Abstract

This study investigated the changes in measures of neuromuscular fatigue and physical performance in young professional rugby union players during a preseason training period. Fourteen young (age; 19.1±1.2years) professional rugby union players participated in the study.

Changes in measures of lower-body neuromuscular fatigue (countermovement jump (CMJ) mean power, mean force, flight time) and physical performance (lower-body strength, 40 m sprint velocity) were assessed during an 11-week preseason period using magnitude–based inferences. CMJ mean power was likely to very likely decreased during week 2 (-8.1±5.5 to -12.5±6.8%), and likely to almost certainly decreased from weeks 5 to 11 (-10±4.3 to -14.7±6.9%), while CMJ flight-time demonstrated likely to very likely decreases during weeks 2, and weeks 4 to 6 (-2.4±1. to -3.3±1.3%), and weeks 9 to 10 (-1.9±0.9 to -2.2±1.5%). Despite this, possible improvements in lower-body strength (5.8±2.7%) and very likely improvements in 40 m velocity (5.5±3.6%) were made. Relationships between changes in CMJ metrics and lower-body strength or 40 m sprint velocity were trivial or small (<0.22).

Increases in lower-body strength and 40 m velocity occurred over the course of an 11-week preseason despite the presence of neuromuscular fatigue (as measured by CMJ). The findings of this study question the usefulness of CMJ for monitoring fatigue in the context of strength and sprint velocity development. Future research is needed to ascertain the consequences of negative changes in CMJ in the context of rugby specific activities to determine the usefulness of this test as a measure of fatigue in this population.

Key Words: fatigue, recovery, performance.

Introduction

Rugby union is a collision sport in which players are required to possess high levels of strength, power, and endurance to compete at an elite level (Duthie, 2006). Therefore enhancement of such physical characteristics is important for the progression of young professional rugby union players towards senior status (Darrall-Jones, Jones, & Till, 2015). In particular, during the pre-season, the development of these physical characteristics is often prioritised with the aim of preparing players for the forthcoming competitive season (Argus, Gill, Keogh, Hopkins, & Beaven, 2010). A major challenge to coaching staff during the preseason is the prescription of appropriate training volumes that result in optimal physiological adaptation and skill development, without incurring negative effects of the high training loads (e.g. fatigue and injury) typically associated with pre-season training (Cross, Williams, Trewartha, Kemp, & Stokes, 2015).

Monitoring of athletes during such intensified training periods is commonly undertaken in order to maximise the physical development of players, while managing the development of fatigue (Halson, 2014). One particular facet of fatigue that is of interest to sports scientists and strength and conditioning practitioners is neuromuscular fatigue. Neuromuscular fatigue manifests as a reduction in the ability to produce force or power (Grassi, Rossiter, & Zoladz, 2015), and thus may compromise physical development and optimal sports performance (Taylor, Cronin, Chapman, Hopkins, & Newton, 2015).

Lower-body neuromuscular fatigue has been shown to occur in the first 24-72 hr post-match in collisions sport athletes, as demonstrated by transient reductions in countermovement jump (CMJ) metrics (e.g. power, flight-time) (McLellan & Lovell, 2012; Shearer et al., 2015; Twist, Waldron, Highton, Burt, & Daniels, 2012; West et al., 2014). Based on these findings, it has been proposed that the CMJ is a practical and valid measure of lower-body neuromuscular fatigue in this population (Shearer et al., 2015; Twist & Highton, 2013; Twist et al., 2012; West et al., 2014). Furthermore, it has been suggested that CMJ performance prior to the commencement of training may be a useful tool for regulating training volume in order to optimise training adaptation while minimising fatigue (Claudino et al., 2012).

Currently however, no study has investigated the relationship between changes in measures of neuromuscular fatigue and physical performance in this population during the preseason. Studies documenting the preseason in rugby players have either reported changes in performance measures (Argus et al., 2010; Bradley et al., 2015; Coutts, Reaburn, Piva, & Murphy, 2007) or neuromuscular fatigue only (Gathercole, Sporer, & Stellingwerff, 2015). Such research would give an insight into the potential usefulness of the CMJ for monitoring neuromuscular fatigue during the preseason period. Therefore the aim of the present study was to describe the changes in measures of lower-body neuromuscular fatigue (CMJ) and physical performance (i.e., lower-body strength and 40 m sprint velocity) during a preseason in young professional rugby union players, and to investigate if any relationships exist between such changes.

Methods

Subjects

Fourteen young professional rugby union players (age 19.1±1.2 years, body mass 96.2±13.2kg, height 186.5±8.2cm) were recruited from a professional rugby union club. Each player was a member of the Senior Academy, a transitional squad from the Junior Academy (under-18's) to the senior squad, consisting of 18-23 year old players. Players typically engaged in 8 individual training sessions across 5 days per week, including resistance training, rugby skills and conditioning. Ethics approval was granted by Leeds Beckett University ethics board and written informed consent was acquired from all subjects.

Design

A within-group repeated measures design was used to examine the magnitude of change in lower-body neuromuscular fatigue (CMJ), and physical performance (lower-body strength and 40 m sprint velocity), and the relationships that exist between such changes, during an 11-week preseason period. The CMJ was assessed on the first and fourth morning of each week following a rest day. Lower-body strength and 40 m sprint velocity were assessed at the beginning and end of preseason.

Lower-body Neuromuscular Fatigue

A CMJ was used to measure lower-body neuromuscular fatigue. It has been recommended that a minimum sampling frequency of 200Hz be used when measuring CMJ performance (Hori et al., 2009). Therefore the CMJ was performed on a portable force plate (400 Series Performance Plate, Fitness Technology, Adelaide, Australia) that was attached to a laptop with software (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) that measured ground reaction forces at 600Hz, as previously used in similar studies (Cormack, Mooney, Morgan, & McGuigan, 2013; Cormack, Newton, McGuigan, & Cormie, 2008). A standardised 2-minute warm-up consisting of dynamic stretching was performed prior to the test (walking lunges, squats, heel flicks, high knees, skipping, legs swings and 3 practice submaximal CMJs). Following the warm-up, players performed 2 maximal CMJs with 1-minute rest between each effort (Roe et al., 2015). Players began standing on the force platform with knees extended and feet in a position of their choice. Subjects were instructed to keep their hands on their hips and jump as a high as possible. The depth of the countermovement was at the discretion of the subject (Cormack, Newton, McGuigan, & Doyle, 2008). Mean power, mean force and flight-time were analysed based on the previous between-day reliability (Coefficient of variance (CV) = 3.1%, 1.0% and 2.6% respectively) of these metrics published in this cohort (Roe et al., 2015). The start time for concentric mean power and mean force was when the velocity was equal to zero (Linthorne, 2001).

Lower-Body Performance

To determine changes in a player's maximal velocity, 40 m sprint testing was undertaken on the same day of the week, at the same time of day and on the same surface (3G pitch) during week 1 and week 10 of pre-season. Players performed a standardised warm-up followed by 3 maximal 40 m sprints with 3 minutes of rest between each effort (Darrall-Jones et al., 2015). Each player wore a 10 Hz GPS unit (Catapult Optimeye S5), which have previously been shown reliable in sprint testing (Varley, Fairweather, & Aughey, 2012). The highest velocity achieved was used in the final analysis.

To determine lower-body strength, front squat 3-repetition max (3RM) was assessed on the same day of the week and at the same time of day during week 1 and week 10. Players performed a standardised warm-up that included 1 set of 8 repetitions with the bar, 2 sets of 5, and 2 sets of 3 repetitions with submaximal loads incrementally approaching their previous 3RM (Darrall-Jones et al., 2015). Players then had 5 attempts to achieve a new 3RM, with 3 minutes of rest between each attempt (Darrall-Jones et al., 2015).

Training Load

Training load was quantified using the session rating of perceived exertion method (sRPE) (Foster et al., 2001) within 15-30 minutes of each session finishing, on a modified Borg scale. This rating was then multiplied by the time spent training to give a training load in arbitrary units (AU) (Foster et al., 2001). Training sessions were categorised into resistance training, off-feet conditioning and field training. Off-feet conditioning consisted of cycle ergometer interval training (Wattbike Pro, Nottingham UK) based on players' average speed achieved during a 3-minute test. . Field training consisted of rugby conditioned-games interspersed with intermittent running based on players' individual 30-15 intermittent fitness test score. Training loads were summated to provide an overall weekly training load.

Statistical Analysis

All data were log transformed to reduce bias as a result of non-uniformity error. Data were all analysed for practical significance using magnitude-based inferences (Hopkins, Marshall, Batterham, & Hanin, 2009). The threshold for a change to be considered practically important (the smallest worthwhile change; SWC) was set at 0.2 x between subject standard deviation (SD), based on Cohen's d effect size (ES) principle. The probability that the magnitude of change was greater than the SWC was rated as <0.5%, almost certainly not; 0.5-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, almost certainly (Hopkins et al., 2009). Where the 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWC (ES±0.2), the magnitude of change was described as unclear (Hopkins et al., 2009).

In order to analyse the relationship between neuromuscular fatigue and changes in physical performance, data were tested for normality using Shapiro-Wilk's test. Neuromuscular fatigue was deemed present on a given testing day if the magnitude of change in a player's CMJ was below the summation of the SWC and the CV (Hopkins, 2004). The relationships between the number of time-points a player demonstrated neuromuscular fatigue (in each CMJ metric) and the percentage change in both 40 m sprint velocity and lower-body strength were examined using Pearson's product-moment correlation coefficient using SPSS for Mac (version 21). The correlation coefficient was ranked as trivial (<0.1), small (0.1-0.29), moderate (0.3-0.49), large (0.5-0.69), very large (0.7-0.89) and nearly perfect (0.9-0.99) (Hopkins et al., 2009).

Results

Total and weekly distribution of training loads across each training category (i.e., resistance training, off-feet conditioning and field training), are presented in Figure 1. The average weekly training load was 1810±339 AU. The weekly training schedule is presented in Table 1.

INSERT FIGURE 1 HERE

INSERT TABLE 1

Changes in measures of neuromuscular performance and fatigue, alongside the total training load are presented in Figure 2. Figure 2b shows that CMJ mean power was likely to very likely decreased during week 2 (-8.1±5.5 to -12.5±6.8%), and likely to almost certainly decreased from weeks 5 to 11 (-10±4.3 to-14.7±6.9%). Figure 2c depicts decreases in flight-time that were likely to very likely during week 2 and weeks 4 to 6 (-2.4±1. to -3.3±1.3%), and during weeks 9 to 10 (-1.9±0.9 to -2.2±1.5%). Changes in CMJ mean force were likely to almost certainly trivial at the majority of time-points (Figure 2d).

Possible improvements in lower-body strength (5.8±2.7%) were made from week 1 to week 10, while very likely improvements in 40 m sprint velocity (5.5±3.6%) occurred between week 1 and week 10 (Figure 2a).

INSERT FIGURE 2

The relationships between the number of times a player demonstrated neuromuscular fatigue in CMJ flight-time and percentage change in 40 m sprint velocity and lower-body strength were trivial (r = 0.09) and small (r = 0.19) respectively. The relationships between the number of times a player demonstrated neuromuscular fatigue in mean power and percentage change in 40 m sprint velocity and lower-body strength were small (r = 0.16 and 0.21 respectively).

Discussion

This study examined the magnitude of change in measures of lower-body neuromuscular fatigue and physical performance over the course of a preseason in young professional rugby union players. Very likely to almost certain reductions in CMJ mean power (-10±4.3 to -14.7±6.9%) were present during the latter half of the preseason, indicating the presence of lower-body neuromuscular fatigue. Regardless of this, possible improvements in strength and very likely improvements in 40 m sprint velocity were apparent. Furthermore the relationships between the number of times a player demonstrated neuromuscular fatigue and changes in both 40 m sprint velocity and lower-body strength was trivial or small (<0.22). These findings suggest that increases in 40 m sprint velocity and lower-body strength can still be achieved when changes in CMJ metrics are indicative of fatigue.

This is the first study to provide training load data during a preseason period for young professional rugby union players. The training load observed in the current pre-season (1810±339 AU) was moderately lower (Cohen's d = -1.01) than those reported in other UK professional rugby union clubs for senior players (2175±380 AU) (Cross et al., 2015). This is likely the result of the difference in training content between a Senior Academy and first team squad. Although players in this study engaged in some first team field sessions, the overall training exposure was determined as appropriate for young professional rugby union players by the coaching team.

This study demonstrated that both CMJ mean power and flight-time decreased following the highest period of training volume (weeks 3-5), suggesting a neuromuscular fatigue response. Following the rest week, flight-time began to return to baseline, although still possibly decreased. However, mean power remained almost certainly decreased. Similarly as training load in the latter stages of the preseason began to reduce, flight-time began to return to baseline, while mean power still remained almost certainly reduced. According to the fitness fatigue model, it is only when the fatigue-inducing training stimulus has been removed or reduced, that improvements in fitness can be observed (Banister, 1991). It is possible that the rest week during week 7 was not long enough to remove the training-induced fatigue and restore CMJ mean power, thus explaining the suppression of this CMJ metric during the latter weeks of the preseason period.

Neuromuscular fatigue may be caused by a combination of central nervous system and peripheral (muscle-tendon unit and nervous system) factors (Boyas & Guével, 2011), both of which contribute to reductions in CMJ performance (Taylor et al., 2015). Given that changes in CMJ mean force were likely to almost certainly trivial at the majority of time-points, it appears that training-induced fatigue in these players influenced the velocity of the movement rather than absolute force production. These findings are in agreement with changes in CMJ force and power reported in professional rugby league players following match-play (McLellan & Lovell, 2012; McLellan, Lovell, & Gass, 2011).

In a similar study design, Gathercole et al (2015) monitored CMJ performance over a 6-week training period in elite female rugby sevens players. The authors observed substantial changes (likely to almost certain) in flight-time during the latter 4-weeks similar to the present study. Conversely however, the authors observed no substantial changes in mean power despite greater overall training loads. The authors suggested that mean power might not be as useful as other CMJ metrics (e.g. flight-time) for assessing lower-body neuromuscular fatigue. However in their study, weekly CMJ testing was undertaken following speed sessions, which may have led to transient post-activation potentiation, masking the effects of neuromuscular fatigue on this CMJ metric. Nevertheless, in the present study, the CMJ was assessed in the morning prior to any training being undertaken, with mean power demonstrating the greatest changes of all the CMJ metrics analysed during the preseason period. The difference between the respective studies highlights the importance of standardising methodologies (e.g. time of day) in order to better understand the effects of training on markers of fatigue.

Despite the negative changes in CMJ metrics in this study, lower-body strength showed improvements (5.8±2.7%) across the preseason that are similar to those previously reported in professional rugby union players across 2 preseason periods (6.5-11.5%) (Appleby, Newton, & Cormie, 2012). However it is possible that greater increases in these physical qualities may have been developed had neuromuscular fatigue not been present, although given the observational nature of this study, this requires further investigation. Argus et al (2010) observed an 11.3±4.7% increase in box squat over a 4-week intensive block of preseason in professional rugby union players. This is in contrast to the 5.8±2.7% in front squat made in the current study. Nevertheless, Argus and colleagues acknowledge that the large increase in strength was likely the result of players being in a 'deconditioned' state following a 6-week off-season period prior to the commencement of preseason. Conversely, the players in the present study only had a 2-3 week off-season and either equally or bettered their previous testing scores during week 1 of preseason. This suggests that the improvements made in the present study were the result of true changes and not of 'reconditioning', as in the case of Argus and colleagues (2010).

Like lower-body strength, 40 m sprint velocity demonstrated improvements (5.5±3.6%) across the preseason period. These results are slightly greater than seasonal changes of 40 m sprint velocity (~2-3%) reported in international under-20 and senior players (Barr, Sheppard, Gabbett, & Newton, 2014). However, the players in the study by Barr and colleagues were of a higher playing standard than in the present study and therefore may have been closer to realising their absolute speed potential. Additionally, the greater increases observed in the present study might be partly the result of running re-education and improvements in technique (Appleby et al., 2012), as sprint training was not undertaken during the latter stages of the previous competitive season. Furthermore, it is also possible that the improvements in lower-body strength transferred through to improvement in 40 m sprint velocity (Seitz, Reyes, Tran, Saez de Villarreal, & Haff, 2014).

Previous studies have shown that CMJ metrics are correlated with sprint performance (Loturco et al., 2015), thus it would be expected that sprint velocity would decline in the presence of reduced CMJ performance. In agreement with the findings of the present study however, Coutts et al (2007) observed no change in 10m and 40 m sprint performance during a deliberate period of over-reaching in semi-professional rugby league players. This was in spite of substantial decreases in other performance measures including lower-body strength, isokinetic power and vertical jump. Furthermore, recovery of sprint performance has been shown to be far quicker than CMJ following field-based training (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015). It is therefore possible that 40 m sprint velocity is less sensitive to neuromuscular fatigue than CMJ mean power.

Alternatively, it is also possible that the development of neuromuscular fatigue, as measured by CMJ, does not compromise the ability to produce an all-out effort in a 40 m sprint test. In the present study, sprint testing was undertaken in a group setting, where competition between players may have influenced maximal exertion (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012). Therefore in such motivational situations, players may be able to produce maximal efforts and temporarily negate the acute effects of neuromuscular fatigue on an isolated 40 m sprint performance.

Although it appeared that neuromuscular fatigue did not influence 40 m sprint velocity or strength development, neuromuscular fatigue may have had a negative effect on other training activities in this group of players. Findings from Australian Rules football suggest that the presence of neuromuscular fatigue unfavourably altered accelerometer-loading patterns of players during match-play (Cormack, Mooney, Morgan, & McGuigan, 2013), and negatively influenced the relationship between the relative accumulated accelerometer load and coaches' perception of player performance (Mooney, Cormack, O'Brien B, Morgan, & McGuigan, 2013). Therefore the fatigue experienced by the players in the present study may have affected rugby specific performance during the preseason period. Unfortunately, an objective measure of such activity was not collected. Future research is needed to examine the influence of neuromuscular fatigue on rugby union specific activities.

A limitation of the present study is the lack of measurement of upper-body neuromuscular fatigue. It has previously been demonstrated that rugby league players experience considerable upper-body neuromuscular fatigue following collision-based training (R. D. Johnston, Gabbett, Seibold, & Jenkins, 2014) and match-play (R. D. Johnston, Gabbett, Jenkins, & Hulin, 2015). Therefore future research is needed to investigate this phenomenon during the preseason period. A further limitation of the present study is the use of GPS to measure maximum velocity during 40m sprinting. It has been demonstrated that GPS is associated with greater testing error at higher speeds (R. J. Johnston, Watsford, Kelly, Pine, & Spurrs, 2014), which must be taken into consideration when making conclusions about changes in these measurements over time. Finally, as objective measures of training load were not collected during the study (for example volume load, GPS metrics) it was not possible to examine the relationship between such measures and strength and speed development. Consequently, future research is needed to examine the relationship between changes in physical performance and objective measures of training load in this cohort during a preseason period.

Conclusion

In conclusion, possible and very likely increases in lower-body maximal strength and 40 m sprint velocity respectively occurred despite the presence of neuromuscular fatigue during an 11-week preseason period in young professional rugby union players. Future research is needed to investigate whether reductions in CMJ performance negatively impact rugby specific activities in order to determine the usefulness of this test as a measure of fatigue in rugby union players.

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Table 1: Weekly training schedule during the 11-week preseason period. CMJ = countermovement jump

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Monitoring	CMJ			CMJ			
a.m.	Upper-body resistance training (50-60 min)	Lower-body resistance training (50-60 min)	OFF	Lower-Body resistance training (50-60min)	Upper-body resistance training (50-60min)	Speed / rugby skills / conditioned games (30-45 min)	OFF
p.m.	Rugby conditioned-games / running conditioning (45-60 min)	Off-feet conditioning (30-45 min)		Rugby conditioned games (30 min) Off-feet conditioning (30 min)			

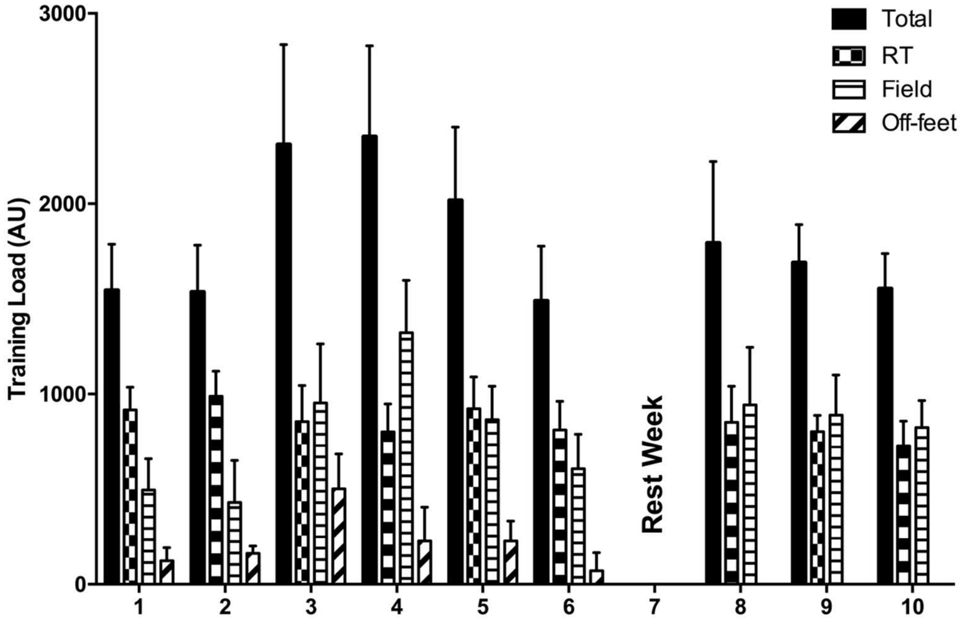

Figure 1: Mean (± SD bars) total weekly training loads and weekly distributions of training loads across each training category. RT = resistance training, Field = field training, Off-feet= off-feet conditioning, Total = total weekly training load.
113x74mm (300 x 300 DPI)

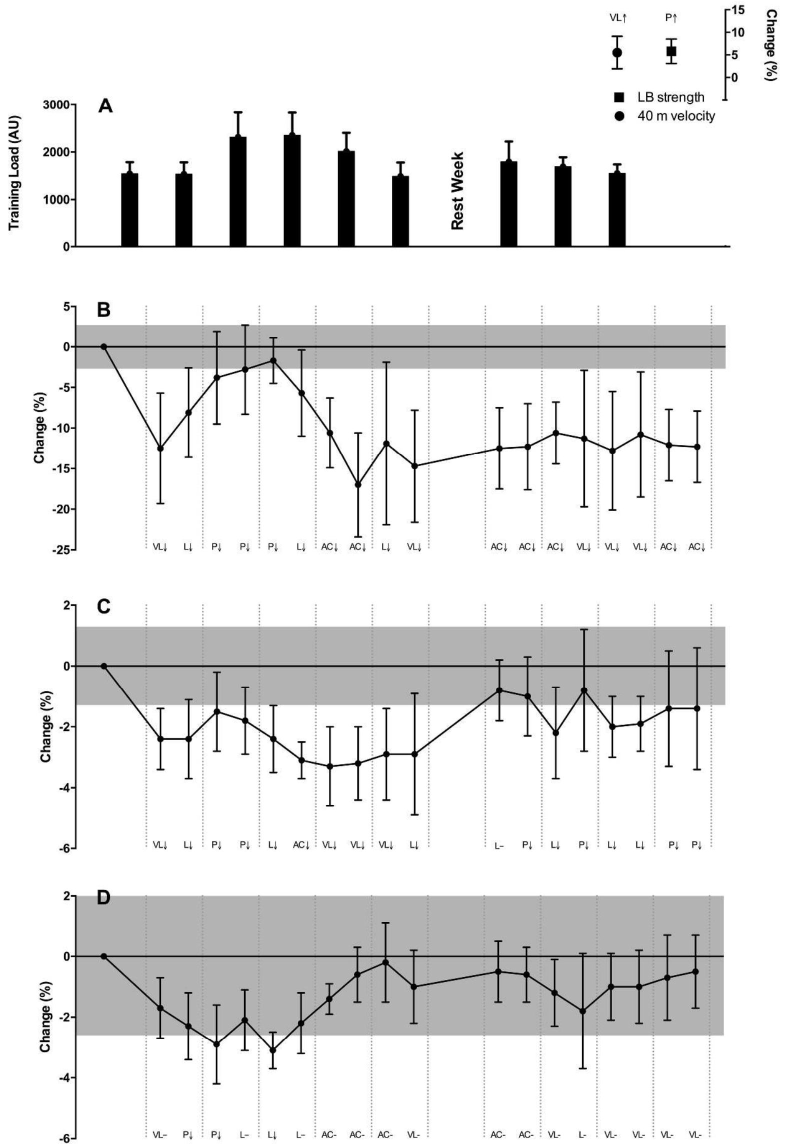

Figure 2: Mean weekly training load (±SD bars) (A), changes in 40 m sprint velocity and lower-body (LB) strength (A), and changes in CMJ mean power (B), flight-time (C) and mean force (D). Change data are percentage change with 90% confidence interval bars and the shaded area representing the smallest worthwhile change as a percentage. P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, - = trivial.
268x391mm (300 x 300 DPI)