Quantification of training load during return to play following upper and lower body injury in Australian Rules Football

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Quantification of training load during return to play following upper and lower body injury in Australian Rules Football

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Abstract

Purpose: Training volume, intensity and distribution are important factors during periods of return to play. The aim of this study was to quantify the effect of injury on training load (TL) before and after return to play (RTP) in professional Australian Rules Football.

Methods: Perceived training load (RPE-TL) for 44 players was obtained for all indoor & outdoor training sessions, while field-based training was monitored via GPS (total distance, high-speed running, mean speed). When a player sustained a competition time-loss injury, weekly TL was quantified for 3 weeks before and after RTP. General linear mixed models, with inference about magnitudes standardized by between-player SD's, were used to quantify effects of lower and upper body injury on TL compared to the team.

Results: While total RPE-TL was similar to the team 2 weeks before RTP, training distribution was different, whereby skills RPE-TL was likely and most likely lower for upper and lower body injury, respectively, and most likely replaced with small-very large increases in running and other conditioning load. Weekly total distance and high-speed running was most likely moderately-largely reduced for lower and upper body injury until after RTP, at which point, total RPE-TL, training distribution, total distance and high-speed running were similar to the team. Mean speed of field-based training was similar before and after RTP compared to the team.

Conclusions: Despite injured athletes obtaining comparable training loads to injured players, training distribution is different until after RTP, indicating the importance of monitoring all types of training athletes complete.

Key words: Competition; training distribution; training volume; training intensity

INTRODUCTION

Australian football (AF) is a high-intensity intermittent contact sport, demanding a wide range of physical attributes such as muscular strength, speed, power, repeated sprint ability, endurance, acceleration and deceleration, and sport specific skills [1-3]. AF often results in players covering anywhere between 9.5-17 km total distance and in excess of 3 km of high speed (>14.4 km/h) distance per match [4]. In addition to the high locomotor demands of AF, the existence of tackling, bumping, blocking, wrestling and contesting of ground balls [5] increases the physiological demand AF athletes are exposed to. As a consequence, both intrinsic (overuse and overexertion) and extrinsic (encompassing collision and contact) injuries commonly occur.

In the 2014 season, it was reported that on average AF clubs had ~41 injury occurrences resulting in 146 games missed [6]. While rehabilitation and return-to-play (RTP) from injury is a complex and multi-faceted process, a fundamental component of this plan is the training process [7] whereby restoration of sport-specific skills are identified as crucial in the final checklist before return to play [8]. Depending on the injury type and severity, athletes' training is either stopped and/or reduced [9], resulting in a period of reduced load and resultant detraining. As the athlete progresses through the various rehabilitation phases, training distribution, intensity and volumes are manipulated so as to return the athlete in a condition that meets the demands of competition. In relation to AF, there are many modes of training prescribed so as to achieve these desired physical qualities. In line with the increased focus on load monitoring in team sports, it is possible to gain information on how athletes train before and after RTP. Indeed, the monitoring of internal (session-RPE (s-RPE); whereby a rating of perceived exertion on a 1-10 scale is multiplied by session duration) and external (GPS) load are effective in capturing the training distrubution and loads of AF for all training over a course of a season [4, 10].

In the context of, has the athlete 'done enough' [7], recent evidence reports that oversight of training load planning and quantification during the RTP process exposes the athlete to increased risk of re-injury upon integration back into competition. Moreover, past injury and/or accelerating RTP and, therefore, not obtaining the necessary appropriate loads before return, may result in an increased risk of re-injury [11]. Therefore, prescription of training loads both before and after RTP so as to ensure optimal preparedeness for competition demands and prevention of re-injury presents practitioners with a challenge. Nonetheless, little is known as to how training load is planned, modified and distributed when returning from injury [12]. Therefore, given the aims of the RTP process [7], it would appear logical to know how athletes train relative to the rest of the team when in a RTP model.

To the author's knowledge, there is no evidence pertaining to the management, prescription and distribution of load in AF when in an injured state. Furthermore, little is known about training load distribution immediately following the RTP. Having an understanding of the impact of injury on subsequent loading strategies is important for practitioners when planning and prescribing RTP training programmes. To this end, the aim of the present study was to quantify the impact of injury on training distribution and load before and after RTP in professional AF players.

METHODS:

Subjects

Forty-four professional AF athletes (mean ± SD: age, 24.1 ± 3.8 years; height, 187.7 ± 7.2 cm; body mass, 87.3 ± 8.2 kg) from the same Australian Football League (AFL) club participated in this study. The participating athletes competed in the AFL and the Victorian Football League (VFL) (the 2nd tier level competition). Each athlete provided written informed consent and ethical approval was approved by the institutions human research ethics committee.

Design

To account for varying approaches to training prescription for upper and lower body injuries, all injuries were split into upper and lower body (Table 1). Weekly totals for a period of 3 weeks before and after RTP were compared relative to those in an uninjured state, i.e. the main group. In most cases, individual athletes' load is compared relative to their own individual norms, however, we aimed to quantify how training when in an injured state is planned and prescribed compared to the training of the main group. Indeed, this 'group load' is what players returning from injury typically need to achieve, thus ensuring a level of resilience to the daily load requirements and minimising the risk of injury reoccurrence. The 3 weeks before RTP were split into Week-3, Week-2, and Week-1 whilst the 3 weeks after RTP were split into Week+1, Week+2, and Week+3 after return. Due to the low number of injuries causing missed games in the pre-season, only in-season injuries and associated changes in TL were considered. As such, there were a total of 38 injuries, resulting in a total number of 126 matches missed with players on average in a rehabilitation model for 29 ± 24 days (see Table 1). Specifically, there were 24 injuries resulting in <3 weeks missed, 8 injuries resulting in >3 weeks missed, 5 injuries resulting in >6 weeks missed and 1 injury resulting in >9 weeks missed. Together, the 3-week period was chosen on the basis that the majority of injuries resulted in a time loss of <3 weeks, and irrespective of injury type, training loads were high as the athlete nears RTP. As such, the 3-week period before and after RTP is the most appropriate time course to quantify TL in this context.

INSERT TABLE 1 HERE

Procedures

The methods of data collection for this study have been described elsewhere [4]. Briefly, training load (TL) data was collected over a 41 week period with internal TL obtained via the s-RPE method (CR-10 scale) 10-30 minutes [13] after every indoor and field-based session. This value was then multiplied by session duration, providing an arbitrary TL value [14]. For all field-based training sessions, athletes wore global positioning systems (GPS) devices so as to capture the external load. Key parameters obtained from GPS include total distance (m), high-speed running (>14.4 km/h (m)) [15], PlayerLoad (accelerometer based measurement, taking into account all movements in the three vectors X,Y,Z) [16], and average movement speed (m/min). Each athlete wore the same device across the season and was worn inside a custom made vest supplied by the manufacturer across the upper back between the left and right scapula. All devices were activated 30-minutes prior to data collection to allow acquisition of satellite signals (>8 satellites). The GPS (MinimaxX S4, Catapult Innovations, Docklands Vic, Australia) units has a sampling rate of 10 Hz, (i.e. ten times per second) and accelerometer sampling rate of 100 Hz. The validity and reliability of GPS units sampling at 10 Hz has been shown previously [17, 18]. Following every training session, all GPS and accelerometer derived data was downloaded and analysed by a specialist GPS software package (Sprint 5.1.3, Catapult Innovations, Docklands, Vic, Australia). Distribution of training was achieved by categorising training into skills (field-based AF specific training), running (field-based conditioning), upper body weights (UB weights), lower body weights (LB weights), and other (boxing, cycling, swimming and cross-training). In order to assess the impact of injury on weekly TL, injury was classified in accordance with the leagues governing body annual injury report [6] by the club's senior physiotherapist, collated and then updated on the club's database. For the purpose of this study an injury was classified as pain or discomfort causing a player to miss one or more matches. In light of recent data on the quantification of the acute:chronic training load ratio [19], total RPE load of the current 7-days was quantified relative to the previous 21 days. The acute:chronic ratio was quantified for Week-1 at the point of RTP, therefore, excluding the game load obtained at the end of Week-1, while, post-RTP the acute:chronic ratio included each weekly game load. Due to no games played prior to RTP, game load is not described in table or figure format and is only represented in text where necessary to support certain points.

Statistical Analyses

Consistent with Ritchie et al. [4] general linear mixed models were developed from 25,900 observations that estimated training loads of players when in their uninjured state by including their injury status as covariates in the model. In this way, training load data for the injured players were considered in the context of the main group and, therefore, compared directly to the weekly total load in which the main group obtained for that given week. Random effects in the model were specified to allow for different between-player standard deviations between blocks (with an unstructured covariance matrix to allow for correlations between blocks) and different within-player standard deviations between blocks (a different residual variance for each block). Effects were assessed with non-clinical magnitude-based inferences, using standardisation to define magnitude thresholds (lower or equal to 0.20 trivial, lower or equal to 0.60 small, lower or equal to 1.20 moderate, lower or equal to 2.0 large, lower or equal to 4.0 very large and >4.0 extremely large). Uncertainty in each effect was expressed as 90% confidence limits (CL) and as probabilities that the true effect was substantially positive or negative [20]. To account for an inflation of error associated with a large number of inferences in the current study, effects were only declared clear at the 99% level.

Results:

RPE Load Prior to Return

At Week-3, lower body injury resulted in lower total RPE load (ES; -0.47 ±0.16) than the main group. At this time, skills load (ES; -1.25 ±0.16) and UB weights load (ES; -2.34 ±1.15) was lower, with other load (ES; 2.06 ±0.16) and LB weights load higher (ES; 0.25 ±0.15). Total RPE load at Week-2 and Week-1 was similar compared to the main group. However, skills load at Week-2 (ES; -0.98 ±0.28) and Week-1 (ES; -0.62 ±0.21) was lower, whilst, running and other load was higher at Week-2 (Running; 0.69 ±0.14, Other; 2.13 ±0.28) and Week-1 (Running; 0.57 ±0.11; Other; 1.39 ±0.18) (Figure 1).

INSERT FIGURE 1 HERE

Upper body injury resulted in lower total RPE (ES; -1.01 ±0.21) and skills load (ES; -1.04 ±0.21) compared to the main group at Week-3. In contrast, running load (ES; 0.50 ±0.09) and other load (ES; 0.95 ±0.19) was higher at Week-3. LB weights load at Week-3 was lower (ES; -0.32 ±0.16), whereas, at Week-2 (ES; 1.07 ±0.42) and Week-1 (ES; 0.58 ±0.25), LB weights load was higher than the main group. Comparatively, UB weights load was lower at Week-3 (-0.60 ±0.36) and Week-1 (-1.06 ±0.60). At Week-2 total RPE load (ES; 1.01 ±0.55) was higher, alongside increased UB weights load (ES; 2.03 ±0.81), running load (ES; 1.54 ±0.22) and other load (ES; 2.11 ±0.43) (Figure 1).

INSERT FIGURE 2 HERE

RPE Load Post Return

While lower body injury resulted in lower total RPE load at Week+1 (ES; -0.27 ±0.18) compared to the main group, changes in skills, running, LB weights, UB weights and other load were trivial or unclear (Figure 1). For upper body injury, UB weights load was lower at Week+2 (ES; -0.49 ±0.37) and Week+3 (ES; -0.22 ±0.22), respectively. All other changes in load following upper body injury were trivial or unclear (Figure 2).

GPS Load

Total distance covered was lower at Week-3 (Lower; -1.73 ±0.14, Upper; -1.54 ±0.19), Week-2 (Lower; -1.55 ±0.28, Upper; -1.26 ±0.60) and Week-1 (Lower; -1.15 ±0.21, Upper; -0.91 ±0.39) compared to the main group. Similarly, HSR distance was lower at Week-3 (Lower; -1.14 ±0.12, Upper; -0.98 ±0.17), Week-2 (Lower; -1.04 ±0.23, Upper; -0.87 ±0.49) and Week-1 (Lower; -0.74 ±0.17, Upper; -0.65 ±0.32). Furthermore, PlayerLoad was lower at Week-3 (Lower; -1.75 ±0.14, Upper; -1.53 ±0.19), Week-2 (Lower; -1.57 ±0.27, Upper; -1.28 ±0.61) and Week-1 (Lower; -1.15 ±0.21, Upper; -0.90 ±0.38). After RTP, there was no effect of lower body injury on total distance covered, HSR distance and PlayerLoad. Following upper body injury, total distance (ES; 0.36 ±0.27), HSR distance (ES;

0.20 ±0.20) and PlayerLoad (ES; 0.37 ±0.28) were higher at Week+1. There was no effect of any injury on mean speed before or after RTP (Figure 3).

INSERT FIGURE 3 HERE

For lower body injury, acute:chronic workload ratio at Week-1, Week+1, Week+2 and Week+3 was 1.02 ±0.32, 1.57 ±0.23, 1.59 ±0.27 and 1.28 ±0.26, respectively. For upper body injury, acute: chronic workload ratio at Week-1, Week+1, Week+2 and Week+3 was 0.89 ±0.28, 1.48 ±0.33, 1.51 ±0.32 and 1.39 ±0.20, respectively.

Discussion

This study aimed to quantify the effect of lower and upper body injury on training distribution and load during and after RTP in professional AF. We report that 3 weeks before RTP, total RPE load for lower and upper body injury was lower compared to that of the main group, likely due to reduced skill load. In turn, there was an increase in other conditioning and running load, which was further accentuated at Week-2 and Week-1 resulting in comparable total RPE load within 2 weeks of RTP. After RTP, there was no difference in training load from the main group following upper body injury, though after lower body injury there was a small reduction in total load in the first week only. Together, these data provide information about the distribution of training and loading strategies employed during RTP from upper and lower body injuries in professional AF.

In general, RTP protocols are tailored specifically towards the type and severity of injury suffered. However, in the acute phase leading up to RTP, athletes in rehabilitation are often prescribed training loads that supersede that of a typical week with the aim being to expose the athlete to sufficient training intensity and volume to protect against re-injury [21]. In this regard, we chose a 3-week period on the basis that the majority of players 1) suffered an injury resulting in a time loss of <3 weeks, and 2) irrespective of injury type, training loads were high as the athlete nears RTP. This study reports that within 2 weeks of RTP following lower body injury, the site in which more than half the total injuries occurred, total RPE load was similar to the main group. Notably, however, the distribution of this training load was still different right up until the point of RTP compared to the main group, with skill load reduced and replaced with running and other conditioning. While not for certain, this distribution of load is possibly aimed at gaining greater control of an injured athlete's training, exposing them to the required stimulus but without the increased risk of the uncontrolled open nature of field-based skills and match simulation. In fact, it is important to note, that skill load of the injured player does not return to that of the main group until after they have returned to play.

In contrast to the TL management of lower body injury, upper body injury was variable before RTP. Consistent with lower body injury, total RPE load was lower at Week-3, however, at Week-2, there was a shift in load volume such that those with an upper body injury obtained higher total RPE load than the main group. Retrospectively, this is likely due to the large and very large increases in running and other conditioning load, respectively. Furthermore, there was a very large increase in UB weights load, suggesting that the collective running, other and UB weights load are responsible for this load increase. One well documented challenge for practitioners is to expose players in rehabilitation to the high loads required to enhance specific physical qualities [22]. While it is unclear as to why these specific loading patterns occurred, these data demonstrate the challenges and issues with training prescription during the acute period prior to RTP.

Training programme design consists of varying frequency, volume and intensity of sessions. In addition to sRPE, which is largely a global descriptor of load [23], this study also has specific field-based information pertaining to the distances and intensities in which the players run. Total distance, considered a measure of training volume, was reduced in the 3 weeks before RTP but gradually increased upon nearing RTP. Similarly, HSR was also reduced, collectively resulting in a reduction in PlayerLoad. Despite this, the average intensity of the field-based training, as represented by m/min, is similar to the main group for the 3 weeks before and after RTP. These data indicate that irrespective of injury type, training volume may be the main modulator of training design in the 3 weeks leading up to RTP. Together, this may suggest that conscious efforts are made to ensure AF players train at similar intensities at which they are required to train at when with the main group.

While an AF player's field-based conditioning is an important aspect in RTP, strength training is also considered a pivotal component contributing to injury prevention and improved performance [1]. It has been reported that strength levels can be maintained for up to 3 weeks during a period of detraining [25], suggesting that less attention may be required to 're-train' strength. Indeed, only small increases in LB weights load (~40 load units) during lower body injury occurred at Week-3 and Week-1 compared to the main group, possibly indicating only a small requirement in improving strength deficits following injury [1]. In contrast, short term periods (up to 4 weeks) of reduced training load (frequency, intensity, volume) result in rapid reductions in cardiovascular fitness (i.e., maximal oxygen uptake, blood volume, stroke volume, cardiac output)[26]. Given these physiological changes it may be no surprise that running and other conditioning was increased by around 300 and 470-700 load units, respectively during RTP. Together, this suggests that in the context of lower body injury, more emphasis and priority is placed on aerobic gains during RTP of AF players than pure strength and/or hypertrophic lean muscle mass gains. In addition, this may also indicate there is an upper weekly limit of total training load, therefore placing greater importance on training distribution during RTP.

An aspect of training prescription that has received little attention in the field is the management of load following RTP. Indeed, after RTP, there is often an increased risk of re-injury owing to the increase in competition load [7]. We report in the week following RTP from lower body injury, a small reduction in total RPE load compared to the main group, very likely due to a lower game load

(ES; 0.50 ±0.28). After this point, however, there was no effect of injury on total RPE load. A novel aspect of the current study is the representation of the acute:chronic workload ratio at the point of RTP and in the following 3 weeks after return. At RTP for lower and upper body injury, the acute:chronic ratio was 1.02 ±0.32 and 0.89 ±0.28, respectively, which are within the proposed thresholds [7]. However, in the week following RTP, moderate spikes in total RPE load were observed for both lower (1.57 ±0.23) and upper body (1.48 ±0.33) injury. This also persisted for Week+2 (Lower body injury: 1.59 ±0.27, Upper body injury, 1.51 ±0.32) before stabilising somewhat in Week+3 (Lower body injury: 1.28 ±0.26, Upper body injury, 1.39 ±0.20). Nevertheless, we observed no reoccurrence of injury in the following weeks post-RTP. These training ratio's should be of little surprise, especially given that AF competition load is the highest stimulus for a given week [4] and thus cannot be readily simulated in training. In this sense, it is important to consider changes in load in the context that they appear and appropriately devise training and recovery plans so as to accommodate increases in load upon RTP.

We acknowledge that a limitation of the current study is the pooling of individual upper and lower body injuries into the respective groups. That said, however, an analysis of each individual injury and the associated TL strategies would require a multitude of injuries of the same type and severity so as to ensure an adequate enough sample size. In this sense, we aimed to quantify on a global level changes in the distribution of training load, in relation to upper and lower body injuries compared to the normal training performed by the main group. We believe that our approach in quantifying global load relative to the main group provides practitioners with an awareness of training load changes in the acute phase before and after RTP. In light of this study, quantifying load during RTP is also important. Recent work has also described the possible use of differential RPE in team sports so as to improve the precision of the observed internal load [26]. Indeed, in the case of return to play, differential RPE may add an important contextual layer in better understanding load during RTP, thus warranting further investigation. Nevertheless, this study is the first to quantify the effect of injury on training load distribution and RTP in professional AF during the course of an in-season period. We reveal that within 3 weeks of RTP, there are only small-moderate changes in total training load relative to that of the main group, with distribution of load most likely the important determining factor during RTP. In addition, this study shows that training distribution is mostly the same as the main group following RTP.

Practical Applications

- The sRPE monitoring approach is a useful tool for quantifying all forms of training owing to its standardised unit of measurement and ease of collection and analysis. This is important in the context of changes in training load distribution during RTP.
- Understanding the context in which the acute:chronic TL ratio occurs, i.e., upon RTP, may be important so as to allow

for appropriate training and recovery plans in the weeks after RTP.

- Training volume appears to be the main mediator of training design in the ~3 week period before RTP, especially given training intensity is consistent with that of the main group during this period.

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References

1. Bilsborough JC, Greenway KG, Opar DA, et al. Comparison of anthropometry, upper-body strength, and lower-body power characteristics in different levels of Australian football players. *J Strength Cond Res.* 2015; 29(3):826-834.
2. Gray AJJ, D. G. Match analysis and the physiological demands of australian football.pdf>. *Sports Med.* 2010; 40(4):347-360.
3. Sullivan C, Bilsborough JC, Cianciosi M, Hocking J, Cordy JT, Coutts AJ. Factors affecting match performance in professional Australian football. *Int J Sports Physiol Perform.* 2014; 9(3):561-566.
4. Ritchie D, Hopkins W, Buchheit M, Cordy J, Bartlett J. Quantification of Training and Competition Load Across a Season in an Elite Australian Football Club. *Int J Sports Physiol Perform.* 2015.
5. Dawson B, Hopkinson R, Appleby B, Stewart G, Roberts C. Player movement patterns and game activities in the Australian Football League. *J Sci Med Sport.* 2004; 7(3):278-291.
6. Orchard JJ, Seward, H., Orchard, J. 2014 AFL Injury Report2015.
7. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *Br J Sports Med.* 2015.
8. Herring SA, Kibler WB, Putukian M. The team physician and the return-to-play decision: a consensus statement-2012 update. *Med Sci Sports Exerc.* 2012; 44(12):2446-2448.
9. Shrier I, Matheson GO, Boudier-Reveret M, Steele RJ. Validating the three-step return-to-play decision model. *Scand J Med Sci Sports.* 2015; 25(2):e231-239.
10. Moreira A, Bilsborough JC, Sullivan CJ, Ciancosi M, Aoki MS, Coutts AJ. The Training Periodization of Professional Australian Football Players During an Entire AFL Season. *Int J Sports Physiol Perform.* 2014.
11. Hrysomallis C. Injury incidence, risk factors and prevention in Australian rules football. *Sports Med.* 2013; 43(5):339-354.
12. Hoover DL, VanWye WR, Judge LW. Periodization and physical therapy: Bridging the gap between training and rehabilitation. *Phys Ther Sport.* 2016; 18:1-20.
13. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001; 15(1):109-115.
14. Borg G, Ljunggren G, Ceci R. The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. *Eur J Appl Physiol Occup Physiol.* 1985; 54(4):343-349.
15. Coutts AJ, Quinn J, Hocking J, Castagna C, Rampinini E. Match running performance in elite Australian Rules Football. *J Sci Med Sport.* 2010; 13(5):543-548.
16. Barrett S, Midgley A, Lovell R. PlayerLoad: reliability, convergent validity, and influence of unit position during

treadmill running. *Int J Sports Physiol Perform.* 2014; 9(6):945-952.
17. Boyd LJ, Ball K, Aughey RJ. Quantifying external load in Australian football matches and training using accelerometers. *Int J Sports Physiol Perform.* 2013; 8(1):44-51.
18. Johnston RJ, Watsford ML, Kelly SJ, Pine MJ, Spurrs RW. Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. *J Strength Cond Res.* 2014; 28(6):1649-1655.
19. Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med.* 2016; 50(4):231-236.
20. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009; 41(1):3-13.
21. Petersen J, Thorborg K, Nielsen MB, Holmich P. Acute hamstring injuries in Danish elite football: a 12-month prospective registration study among 374 players. *Scand J Med Sci Sports.* 2010; 20(4):588-592.
22. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med.* 2016; 50(5):273-280.
23. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J Strength Cond Res.* 2013; 27(1):270-276.
24. McMaster DT, Gill N, Cronin J, McGuigan. The development, retention and decay rates of strength and power in elite rugby union, rugby league and American football: a systematic review. *Sports Med.* 2013; 43(5):367-384.
25. Mujika I, Padilla S. Detraining: loss of training-induced physiological and performance adaptations. Part 1: short term insufficient training stimulus. *Sports Med.* 2000; 30(2):79-87.
26. McLaren SJ, Graham M, Spears, IR, Weston M. The sensitivity of differential ratings of percieved exertion as measures of training load. *Int J Sports Physiol Perform.* 2016; 11(3):404-406.

Table 1. Classification and count of pre-season and in-season injuries.

Figure 1. Effect of lower body injury on mode distribution of training determined from RPE. a) Total RPE load, b) Skills RPE load, c) Running RPE load, d) Other RPE load, e) LB weights RPE load, and f) UB weights RPE load. Data is shown as mean change in load ± CL compared to main group. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

Figure 2. Effect of upper body injury on mode distribution of training determined from RPE. a) Total RPE load, b) Skills RPE load, c) Running RPE load, d) Other RPE load, e) LB weights RPE load, and f) UB weights RPE load. Data is shown as mean change in load ± CL compared to main group. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

Figure 3. Effect of lower and upper body injury on weekly external load determined from GPS. a) total distance covered, b) high-speed running distance, c) PlayerLoad, and d) mean speed. Data is shown as mean change ± CL compared to main group. HSR = High-Speed Running. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

Table 1. Classification and count of pre-season and in-season injuries

Body Area	**N**	**Injury Incidence %**	**Pre-season N**	**In-season N**	**Games Missed N**	**Games Missed %**
Upper	13	32%	1	12	48	38
Shoulder/arm/elbow	8	20%		8	28	22
Forearm/wrist/hand	1	2%		1	3	2
Trunk/back	4	10%	1	3	17	13
Lower	23	56%	2	21	70	55
Hip/groin/thigh	6	15%		6	17	13
Knee	6	15%	1	5	31	24
Shin/ankle/foot	11	27%	1	10	22	17
Other	5	12%		5	8	6
Head/neck	2	5%		2	2	1
Illness	3	7%		3	6	5
Total	**41**	**-**	**3**	**38**	**126**	**-**

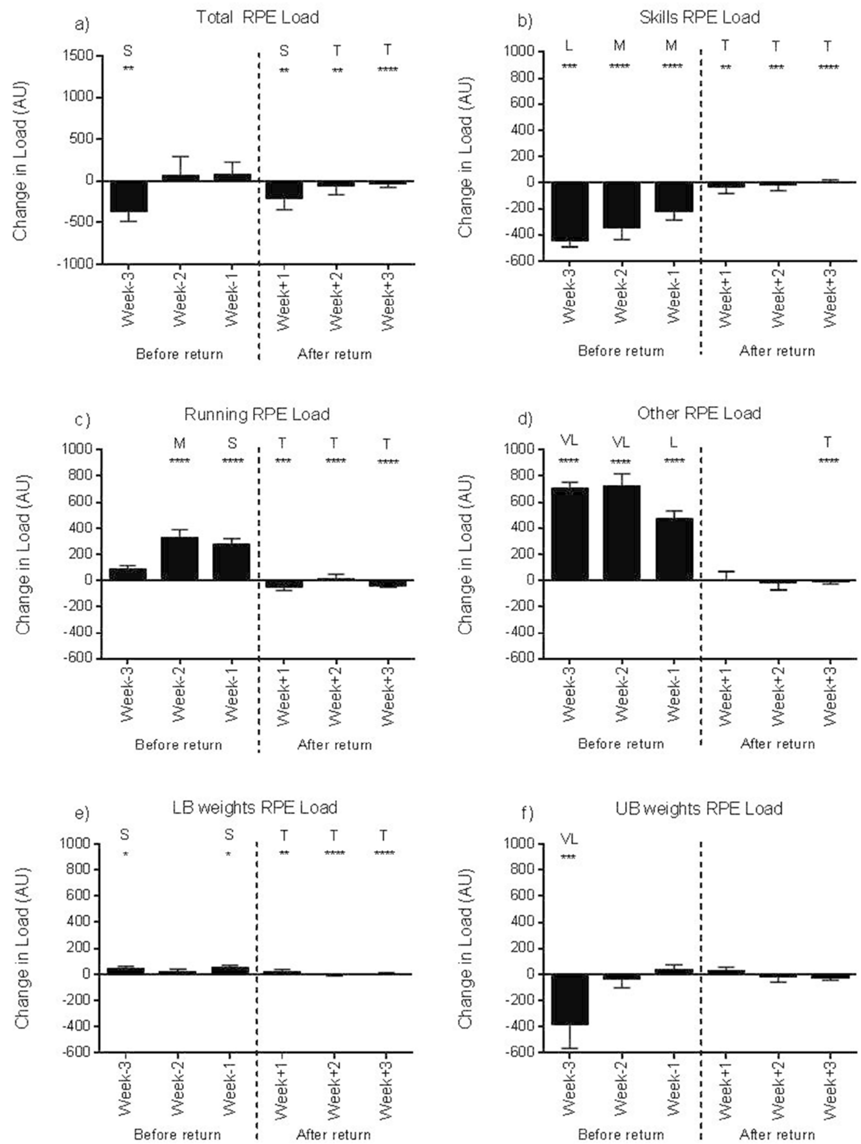

Figure 1. Effect of lower body injury on mode distribution of training determined from RPE. a) Total RPE load, b) Skills RPE load, c) Running RPE load, d) Other RPE load, e) LB weights RPE load, and f) UB weights RPE load. Data is shown as mean change in load ± CL compared to main group. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

143x188mm (150 x 150 DPI)

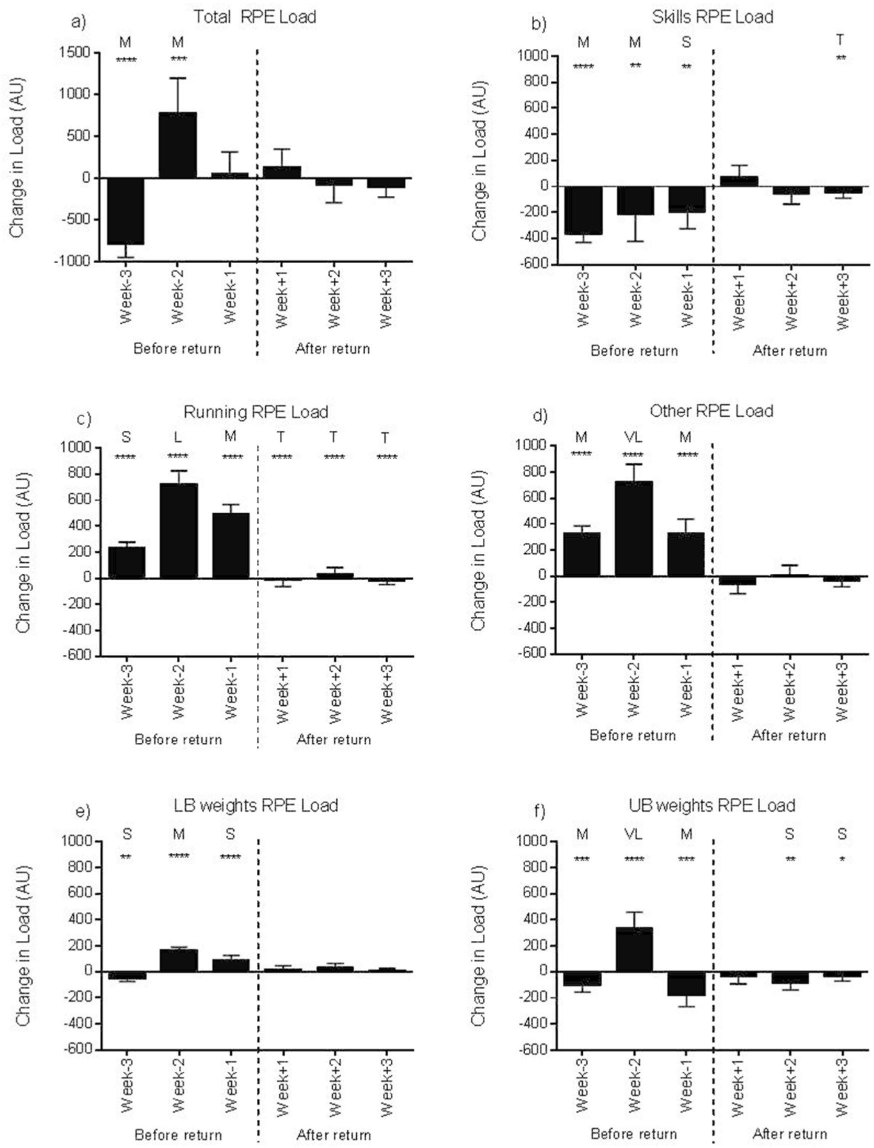

Figure 2. Effect of upper body injury on mode distribution of training determined from RPE. a) Total RPE load, b) Skills RPE load, c) Running RPE load, d) Other RPE load, e) LB weights RPE load, and f) UB weights RPE load. Data is shown as mean change in load ± CL compared to main group. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

143x185mm (150 x 150 DPI)

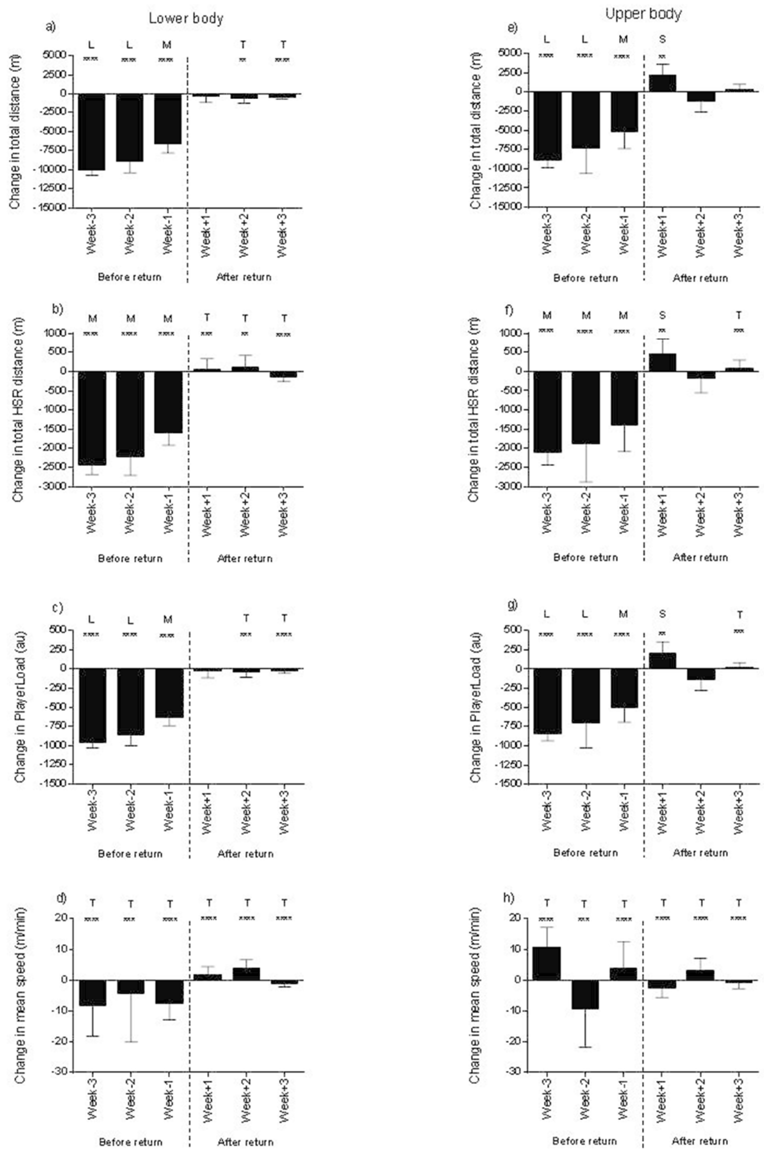

Figure 3. Effect of lower and upper body injury on weekly external load determined from GPS. a) total distance covered, b) high-speed running distance, c) PlayerLoad, and d) mean speed. Data is shown as mean change ± CL compared to main group. HSR = High-Speed Running. T=trivial, S=small, M=moderate, L=large, VL=very large. * indicates 'possible', ** indicates 'likely', *** indicates 'very likely', **** indicates 'most likely'.

125x186mm (150 x 150 DPI)