The Acute:Chonic Workload Ratio In Relation To Injury Risk In Professional Soccer

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The acute:chonic workload ratio in relation to injury risk in professional soccer

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ABSTRACT

Objectives: To examine the association between combined sRPE measures and injury risk in elite professional soccer.
Design: Observational cohort study.
Methods: Forty-eight professional soccer players (mean ± SD age of 25.3 ± 3.1 yr) from two elite European teams were involved within a one season study. Players completed a test of intermittent-aerobic capacity (Yo-YoIR1) to assess player's injury risk in relation to intermittent aerobic capacity. Weekly workload measures and time loss injuries were recorded during the entire period. Rolling weekly sums and week-to-week changes in workload were measured, allowing for the calculation of the acute:chronic workload ratio, which was calculated by dividing the acute (1-weekly) and chronic (4-weekly) workloads. All derived workload measures were modelled against injury data using logistic regression. Odds ratios (OR) were reported against a reference group.
Results: Players who exerted pre-season 1-weekly loads of ≥1500 to ≤2120 AU were at significantly higher risk of injury compared to the reference group of ≤1500 AU (OR = 1.95, p = 0.006). Players with increased intermittent-aerobic capacity were better able to tolerate increased 1-weekly absolute changes in training load than players with lower fitness levels (OR = 4.52, p = 0.011). Players who exerted in-season acute:chronic workload ratios of >1.00 to <1.25 (OR = 0.68, p = 0.006) were at significantly lower risk of injury compared to the reference group (≤0.85).
Conclusions: These findings demonstrate that an acute:chronic workload of between 1.00 and 1.25 is protective for professional soccer players. A higher intermittent-aerobic capacity appears to offer greater injury protection when players are exposed to rapid changes in workload in elite soccer players. Moderate workloads, coupled with moderate-low to moderate-high acute:chronic workload ratios, appear to be protective for professional soccer players.

1. Introduction

Soccer is an intermittent sport characterised by repeated bouts of high-intensity running interspersed with periods of rest or low-intensity running.[1] Within professional soccer the occurrence of competitive matches is high and players are frequently required to play consecutive matches with 3-days recovery.[2] Therefore, these players have an inherently high training load due to poor recovery periods between games and subsequent training sessions. These elite players are often exposed to year-long training and high match frequencies, with periods of a congested calendar, which sometimes increases injury risk.[3] These competitive demands place physical stress on players, requiring well-developed physical qualities to avoid injury and illness, and to perform optimally.[3] The implications of a high number of training days and matches lost due to injury is suggested to be detrimental to team success,[4] especially for soccer teams unable to replace players of similar abilities due to limited resources.[5] Recently, Malone et al.[6] reported a clear association between higher training loads and increased likelihoods of

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injury within team sport athletes. The evolving nature of professional soccer has resulted in an increased interest in monitoring player activities quantitatively on a daily and weekly basis.[7] Interestingly to date, few studies have documented the relationship between training load and injury rates in elite football players.[8]

Although poorly investigated within soccer specific context the workload-injury relationship has been examined within other team sport contexts. In Australian rules football 1-weekly, 2 weekly and previous to current week changes of ≥75% were significantly associated with increased relative risk of injury during the in-season period compared against a reference grouping of ~15%. Recently, Owen et al.,[5] reported that higher training time spent above 85% HR_{max} resulted in increased injury risk for players in subsequent match-play and training sessions. However, these results need to be contextualised given the known relationships between increased fitness and reduced injury risk for team sport players.[3] There is a requirement for coaches to prescribe an appropriate training load to increase players' fitness to protect from subsequent risk.[3]

Recent workload-performance investigations have examined absolute workload performed in 1-week (referred to as acute workload) relative to 4-week chronic workload (i.e. 4-week average acute workload).[9] A comparison of the acute load to the chronic load as a ratio is therefore a dynamic representation of a player's preparedness. The ratio ultimately considers the training load the athlete has performed relative to the training load the athlete has prepared for.[10] Using the acute:chronic workload ratio, it has been demonstrated that higher chronic workloads protect against injury in cricket.[9] Within Rugby League cohorts, higher workloads have been reported to have either positive or negative influences on injury risk. Specifically, compared with players who had a low chronic workload, players with a high chronic workload were more resistant to injury with moderate-low through moderate-high (0.85–1.35) acute:chronic workload ratios and less resistant to injury when subjected to 'spikes' in acute workload.[10,11] Due to the lack of current data available in elite soccer players, the current study aimed to investigate the relationship between workload measures and injury risk in elite soccer players.

2. Methods

The current investigation was a prospective cohort study of elite soccer players competing for two teams at the highest level of European competition. Data were collected for 48 players (Mean ± SD, age: 25.3 ± 3.1 years; height: 183 ± 7 cm; mass: 72 ± 7 kg) over one season. The study was approved by the local institute's research ethics committee and written informed consent was obtained from each participant. All time-loss injuries were recorded using a bespoke database for data collection. All injuries that prevented a player from taking full part in all training and match-play activities typically planned for that day, and prevented participation for a period greater than 24 h were recorded. The current definition mirrors that employed by Brooks et al.[14] and conforms to the consensus time-loss injury definitions proposed for team sport athletes.[15–17] All injuries were classified as being low severity (resulting in training modification or 1–3 missed training sessions); moderate severity (where a player was unavailable for 1–2 weeks training); or high severity (where a player missed 3+ weeks of training). Injuries were also categorised for injury type (description), body site (injury location) and mechanism.[20] The intensity of all training sessions (including gym based and rehabilitation gym and pitch sessions) and match-play were estimated using the modified Borg CR-10 rate of perceived exertion (RPE) scale, with ratings obtained from each individual player immediately after the end of each match and training session. They were prompted for their RPE individually using a custom-designed application on a portable computer tablet (iPad, Apple Inc, California, USA). Each player selected his RPE rating by touching the respective score on the tablet, which was then automatically saved under the player's profile. This method helped minimize factors that may influence a player's RPE rating, such as peer pressure and replicating other players' ratings.[7] Each individual RPE value was multiplied by the session duration to generate an internal load score.[12] The fitness of players was assessed by the strength and conditioning staff at two time points during each phase of the season (at the start of each phase). Players completed the Yo-Yo Intermittent recovery test level 1 (Yo-Yo IR1) with players final distance used for the analysis of aerobic fitness. All players were familiarised with the test during the pre-season phase prior to testing. The test was administered to both teams according to the procedures described by Bangsbo et al.[13]. The Yo-Yo IR1 consists of 2 × 20-m shuttle runs at increasing speeds interspersed with a 10-s active recovery (controlled by audio signals from a compact disc player). The Yo-Yo IR1 has been shown to be a valid test in soccer populations[13,14] and has been related to positional match-play running performance within soccer cohorts.[13,14] All testing took place between 10:00 and 12:00 h. Temperatures during testing ranged from 10 to 22 °C. The competitive season was divided into two distinct phases for descriptive purposes: 'pre-season' (between July and August) the 'early in-season' (September–May).[15] In addition to weekly training load, a number of other training load measures were derived based on previous studies: (1) cumulative two, three and four weekly loads (2) the absolute change in load from the previous week, and (3) the acute:chronic workload ratio.[3,10,11] Data were analysed in SPSS Version 22.0 (IBM Corporation, New York, USA). Initial analysis of injury incidence was calculated by dividing total number of injuries by exposure time and reported as rates per 1000 training and game hours. Analysis of workload across phases took place using a one-way ANOVA. A chi-squared analysis was used to compare the frequency of injuries between seasonal phases, and workloads in players with different fitness levels (Yo-Yo IR1 performance). Based on a total of 75 injuries from 22,080 player-sessions (48 players participating in 460 training sessions), the calculated statistical power to establish the association between internal loads and soft-tissue injuries was 90%. Weekly load exposure values and all injury data (injury vs. no injury) including subsequent week injuries were then modelled using a logistic regression analysis. Data were divided into four groups, with the lowest workload range being the reference group. Odds ratios (OR) were calculated to determine the injury risk at a given cumulative workload (1, 2, 3 and 4-weekly cumulative), acute:chronic workload ratio and for absolute change in workload (the previous to current week). Correlation coefficients between the training load measures, alongside Variance Inflation Factors (VIF), were used to detect multi-collinearity between the predictor variables. A VIF of ≥10 was deemed indicative of substantial multi-collinearity.[16] Within our current model all load measures provided a VIF of ≤10 therefore providing acceptable levels of multi-collinearity. When an OR was greater than 1, an increased risk of injury was reported (i.e. OR = 1.50 is indicative of a 50% increased risk) and vice versa.

3. Results

During the investigation 75 time-loss injuries were reported. The incidence proportion was 1.6 per player. Overall, match injury incidence was 4.9/1000 h, (95% CI: 4.11–5.12) and training injury incidence was 6.9/1000 h (95% CI: 6.15–7.33). Lower limb injuries resulted in the highest incidence across the year 10.2/1000 h (95% CI: 9.45–10.84) with muscular injuries being the highest sub group of injury types (8.5/1000 h; 95% CI: 7.44–9.15) (Supplementary Table 1). There were significant differences between pre-season

Table 1
Seasonal phase risk factors for injury for rolling weekly workload in elite soccer players. Data presented as OR (95% CI).

Cumulative load (Sum)	Training load component	Pre-season (July–August)	In-season (September–May)
RPE (AU)	1 Week		
	≤1500 AU (Reference)	1.00	1.00
	Between ≥1500 AU – ≤2120 AU	1.95 (0.98–3.95)	0.95 (0.23–2.95)
	Between ≥2120 AU – ≤3200 AU	2.44 (1.98–4.66)	0.44 (0.18–1.66)
	≥3200 AU	3.33 (1.69–6.75)	2.33 (1.69–3.75)
	2 Weekly		
	≤3250 AU (Reference)	1.00	1.00
	Between ≥3250 AU – ≤3550 AU	2.98 (1.98–3.85)	2.98 (1.98–3.85)
	Between ≥3350 AU – ≤5980 AU	4.03 (2.11–5.45)	0.03 (0.11–3.45)
	≥5980 AU	4.74 (2.74–5.66)	0.74 (0.24–2.66)
	3 Weekly		
	≤7260 AU (Reference)	1.00	1.00
	Between ≥7260 AU – ≤7580 AU	3.88 (2.47–4.55)	2.88 (2.47–4.55)
	Between ≥ 7580 AU – ≤9154 AU	4.11 (3.11–5.65)	0.11 (0.01–1.65)
	≥9154 AU	5.11 (4.26–5.14)	0.91 (0.26–3.14)
	4 Weekly		
	≤8550 AU (Reference)	1.00	1.00
	Between ≥8550 AU – ≤8941 AU	5.11 (4.12–7.45)	3.11 (2.12–5.45)
	Between ≥8941 AU – ≤10,985 AU	5.44 (4.23–9.14)	0.44 (0.23–3.14)
	≥10,985 AU	5.11 (6.22–9.25)	2.11 (0.92–2.25)
	Absolute Change from previous week		
	≤200 AU (Reference)	1.00	1.00
	Between 200 AU – ≤350 AU	0.89 (0.50–1.98)	0.89 (0.50–1.98)
	Between ≥350 AU – ≤ 550 AU	1.66 (1.30–2.21)	0.66 (0.30–1.21)
	Between ≥550 AU – ≤1000 AU	1.44 (1.01–4.25)	1.44 (1.01–4.25)
	≥1000 AU	2.58 (2.09–4.52)	2.58 (1.09–4.52)

Table 2
Elite Soccer fitness levels as determined by a Yo-YoIR1 as a risk factor for injury above certain training and game load values. Data presented as OR (95% CI) when compared to a reference group.

Load calculation	In-season			
	OR Exp (B)	95% confidence interval		*p*-Value
		Lower	Upper	
Cumulative load (sum)				
1 week				
>2450 AU				
2560–2880-m	1.00			
2200–2520-m	3.51	2.09	3.29	0.009
1840–2160-m	4.08	2.16	4.93	0.035
1480–1800-m	4.50	3.98	5.50	0.033
Absolute change (±)				
Previous to current week				
>300 AU–1000 AU				
2560–2880-m	1.00			
2200–2520-m	2.54	0.75	2.97	0.009
1840–2160-m	3.53	2.66	3.88	0.011
1480–1800-m	4.52	3.98	4.92	0.023
Acute:chronic workload (AU)				
>1.25 AU				
2560–2880-m	1.00			
2200–2520-m	1.02	0.26	2.59	0.425
1840–2160-m	2.48	1.50	4.98	0.045
1480–1800-m	5.10	3.98	6.10	0.033

(2984 ± 615 AU) and in-season (2441 ± 215 AU) for average weekly training loads (P = 0.004). At similar weekly workload, there was a reduced injury risk in-season compared to pre-season (Table 2). Players who exerted pre-season 1-weekly workloads of ≥1500 to ≤2120 AU were at significantly higher risk of injury compared to the reference group of ≤1500 AU (OR = 1.95, 95% CI: 0.98–3.95, p = 0.006). Similarly, players who had completed a pre-season 2-weekly and 3-weekly workload of ≥5980 AU and ≥9154 AU were at significantly higher risk of injury compared to the reference group of <3250 AU (OR = 4.74, 95% CI: 2.74–5.66, p = 0.033) and <7260 AU (OR = 5.11, 95% CI: 4.26–5.14, p = 0.023) (Table 1). Interestingly similar 2-weekly (≥5980 AU) and 3-weekly (≥9154 AU) workloads had reduced risk during the in-season compared to the reference groups of <3250 AU (OR = 0.74, 95% CI: 0.24–2.66) and <7260 AU (OR = 0.91, 95% CI: 0.26–3.14). Injury risk during the pre-season (OR = 1.66, 95% CI: 1.30–2.21) was higher than the in-season phase (OR = 0.66, 95% CI 0.30–1.21, p = 0.002), and higher for players who experienced a previous to current week change in load of >350–550 AU compared to the reference group of <200 AU. Players who exerted in-season acute:chronic workload ratios of >1.00 to <1.25 (OR = 0.68, 95% CI 0.08–1.66, p = 0.006) were at significantly lower risk of injury compared to the reference group of ≤0.85. However, players who exerted similar in-season acute:chronic workload ratios of >1.00 to <1.25 were at further reduced risk of injury (OR = 0.28, 95% CI 0.08–1.26, p = 0.001) compared to the reference group of ≤0.85. When intermittent aerobic capacity was considered based on Yo-Yo IR1 performance (Table 2), players with a poor intermittent aerobic capacity had a higher risk of injury than the players with better-developed aerobic fitness (OR = 4.50, 95% CI: 3.98–5.50, p = 0.009) when 1-weekly training load was >2450 AU. Players with higher fitness were better able to tolerate 1-weekly absolute changes in training load compared to players with lower fitness levels (OR = 4.52, 95% CI: 3.98–4.92, p = 0.0011). Players with poorer fitness levels were unable to tolerate acute:chronic workloads of ≥1.25, experiencing greater injury risk compared to players with higher fitness (OR = 5.10, 95% CI: 3.98–6.10, p = 0.033) (Table 3).

4. Discussion

The current study is the first to investigate the association between training and game loads and injury risk in elite soccer players. The presented data suggest that a positive linear association exists between weekly workload, absolute week-to-week changes in workload and subsequent injury risk throughout the duration of the competitive season with increased risk also experienced during the pre-season phase. The presented data further highlights that poor intermittent aerobic capacity has a negative impact on injury risks associated with absolute weekly training load and changes in load. The findings of the current study suggest that weekly training load, absolute week-to-week changes in training load, 2-weekly, 3-weekly, 4-weekly cumulative loads and

Table 3
Seasonal phase risk factors for injury for acute:chronic workload ratio in elite soccer players. Data presented as OR (95% CI).

	Training load component	Pre-season (July–August)	In-season (September–May)
Cumulative load (Sum)		OR EXP B (95% CI)	OR EXP B (95% CI)
	Acute: chronic workload ratio		
	≤0.85 (Reference)	1.00	1.00
	Between 0.85 AU to ≤1.00 AU	0.95 (0.98–3.95)	1.05 (0.98–3.95)
	Between ≥1.00 AU to ≤1.25 AU	0.68 (0.08–1.66)	0.28 (0.08– 1.26)
	≥1.50 AU	2.33 (1.69–4.75)	3.03 (1.69–3.75)

acute:chronic workload ratios should be monitored by elite soccer teams in order to reduce injury risk across all phases of the competitive season. Furthermore the current observations suggest that this injury risk can be offset by coaches improving player's intermittent aerobic capacity as reflected by players with improved Yo-YoIR1 performance having reduced injury risk when compared to their poor counterparts.

Our findings demonstrate for the first time the relationship between weekly internal training loads and injury risk in professional soccer players. Interestingly, the risk for injury was phase dependant with reduced risk of injury at similar loads during the in-season compared to the pre-season periods. In agreement with previous studies, increased weekly workloads resulted in increased risk of injury for players. Players who exerted pre-season 1-weekly workloads of ≥1500 to ≤2120 AU were at significantly higher risk of injury compared to those players who exerted ≤1500 AU (OR = 1.95). Similarly, players who had completed a pre-season 2-weekly and 3-weekly load of ≥5980 AU and ≥9154 AU were at significantly higher risk of injury compared to players who exerted <3250 AU (OR = 4.74) and <7260 AU (OR = 5.1) (Table 2). Interestingly similar 2-weekly (≥5980 AU) and 3-weekly (≥9154 AU) training loads had reduced risk during the in-season compared to the reference groups of <3250 AU (OR = 0.74) and <7260 AU (OR = 0.91). Therefore coaches and medical staff need to be mindful that players tolerate workloads differently as the season progresses.[6] In order to effectively reduce the injury risk of players, specific preventive and multimodal programs have been proposed,[5] although a periodised approach to training in order to facilitate a progressive training load whilst also reducing injury risk may be more appropriate. Previous literature has shown that balancing the proportion of high-intensity on-pitch training content is important to the overall health and injury status of players.[5]

Weekly pre-season (2984 ± 615 AU) workloads were higher than in-season (2441 ± 215 AU) weekly workloads. The current finding is in agreement with many other team sport investigations on player workloads where significant reductions in workload have been observed as the season progress.[3,18] Previously, Wrigley et al.,[19] reported average RPE-load values of 3948 ± 222 AU for elite U-18 soccer players during a 2-week preseason phase. Although those values are higher than those reported in our study, it appears that the TL undertaken by players in the current study may be unique to the design and schedule employed during a short 4 week pre-season, coupled with friendly games every weekend. In agreement with recent findings from Australian football[20] and rugby union[21] absolute changes in week-to-week loads increased the risk of injury. An absolute weekly change in load of >350–550 AU was associated with a significant increase in the risk of injury. Interestingly increased fitness allowed players to tolerate greater changes in load compared to lower fitness groupings. This is an important consideration for coaches when manipulating training components during congested periods of the season.

Our findings suggest that players with higher intermittent aerobic capacity (as determined by increased Yo-Yo IR1 performance) were at lower risk of injury. We also observed that greater fitness allowed players to experience higher acute:chronic workloads of >1.25 AU with reduced risk. This is an important consideration for coaches and may suggest the value of post-season fitness programs for players to maintain or improve fitness levels in order to reduce subsequent risk in the pre-season periods. This would reduce the emphasis of excessive pre-season training loads to rebuild fitness parameters due to detraining that occurs during the off-season.[7,22] Additionally, with relationships being shown between Yo-YoIR1 and match player performances,[13] the current data could suggest that athletes who do not have the required physical qualities to tolerate the physiological demands of training and competition are likely to have reduced match play performances in addition to these players being at increased injury risk. These findings are consistent with others[18,23] who have shown that well-developed physical qualities are associated with decreased injury risk in elite team based field sports.[23] The requirement of coaches to develop the physical capacity of players is of importance from both a performance and injury prevention perspective. Indeed, previous investigations have shown that reductions in workload can not only reduce injury risk but also improve aerobic capacity within team sport players.[18]

Uniquely, findings from the investigation provided normative data on the acute:chronic workloads of soccer players across a competitive season. To optimally prepare for competition demands, athletes need to (gradually) increase their weekly workloads (acute workloads) so that their fitness (chronic workload) is sufficient to overcome acute fatigue demands.[3] Presently, the acute:chronic workload ratio offers coaches a dynamic method of monitoring player preparedness. Our data suggest that a moderate-low through moderate-high acute:chronic workload of between 1.00 and 1.25 is protective for players in both the pre-season (OR = 0.68) and the in-season period (OR = 0.28). These results are in agreement with previous studies in Rugby League cohorts, where acute:chronic workload ratios of between 0.85 and 1.35 resulted in reduced injury risk. Traditionally the in-season phase in soccer cohorts is focused on training to develop technical and tactical development in conjunction with the maintenance of the physical capacities developed during pre-season phase. These factors, in conjunction with the known increase in competition demands[7] suggest that coaches should aim to maintain training loads stable with low increases in week-to-week training loads.

Many factors in addition to training and match load impact on players' injury risk. e.g. previous injury,[15] perceived muscle soreness, fatigue, mood, sleep ratings[24] and psychological stressors[25] were not accounted for in the current analysis. Unfortunately, it was not possible to describe the training loads of specific session types in this study. Additionally, whilst the session-RPE method has been proposed as an acceptable method of quantifying training load in team sports,[26] GPS measures might provide important insight into the relationship between external training load and injury risk. Previously HR measures have been shown to relate to injury risk in soccer players[5] therefore, there is a need to assess the utility of combining external:internal load ratios (GPS:HR) as a potential metric for injury risk assessment within soccer and other team sports. Finally as with any analysis, the model will be best suited to the population from which it is derived.[27]

5. Conclusion

In conclusion the current investigation is the first to report associations between training load measures and injury risk in elite soccer players. Players were at increased risk of injury when they experienced high one weekly cumulative training loads (≥1500 to ≤2120 AU) with increases in risk also greater when cumulative load was higher or large weekly changes in load were experienced. Greater fitness allowed greater increases in training load from week-to-week with no increase in relative risk. To conclude, we found a reduced risk of injury in elite soccer players when exposed to moderate-low to moderate-high acute:chronic workload ratios. Additionally, elite soccer players were protected against rapid increases in workloads (i.e. "spikes") when they possessed a higher intermittent-aerobic capacity.

Practical applications

- The non-invasive and simple session-RPE method is useful for tracking training and game loads in respect to injury risk in elite soccer settings.
- Substantial associations between intermittent aerobic capacity and injuries were reported for the first time in an elite soccer setting. Coaches should consider the value of off-season conditioning programs to maintain or improve fitness capacities of players with this linked to reduced injury risk for players.
- The thresholds for injury risk related to training load have been identified for the first time in elite soccer players. Players appear to be at an increased risk of injury when they experience a high one week cumulative load (≥2120 AU to ≤3000 AU) with increases risk when cumulative load was higher (≥3000 AU) or a large week-to week changes in load (550–1000 AU) were experienced.
- For the first time normative data for the acute:chronic workload ratio is presented for elite soccer. Acute:chronic workloads of 1.00–1.25 offer protective effects for players. Therefore medical and coaching staff should utilise this training load component as it has shown relationships with injury risk for elite soccer players.
- Injury risk in soccer appears to be phase dependant, with reduced risk in the in-season compared to the pre-season at similar training loads. Coaches, medical, rehabilitation, and strength and conditioning staff should endeavour to work together in an interdisciplinary fashion to best plan training loads to reduce the risk of injury.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jsams.2016.10.014.

References

1. Little T, Williams AG. Effects of sprint duration and exercise: rest ratio on repeated sprint performance and physiological responses in professional soccer players. *J Strength Cond Res* 2007; 21(2):646–648.
2. Nedelec M, Halson SL, Abd-Elbasset A et al. Stress, sleep and recovery in elite soccer: a critical review of the literature. *Sport Med* 2015; 45(10):1387–1400.
3. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med* 2016; 50(5):273–280. http://dx.doi.org/10.1136/bjsports-2015-095788.
4. Arnason A, Sigurdsson SB, Gudmundsson A et al. Physical fitness, injuries, and team performance in soccer. *Med Sci Sports Exerc* 2004; 36:278–285.
5. Owen AL, Forsyth JJ, Wong DP et al. Heart-rate based training intensity and its impact on injury incidence among elite-level professional soccer players. *J Strength Cond Res* 2015; 29(6):1705–1712.
6. Malone S, Roe M, Doran DA et al. Aerobic fitness and playing experience protect against spikes in workload: the role of the acute:chronic workload ratio on injury risk in elite Gaelic football. *Int J Sports Physiol Perform* 2016; 24:1–25. Ahead of print http://dx.doi.org/10.1123/ijspp.2016-0090.
7. Malone JJ, Di Michele R, Morgans R et al. Seasonal training-load quantification in elite English premier league soccer players. *Int J Sports Physiol Perform* 2015; 10:489–497.
8. Nasis GP, Gabbett TJ. Is workload associated with injuries and performance in elite football? A call for action. *Br J Sports Med* 2016;(3). http://dx.doi.org/10.1136/bjsports-2016-095988.
9. Hulin BT, Gabbett TJ, Blanch P et al. Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *Br J Sports Med* 2013; 48(8):708–712. http://dx.doi.org/10.1136/bjsports-2013-092524.
10. Hulin BT, Gabberr TJ, Capuyi P et al. Low chronic workload and the acute:chronic workload ratio are more predictive of injury than between-match recovery time: a two-season prospective cohort study in elite rugby league players. *Br J Sports Med* 2016. http://dx.doi.org/10.1136/bjsports-2015-095364.
11. [Hulin BT, Gabbett TJ, Lawson DW et al. 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. http://dx.doi.org/10.1136/bjsports-2015-094817.
12. Foster C, Daines E, Hector L et al. Athletic performance in relation to training load. *Wis Med J* 1996; 95(6):370–374.
13. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 2008; 38(1):37–51.
14. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *Br J Sports Med* 2005; 39:757–766.
15. Hägglund M, Walden M, Magnusson H et al. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 2013; 47(12):738–742.
16. Fuller CW, Ekstrand J, Junge A et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clin. J. Sports Med* 2006; 16(2):97–106.
17. Owen AL, Wong PL. In-season weekly high-intensity training volume among professional English soccer players: a 20-week study. *Soccer J* 2009; 54:28–32.
18. Gastin PB, Fahrner B, Meyer D et al. Influence of physical fitness, age, experience, and weekly training load on match performance in elite Australian football. *J Strength Cond Res* 2013; 27(5):1272–1279.
19. Wrigley R, Drust B, Stratton G et al. Quantification of the typical weekly in-season training load in elite junior soccer players. *J Sports Sci* 2012; 30:1573–1580.
20. Rogalski B, Dawson B, Heasman J et al. Training and game loads and injury risk in elite Australian footballers. *J Sci Med Sport* 2013; 16(6):499–503.
21. Cross MJ, Williams S, Trewartha G et al. The influence of in-seaon training loads on injury risk in professional rugby union. *Int J Sports Physiol Perform* 2016; 11(3):350–355. http://dx.doi.org/10.1123/ijspp.2015-0187.
22. Reilly T. The training process, in *The science of training—soccer: a scientific approach to developing strength, speed and endurance*, Reilly T, editor, London, Routledge, 2007, p. 1–19.
23. Gabbett TJ, Domrow N. Relationships between training load, injury, and fitness in sub-elite collision sport athletes. *J Sports Sci* 2007; 25(13):1507–1519.
24. Issurin VB. New horizons for the methodology and physiology of training periodization. *Sports Med* 2010; 40:189–206.
25. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med* 2014; 44(2):139–147.
26. Clarke N, Farthing JP, Norris SR et al. Quantification of training load in Canadian football: application of session-RPE in collision-based team sports. *J Strength Cond Res* 2013; 27(8):2198–2205.
27. Fuller CW, Molloy MG, Bagate C et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med* 2007; 41:328–331.