30 minutes after each training session. Weekly and total training load for the 7-week period was calculated for each component by summing the scores accordingly.

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Changes in each dependant variable were analysed using effect sizes and associated 90% confidence intervals, with effect sizes calculated as the difference between trials divided by the pooled SD to assess the change in physical qualities after the 7-week training phase. Threshold values for effect sizes were: 0.0-0.19, *trivial*; 0.2-0.59, *small*; 0.6-1.19, *moderate*; 1.2-1.99, *large*; >2.0, *very large*. Threshold probabilities for a mechanistic effect based on the 90% confidence limits were: 25-75% *possibly*, 75-95% *likely*, 95-99% *very likely* and > 99.5 *most likely* (Batterham & Hopkins 2006). Effects with confidence limits spanning a likely small positive or negative change were classified as *unclear*. To determine the relationship between the sRPE-TL and changes in physical qualities, Pearson's correlation (*r*) was used with the following criteria applied: < 0.1, *trivial*; >0.1-0.3, *small*; >0.3-0.5, *moderate*; >0.5-0.7, *large*; >0.7-0.9, *very* *large*; and >0.9-1.0, *almost perfect*. Within-player variability in training load for each component was also calculated using the coefficient of variation (CV%). Statistical analysis was conducted using a predesigned spreadsheet for comparing means (Hopkins 2006) and correlations coefficient (Hopkins 2015).

Results

Changes in training load over the pre-season period

The mean weekly training load for the pre-season period was 1310 ± 540, 1625 ± 839 and 191 ± 70 AU for Gym, Field and Wrestle sessions, respectively. The mean accumulated sRPE-TL during this phase for Gym, Field and Wrestle sessions was 9176 ± 1187, 10906 ± 2162, and 1072 ± 315 AU, respectively. Within-player variability (coefficient of variation, CV%) in training load across the pre-season phase was CV% = 38.7 ± 10.3% (41.4 ± 2.5, 53.0 ± 15.9, 37.8 ± 12.6% for Gym, Field and Wrestle, respectively), while between-player variability was CV% = 20.2 ± 6.5% (14.4 ± 5.3, 14.6 ± 8.9, 15.0 ± 8.5% for Gym, Field and Wrestle, respectively). Data are shown in Figure 1.

*****Insert Figure 1 here*****

Changes in physical qualities

There were *most likely* improvements in 3RM back squat (181 ± 21 cf. 199 ± 25 kg), prone pull ups (15 ± 5 cf. 23 ± 8) and Prone Yo-Yo IR1 (946 ± 195 cf. 1220 ± 193 m) and *likely* improvements in bench press (125 ± 16 cf. 130 ± 17 kg), bench throw (1057.8 ± 140.6 cf. 1120.9 ± 154.8 W) and squat jump (1050.1 ± 56.8 cf. 1081.7 ± 60.8 W) after the seven-week training programme. All data are shown in Figure 2.

***** Insert Figure 2 here *****

Associations between changes in physical qualities and training load

The relationship between mean weekly sRPE-TL and changes in bench press (r = -0.19 ± 0.36, *trivial*), back squat (r = 0.34 ± 0.33, *small*), prone pull-up (r = 0.09 ± 0.37, *trivial*), bench throw (r = -0.67 ± 0.22, *large*), jump squat (r = 0.0 ± 0.3, *trivial*) and prone Yo-Yo IR1 (r = -0.21 ± 0.36, *small*) are shown in Figure 3. Relationships between mean weekly sRPE-TL for Gym and changes in bench throw were *moderate* (r = -0.56) whereas relationships for bench press (r = -0.16), back squat (r = 0.14), pull ups (r = -0.01) and jump squat (r = 0.10) were all *trivial to small*. The relationship between mean weekly sRPE-TL for Field training and changes in Prone Yo-Yo were *small* (r = -0.14). Relationships between mean weekly sRPE-TL for Wrestle and changes in bench throw (r = -0.57) were *moderate* but *trivial to small* for pull ups (r = 0.17), squat (r = 0.23), bench press (r = -0.19) and jump squat (r = -0.003)

***** Insert Figure 3 here *****

Discussion

This study presents changes in strength, power and endurance characteristics of elite rugby league players and their associations with mean weekly training load during a 7-week pre-season training phase. Positive changes in all of the physical qualities over the 7-week phase suggested the training performed was effective. Despite a large negative relationship with changes in bench throw performance, sRPE-TL showed only trivial to small relationships with changes in prone Yo-Yo IR1, bench press, back squat prone pull-ups and jump squats.

For the first time this study reports the training distribution and content of professional rugby league players during a pre-season training phase. The mean weekly training load over the pre-season period confirms values reported previously in professional rugby league players (~2800-3200 AU) during a pre-season phase (Killen et al. 2010; Gabbett & Jenkins 2011), but higher than that reported in sub-elite players (Gabbett & Domorw 2007). The highest total load occurred during field-based sessions, followed by gym-based and wrestle sessions. These results are unsurprising given the scheduling of training sessions during this training phase focused on field-based (48.5%) and then gym-based (37.9%) sessions, with wrestle sessions accounting for only a small proportion of training time (13.6%).

A 29.9% improvement in prone Yo-Yo IR 1 performance over the preseason period is within the range (12.7-31.1%) reported for professional male team sport athletes over the same training phase and duration (Bangsbo et al. 2008). The mean improvement of 274 m by players was also greater than the 120 m known to reflect a meaningful change in the prone YoYo IR 1 test for rugby league players (Dobbin et al. 2018a). However, this meaningful change in prone Yo-Yo IR1 distance was not related to the training load measured using sRPE-TL. The weaker association between sRPE-TL and changes in high-intensity intermittent running performance is in contrast to previous work by Campos-Vazquez et al. (2017) in soccer players and confirms poor association between perceived measures of training load and changes in VO_{2max} of rugby players reported by Taylor and colleagues (2017). It is possible that sRPE-TL might lack sensitivity when used to quantify the internal loads of rugby-specific movements (e.g., high-intensity running, sprinting, collisions) compared to non-contact team sports (MacLaren et al. 2016) and is therefore unable to establish a dose-response relationship between the training load and improvements in intermittent running capacity of elite players during the pre-season phase.

Training of strength and power, using both gym and wrestle specific training, accounted for ~48% of the professional players' preseason training load. This training was reflected in the small to moderate improvements in maximal bench press (4.2%), back squat (9.9%), prone pull ups (50.9%), bench throw (~6%) and jump squat (~3%) after the 7-week training period. Back squat (~198 kg) and bench press (~130 kg) loads were within the ranges reported previously for professional rugby league players (Baker 2001; Baker & Newton 2006; O'Connor & Crowe 2007, with the improvements over the pre-season ~7% lower for bench press but similar for back squat, bench throw and jump squat when compared to rugby union players after a 4-week preseason period (Argus et al. 2010). Improvement in prone pull-ups (~23 repetitions) over the training phase was superior to that reported in youth male (~14 repetitions, Weakley et al. 2017) and professional male players (~16 repetitions, O'Connor & Crowe 2007). However, total training load (sRPE-TL) showed only a moderate positive relationship with change in back squat performances, while moderate to large negative relationships were reported between total and gym sRPE-TL and changes in bench throw. All remaining associations between perceived training load measures and changes in muscle strength and power were trivial to small. Negative associations between sRPE-TL and changes in upper body bench throw are counterintuitive and might reflect better explosive muscle adaptations on those athletes training with lighter loads or a greater emphasis on maximal strength development. Alternatively, in presenting novel data on the dose-response between perceived training load and adaptation in measures of strength and power, we propose that sRPE-TL was unable to reflect the neuromuscular stresses that lead to improvements in muscle function. More objective measures, such as volume load and velocity of training (Scott et al., 2016), might be needed to offer a valid appraisal of resistance training load in rugby players.

Collectively, our data reaffirm the inability of sRPE-TL to inform a dose-response relationship (Akubat et al. 2012; Taylor et al. 2017). The relatively low (CV% = ~14-20%) between participant variability in sRPE-TL for overall and individual component training loads suggested a fairly homogenous load response for this group. A lack of variability might therefore have influenced the association between training load (dose) and the change in fitness (response). It is also possible that sRPE alone is unable to accurately reflect the intensity of the training approaches adopted by professional rugby league players during a pre-season period. Therefore, the adoption of multi-component approach using both internal and external measures is perhaps needed to provide a better reflection of training dose (Weaving et al. 2017; Rabbani et al. 2019). While a multi-component approach seems necessary it does deviate from the simplified method offered by sRPE-TL that requires greater resourcing and an ability to collectively interpret numerous data. These findings have implications for practitioners wanting to quantify the training load of professional rugby league players.

Conclusion

This study reports that after a seven-week pre-season training period in an elite rugby league club, athletes had small to moderate improvements in maximal upper and lower body strength, upper and lower body power and large increases in high intensity intermittent running capacity. Our findings reaffirm the importance of these physical qualities in professional rugby league players, and that these qualities can be improved with training in elite players. Despite the prevalent use of sRPE-TL in practice and its association with injury risk, this measure of training load did not correlate with the reported improvements in high-intensity intermittent running performance and most of the measures of muscle strength and power. These findings therefore question the efficacy of sRPE-TL as a training load measure in elite rugby league players.

Practical applications

This study provides practitioners with evidence of the expected changes in fitness qualities of elite rugby league players over a 7-week pre-season training period. Where practitioners wish to understand the dose-response relationship between training load of typical rugby league practices and changes in fundamental physical qualities the use of sRPE-TL is not suitable.

References

Akubat I, Patel E, Barrett S, Abt G. 2012. Methods of monitoring the training and match load and their relationship to changes in fitness in professional youth soccer players. J Sports Sci. 30:1473–1480.

Argus CK, Gill N, Keogh J, Hopkins WG, Beaven CM. 2010. Effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional rugby union players. J Sports Sci. 28:679–686.

Baker DG. (2001). A series of studies on the training of high-intensity muscle power in rugby league football players. J Strength Cond Res. 15(2):198–209.

Baker DG, Newton RU. 2006. Discriminative analyses of various upper body tests in professional rugby-league players. Int J Sports Physiol Perf. 1:347-360.

Bangsbo J, Iaia FM, Krustrup P. 2008. The Yo-Yo Intermittent Recovery Test: a useful test for evaluation of physical performance in intermittent sports. Sports Med. 38:37-51.

Batterham AM, Hopkins WG. 2006. Making meaningful inference about magnitudes. Int J Sports Physiol Perf. 1:50-57.

Borresen J, Lambert MI. 2009. The quantification of training load, the training response and the effect on performance. Sports Med. 39:779-795.

Bradley WJ, Cavanagh BP, Douglas W, Donovan TF, Morton JP, Close GL. 2015 Quantification of training load, energy intake, and physiological adaptations during a rugby preseason: a case study from an elite European rugby union squad. J Strength Cond Res. 29:534-544.

Campos-Vazquez MA, Toscano-Bendala FJ, Mora-Ferrera JC, Suarez-Arrones LJ. 2017. Relationship between internal load indicators and changes on intermittent performance after the preseason in professional soccer players. J Strength Cond Res. 31:1477-485.

Comfort P, Graham-Smith P, Matthews MJ, Bamber C. 2011. Strength and power characteristics in English elite rugby league players. J Strength Cond Res. 25:1374-1384.

Coutts A, Murphy A, Pine M, Reaburn P, Impellizzeri F. 2003. Validity of the session-RPE method for determining training load in team sport athletes. J Sci Med Sport. 6:525.

Day ML, McGuigan MR, Brice G, Foster C. 2004. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res. 18:353-358.

Delaney JA, Thornton HR, Duthie GM, Dascombe BJ. 2016. Factors that influence running intensity in interchange players in professional rugby league. Int J Sports Physiol Perf. 11:1047-1052.

Dobbin N, Hunwicks R, Highton J, Twist C. 2018a. A reliable testing battery for assessing physical qualities of elite academy rugby league players. J Strength Cond Res. 32:3232-3238.

Dobbin N, Moss SL, Hunwicks R, Highton J, Twist, C. 2018b. The concurrent validity of a rugby-specific Yo-Yo Intermittent Recovery Test (Level 1) for assessing match-related running performance. J Strength Cond Res. doi: 10.1519/JSC.0000000000002621.

Fernandes JFT, Lamb KL, Twist, C. 2016. The intra- and inter-day reliability of the FitroDyne as a measure of multi-jointed muscle function. Isokinetics Exerc Sci. 24:39-49.

Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. 2001. A new approach to monitoring exercise training. J Strength Cond Res. 15:109-115.

Gabbett TJ. 2004. Reductions in pre-season training loads reduce training injury rates in rugby league players. Brit J Sports Med. 38:743-749.

Gabbett TJ, Domrow N. 2007. Relationships between training load, injury, and fitness in sub-elite collision sport athletes. J Sports Sci. 25:1507-1519.

Gabbett TJ, Johns J, Riemann M. 2008. Performance changes following training in junior rugby league players. J Strength Cond Res. 22:910-917.

Gabbett TJ, Jenkins DG, Abernethy B. 2011. Relative importance of physiological, anthropometric, and skill qualities to team selection in professional rugby league. J Sports Sci. 29:1453-1461.

Gabbett TJ, Jenkins DG. 2011. Relationship between training load and injury in professional rugby league players. J Sci Med Sport. 14: 204-209.

Gabbett TJ, Seibold A. 2013. Relationship between tests of physical qualities, team selection, and physical match performance in semiprofessional rugby league players. J Strength Cond Res. 27:3259-3265.

Gabbett TJ, Stein JG, Kemp JG, Lorenzen C. 2013. Relationship between tests of physical qualities and physical match performance in elite rugby league players. 27:1539-1545.

Hopkins WG. 2006. Spreadsheets for analysis of controlled trials with adjustment for a subject characteristic. Sportscience. 10:46-50.

Hopkins WG. 2015. Spreadsheets for analysis of validity and reliability. Sportscience. 19:36-42.

Jeong TS, Reilly T, Morton J, Bae SW, Drust B. 2011. Quantification of the physiological loading of one week of “pre-season” and one week of “in-season” training in professional soccer players. J Sports Sci. 29:1161-1166.

Johnston RD, Gabbett TJ, Jenkins DG, Hulin BT. 2015. Influence of physical qualities on post-match fatigue in rugby league players. J Sci Med Sport. 18:209-213.

Killen N, Gabbett T, Jenkins D. 2010. Training loads and incidence of injury during the preseason in professional rugby league players. J Strength Cond Res. 24:2079-2084.

Lovell TW, Sirotic AC, Impllizzeri FM, Coutts AJ. 2013. Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. Int J Sports Physiol Perf. 8:62-69.

McLaren SJ, Weston M, Smith A, Cramb R, Portas MD. 2016. Variability of physical performance and player match loads in professional rugby union. J Sci Med Sport. 19:493-497.

O'Connor DM, Crowe MJ. 2007. Effects of six weeks of β-hydroxy-β-methylbutyrate (hmb) and hmb/creatine supplementation on strength, power, and anthropometry of highly trained athletes. J Strength Cond Res. 21:419.

Rabbani A, Kargarfard M, Castagna, Clemente FM, Twist C. 2019. Associations between selected training stress measures and fitness changes in male soccer players. Int J Sports Physiol Perf. In Press

Sanders D, Abt G, Hesselink MKC, Myers T, Akubat. 2017. Methods of monitoring training load and their relationships to changes in fitness and performance in competitive road cyclists. Int J Sports Physiol Perf. 12:668–675.

Scott BR, Duthie GM, Thornton HR, Dascombe BJ. 2016. Training monitoring for resistance exercise: theory and applications. Sports Med. 46:687-698.

Speranza MJ, Gabbett TJ, Johnston RD, Sheppard JM. 2015. Muscular strength and power correlates of tackling ability in semiprofessional rugby league players. J Strength Cond Res. 29:2071-2078.

Speranza MJ, Gabbett TJ, Johnston RD, Sheppard JM. 2016. Effect of strength and power training on tackling ability in semiprofessional rugby league players. J Strength Cond Res. 30:336-343.

Taylor RJ, Sanders D, Myers T, Abt G, Taylor CA, Akubat I. 2018. The dose-response relationship between training load and aerobic fitness in academy rugby union players. Int J Sports Physiol Perf. 13:163-169.

Till K, Jones B, Geeson-Brown T. 2016. Do physical qualities influence the attainment of professional status within elite 16–19 year old rugby league players? J Sci Med Sport. 19: 585-589.

Weakley JSS, Till K, Darrall-Jones J, Roe GAB, Phibbs PJ, Read DB, Jones BL. 2017. The influence of resistance training experience on the between-day reliability of commonly used strength measures in male youth. J Strength Cond Res, 31:2005-2010.

Weaving D, Jones B, Marshall P, Till K, Abt G. 2017. Multiple measures are needed to quantify training loads in professional rugby league. Int J Sports Med. 38:735-740.

Waldron M, Twist C, Highton J, Worsfold P, Daniels M. 2011. Movement and physiological match demands of elite rugby league using portable global positioning systems. J Sports Sci. 29:1223-1230.

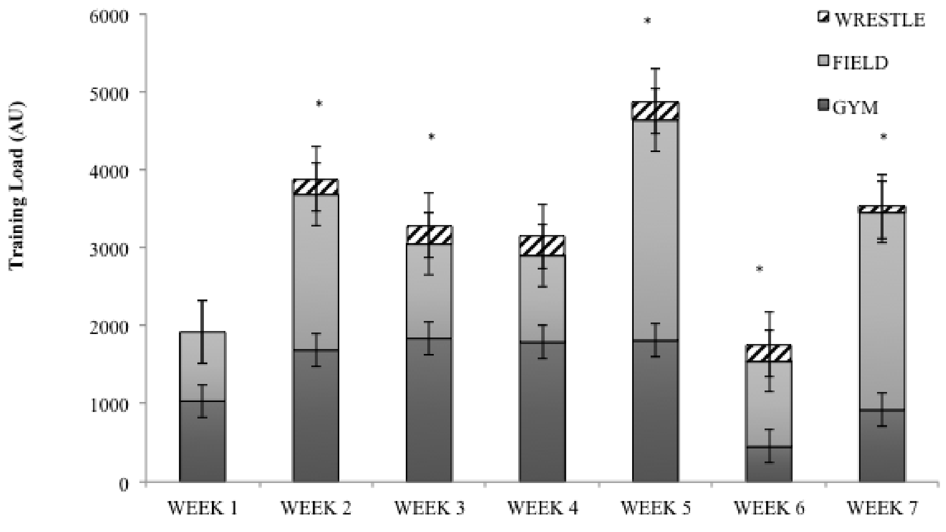
Williams S, Trewartha G, Cross MJ, Kemp SPT, Stokes KA. 2017. Monitoring what matters: A systematic process for selecting training-load measures. Int J Sports Physiol Perf. 12:S2101-S2106.

Figures

Figure 1. Changes in total and specific training load for professional rugby league players (n = 22) during a seven-week pre-season period. Values are mean ± SD.

Figure 2. Changes in physical qualities (± 90% CI) of elite rugby league players after a 7-week pre-season training phase presented as standardised (A) and percentage (B) changes. Shaded area represents the range of trivial change

Figure 3. Relationships between change in physical qualities and sRPE. Values are r-value ± 90% CI



WRESTLE
FIELD
GYM
Training Load (AU)
6000
5000
4000
3000
2000
1000
0
WEEK 1
WEEK 2
WEEK 3
WEEK 4
WEEK 5
WEEK 6
WEEK 7

Figure 1

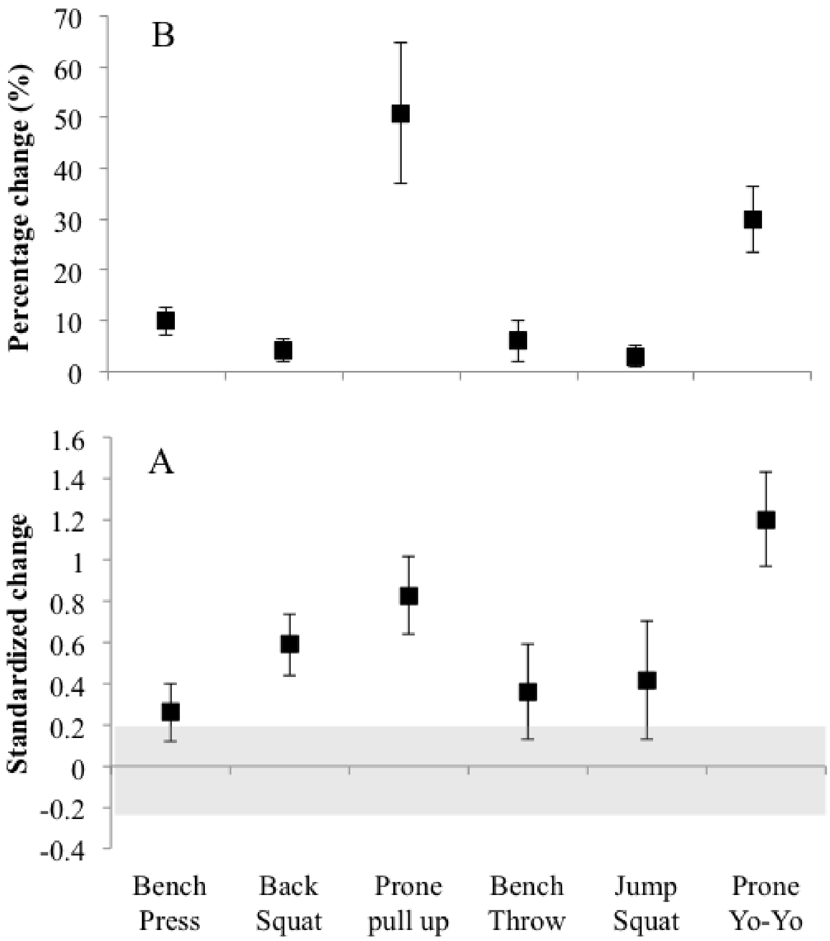

B
Percentage change (%)
70
60
50
40
30
20
10
0
A
Standardized change
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Bench Press
Back Squat
Prone pull up
Bench Throw
Jump Squat
Prone Yo-Yo

Figure 2

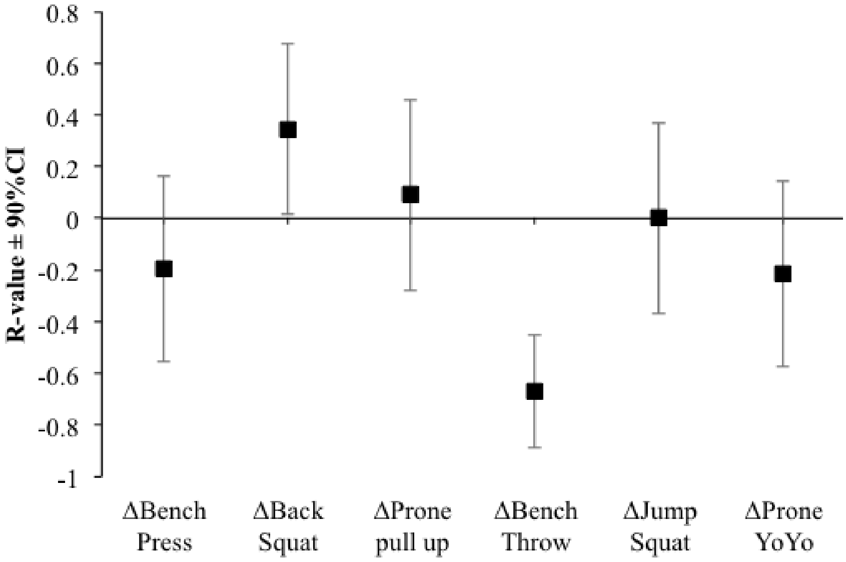

0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
R-value ± 90%CI
ΔBench Press
ΔBack Squat
ΔProne pull up
ΔBench Throw
ΔJump Squat
ΔProne YoYo

Figure 3

Table 1 Overview of content for a typical pre-season training week

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Morning	Daily health markers Pre-habilitation training Gym Wrestle	Daily health markers Pre-habilitation training Meeting Field Conditioning	REST	Daily health markers Pre-habilitation training Meeting Field Games Conditioning	Daily health markers Pre-habilitation training Gym Wrestle	Daily health markers Pre-habilitation training Alternate conditioning/ Field Skills	REST
	Lunch	Lunch		Lunch	Lunch		
Afternoon	Meeting Field Skills	Pre-habilitation training Gym Massage		Pre-habilitation training Gym Massage	Meeting Skills	REST	

Key: Daily health markers = Wellbeing questions, adductor squeeze, counter movement jump, hand grip dynamometer; Pre-habilitation = Physiotherapist-led upper and lower body mobility exercises; Gym = Upper and lower body strength and power programme; Wrestle = Contact progressions involving tackle technique; Field Skills = Rugby skill specific drills; Field Conditioning = Aerobic and anaerobic running sessions; Field Games Conditioning = Small-sided games; Alternate conditioning = Hill sprints; Massage = Soft tissue massage.