Available online at www.sciencedirect.com

Journal of Science and Medicine in Sport 14 (2011) 204–209

Original research

Relationship between training load and injury in professional rugby league players

Tim J. Gabbetta a, b, *, David G. Jenkins b

a School of Exercise Science, Australian Catholic University, Australia
b School of Human Movement Studies, The University of Queensland, Australia

Received 20 September 2010; received in revised form 15 November 2010; accepted 10 December 2010

Abstract

Objectives: To investigate the relationship between training load and injury in professional rugby league players; Design: Prospective cohort study; Methods: Seventy-nine professional rugby league players (mean ± SD age, 23.3 ± 3.8 years) participated in this four-year study. A periodized field, strength, and power training program was implemented, with training loads progressively increased in the general preparatory phase of the season and reduced during the competitive phase of the season. Training loads and injuries were recorded for each training session.

Results: Training load was significantly related (P < 0.05) to overall injury (r = 0.82), non-contact field injury (r = 0.82), and contact field injury (r = 0.80) rates. Significant relationships were also observed between the field training load and overall field injury (r = 0.68), non-contact field injury (r = 0.65), and contact field injury (r = 0.63) rates. Strength and power training loads were significantly related to the incidence of strength and power injuries (r = 0.63). There was no significant relationship between field training loads and the incidence of strength and power injuries. However, strength and power training loads were significantly (P < 0.01) associated with the incidence of contact (r = 0.75) and non-contact (r = 0.82) field training injuries.

Conclusions: These findings suggest that the harder rugby league players train, the more injuries they will sustain, and that high strength and power training loads may contribute indirectly to field injuries. Monitoring of training loads and careful scheduling of field and gymnasium sessions to avoid residual fatigue is warranted to minimize the effect of training-related injuries on professional rugby league players.

© 2010 Sports Medicine Australia. Published by Elsevier Ltd. All rights reserved.

Keywords: Team sport; Injury incidence; Performance; Injury prediction; Correlation; Training monitoring

1. Introduction

Rugby league is an international collision sport played at both junior and senior levels. A typical rugby league match requires players to compete in a challenging contest, comprising intense bouts of sprinting and tackling, separated by short bouts of lower intensity activity. During the course of a rugby league match, each team will perform an average of 300 tackles; forwards are exposed to an average of 55 physical collisions (39 tackles, 16 hit-ups), while backs are exposed to an average of 29 physical collisions (16 tackles, 13 hit-ups). As a result, rugby league players are required to have well developed physiological and anthropometric qualities, combined with a wide range of offensive and defensive skills.

Several studies have documented the relationship between training loads and injury rates in sub-elite rugby league players. In the first study to investigate the influence of training load on injury rates, Gabbett reported a significant correlation (r = 0.86) between training load and injury, suggesting that the harder rugby league players train, the more injuries they will sustain. In a subsequent study of sub-elite players it was shown that reductions in training load resulted in marked reductions in injury rates, without compromising training-induced improvements in physical qualities. Similar findings have been observed in sub-elite junior and senior rugby league players; high training loads in the early phases of the season are associated with higher injury rates, while reductions in training loads in the competitive phase of the season results in lower training injury rates. Despite the reported relationship between training load and injury, there is also evidence to suggest that poor fitness and low...
training loads contribute to injury risk in rugby league. Gabbett and Domrow \(^7\) studied risk factors for injury in sub-elite rugby league players and found that players with poor aerobic fitness and those that had performed less than 18 weeks of pre-season training were at increased risk of injury. Collectively these findings demonstrate an equivocal relationship between training load and injury risk in sub-elite rugby league players.

Despite the wealth of studies documenting the training–injury relationship in sub-elite rugby league players, evidence linking training load and injury in professional players is far from substantive. In the only study to investigate the training loads of professional rugby league players, Killen et al. \(^8\) failed to find a relationship between training load and injury over a 14 week pre-season training program. While this study provided important information on the training-injury relationship of elite level team sport athletes, the short training period, and the small number of injuries limits the generalisability of these findings across teams and training periods.

While rugby league involves bouts of high-intensity running, the game includes physical demands that are unique from many other team sports, with the large numbers of collisions and tackles performed during a match contributing to playing intensity and player fatigue. The relationship between training load and injury in rugby league players is further complicated by these contact demands, with players required to perform multiple collisions during training in order to adequately prepare for the most demanding passages of play expected during competition. However, to date, studies of the training load–injury relationship have neglected to differentiate non-contact soft tissue injuries from those that occur as a result of physical contact.

Given that rugby league training loads are manipulated through changes in either running loads, contact loads, or strength and power training loads, it follows that increases in training loads could lead to increases in contact injuries, non-contact injuries, or both. Furthermore, the relationship between different training modalities and injury risk in a separate and different training modality has yet to be determined. With this in mind, the purpose of this study was to investigate the relationship between training load and injury in professional rugby league players.

2. Methods

Seventy-nine professional rugby league players (mean ± SD age, height, and body mass; 23.3 ± 3.8 years, 183.8 ± 5.6 cm, and 96.1 ± 10.1 kg, respectively) participated in this four-year prospective study (2007–2010). All players were highly motivated players from the same professional rugby league club and were competing in the elite National Rugby League (NRL) competition. Players had completed a 4-week active recovery off-season period, and were free from injury at the commencement of the study. All players received a clear explanation of the study, including the risks and benefits of participation and written consent was obtained. The Institutional Review Board for Human Investigation approved all experimental procedures.

A periodized, game-specific field and strength training program was implemented, with training loads progressively increased in the general preparatory phase of the season (i.e. November to February) and reduced during the competitive phase of the season (i.e. March to October). The training program progressed from high volume-low intensity activities during the pre-season conditioning period, to low volume-high intensity activities during the in-season conditioning period. Each player participated in up to 5 organised field-training sessions and 4 gymnasium-based strength sessions per week in the pre-season period, and 2–4 field-training sessions and 1–2 gymnasium-based strength and power sessions per week in the competitive phase of the season. Training load and injury data were recorded for every session.

Field training sessions consisted of specific skills, speed, muscular power, agility, and endurance training common to rugby league. While some differences existed in the intensity of activities performed throughout the season, the types of activities performed in the pre-season training phase (e.g. basic skills, light and full contact tackling drills and longer interval running) were similar to the early-competition and late-competition training phases (e.g. light contact tackling drills, advanced skills, and shorter repeated-sprint training). The duration of training sessions was recorded, with sessions typically lasting between 60 and 120 min.

Training loads were recorded for every session. The intensity of individual training sessions was estimated using a modified rating of perceived exertion (RPE) scale. \(^9\) Training load was calculated by multiplying the training session intensity by the duration of the training session and was reported in arbitrary units. Intensity estimates were obtained 30 min after completing the training session. When compared to heart rate and blood lactate concentration, the RPE scale has been shown to provide a valid estimate of exercise intensity. \(^10\), \(^11\) In addition, prior to commencing the study we investigated the relationship between heart rate and RPE, and blood lactate concentration and RPE on a subset of 33 subjects during typical rugby league field training (e.g. skills drills, small-sided games, and repeated effort) activities. The correlation between training heart rate and training RPE, and training blood lactate concentration and training RPE were 0.89 and 0.86, respectively. \(^7\) A subset of players \((n = 11)\) also completed two identical off-season training sessions, performed one week apart, prior to the commencement of the study, to determine test–retest reliability. The intraclass correlation coefficient for test–retest reliability and typical error of measurement for the RPE scale were 0.99 and 4.0%, respectively. Collectively, these results demonstrate that the RPE scale offers an acceptable method of quantifying training intensity for collision sport athletes.

For the purpose of this study, an injury was defined as any pain or disability suffered by a player during a training session. \(^12\) All injuries were diagnosed by a physiotherapist.
who was employed by the club in a full-time capacity. Injuries were diagnosed in two ways: (1) immediately at the time of injury, or (2) during the player’s scheduled physiotherapy appointment. Injuries were classified according to time lost; transient (no training missed), minor (up to 7 days missed), moderate (8–28 days missed), or major (29 days or greater missed), and matches missed; transient (no matches missed), minor (1 match missed), moderate (2–4 matches missed), or major (5 or more matches missed). In addition, injuries were classified according to the site, type, and activity at the time of injury.

Injury exposure was calculated by multiplying the number of players by the session duration. Injury incidence was calculated by dividing the total number of injuries by the overall injury exposure, and expressed as rates per 1000 training hours. Pearson product moment correlation coefficients were used to determine the relationship between training loads and injury incidence. Data are reported as means and 95% confidence intervals (CI), and the level of significance was set at \( P < 0.05 \).

### 3. Results

A total of 251 training injuries were sustained over the four seasons, giving an overall injury incidence of 10.5 (95% CI, 9.2–11.8) per 1000 training hours. The incidence of non-contact field injuries, contact field injuries, and strength and power injuries was 21.8 (95% CI, 18.5–25.0), 6.1 (95% CI, 4.4–7.8), and 3.4 (95% CI, 2.1–4.7) per 1000 h, respectively.

The incidence of non-contact field injuries resulting in a loss of training time (9.6 [95% CI, 7.4–11.7] per 1000 h) was 2.7–3.2 fold higher than the incidence of contact field injuries (3.6 [95% CI, 2.3–4.9] per 1000 h) and the incidence of injuries sustained in strength and power activities (1.5 [95% CI, 0.7–2.4] per 1000 h). In addition, the incidence of non-contact field training injuries that resulted in a missed match was almost 3-fold higher (2.6 [95% CI, 1.5–3.7] per 1000 h) than contact field training injuries that resulted in a subsequent missed match (1.0 [95% CI, 0.3–1.7] per 1000 h). No strength and power injuries resulted in a missed match (Table 1).

The site and type of injuries sustained in non-contact and contact field sessions, and strength and power sessions are shown in Supplemental Tables 1 and 2. The thigh, calf, and groin were the most common sites of non-contact field injuries (64.0%). The shoulder and anterior and posterior thigh were the most common sites of contact field injuries (42.8%). The thorax and abdomen was the most common site of injury (48.1%) in strength and power sessions (Supplemental Table 1).

Muscular strains were the most common type of non-contact field injuries (36.6%). Contact field training activities were associated with hematomas, muscular strains, and joint sprains (67.3%). The most common type of strength and power injuries was joint sprains (22.5%) (Supplemental Table 2).
Table 2
Relationship among field, strength, and overall training load, and field (contact and non-contact), strength, and overall injury rate in high-performance rugby league players.

<table>
<thead>
<tr>
<th></th>
<th>TL</th>
<th>FieldTL</th>
<th>StrengthTL</th>
<th>InjTotal</th>
<th>InjField</th>
<th>InjNonCont</th>
<th>InjCon</th>
<th>InjStrength</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FieldTL</td>
<td>0.84†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StrengthTL</td>
<td>0.99†</td>
<td>0.84†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>InjTotal</td>
<td>0.82†</td>
<td>0.67*</td>
<td>0.81†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>InjField</td>
<td>0.86†</td>
<td>0.68*</td>
<td>0.87†</td>
<td>0.76†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>InjNonCont</td>
<td>0.82†</td>
<td>0.65*</td>
<td>0.82†</td>
<td>0.96*</td>
<td>0.82†</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>InjCon</td>
<td>0.80†</td>
<td>0.63*</td>
<td>0.75†</td>
<td>0.81†</td>
<td>0.65*</td>
<td>0.68*</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>InjStrength</td>
<td>0.59</td>
<td>0.43</td>
<td>0.63*</td>
<td>0.54</td>
<td>0.47</td>
<td>0.44</td>
<td>0.44</td>
<td>0.67†</td>
</tr>
</tbody>
</table>

TL = overall training load; FieldTL = field training load; StrengthTL = strength and power training load; InjTotal = overall injury rate; InjField = field injury rate; InjNonCont = non-contact injury rate; InjCon = contact injury rate; InjStrength = strength and power injury rate. Data are reported as Pearson product moment correlation coefficients, r.

* Denotes significance at $P \leq 0.05$.
† Denotes significance at $P \leq 0.01$.

The weekly training intensity and training load is shown in Fig. 1. Pre-season training loads were higher than the early competition and late competition training loads. The average weekly training intensity was highest in the pre-season and tended to increase in the late competition phase of the season.

The total training load was related to the overall incidence of injury ($r = 0.82$, $P < 0.01$), non-contact field injury incidence ($r = 0.82$, $P < 0.01$), and contact field injury incidence ($r = 0.80$, $P < 0.01$). Significant relationships were also observed between the field training load and the overall field injury rate ($r = 0.68$, $P < 0.05$), non-contact field injury ($r = 0.65$, $P < 0.05$), and contact field injury ($r = 0.63$, $P < 0.05$). Strength and power training loads were significantly related to the incidence of strength and power injuries ($r = 0.63$, $P < 0.05$). There was no significant relationship between field training loads and the incidence of strength and power injuries. However, strength and power training loads were significantly associated with the incidence of contact ($r = 0.75$, $P < 0.01$) and non-contact ($r = 0.82$, $P < 0.01$) field training injuries (Table 2 and Supplemental Figs. 2–6).

4. Discussion

This study investigated the relationship between training loads and injury incidence in professional rugby league players. While previous studies have examined the training–injury relationship in sub-elite rugby league players,3–6 and during the pre-season in professional rugby league players,8 this study is the first to investigate this relationship in high-performance rugby league players over the course of several competitive seasons. The results of this study demonstrate a significant relationship between training load and injury incidence in professional rugby league players. Field training loads were significantly associated with both contact and non-contact field training injuries, while strength and power loads were significantly associated with injuries sustained in strength and power activities. These findings suggest that the harder professional rugby league players train, the more injuries they are likely to sustain. Monitoring of training loads and recovery status is clearly warranted to minimize the effect of training-related injuries in the professional team sport environment.
The training loads reported in this study are considerably higher than those reported previously in sub-elite rugby league players, reflecting the higher training intensity at higher playing levels, and the greater volume of training required for elite competition.\textsuperscript{3–7} The finding of higher injury rates with greater training loads is consistent with previous studies from a cohort \((N = 36–220)\) of sub-elite rugby league players.\textsuperscript{3,5,6} Furthermore, the findings of this study extend those of others by also demonstrating that field training loads are significantly associated with both contact and non-contact field training injuries. Rugby league players are required to perform multiple physical collisions during a match. Therefore training for rugby league commonly involves large numbers of collisions in order to adequately prepare players for the most demanding passages of play expected during competition. This study acknowledges the importance of physical collisions on the physiological demands of rugby league players by separately investigating the relationship between field training loads and contact and non-contact training injuries. As expected, and in agreement with several previous studies,\textsuperscript{3–6} high field training loads were associated with a high incidence of non-contact injuries. However, these results also demonstrate that increases in field training loads may also result in increases in contact injury rates.

The incidence of non-contact field training injuries (9.6 per 1000 h) resulting in missed training time was 2.7–3.2 fold higher than contact field training injuries (3.6 per 1000 h) and strength and power training injuries (1.5 per 1000 h). Furthermore, no strength and power injuries resulted in a missed match, while the incidence of missed match contact injuries was \(\sim 60\%\) lower than non-contact injuries resulting in a missed match (1.0 per 1000 h vs. 2.6 per 1000 h). The low rate of contact injuries is consistent with our recent findings that demonstrated that physical collisions were associated with a low injury risk, despite the fact that players perform \(\sim 2000\) physical collisions over the course of a training season.\textsuperscript{14} Given that soft-tissue injuries are often viewed as preventable, these results highlight the importance of implementing evidence-based soft-tissue injury prevention strategies for professional rugby league players. Furthermore, given the significant relationships between training loads and training injury rates observed in this study, the development and implementation of a training and recovery monitoring system to predict and prevent non-contact, soft-tissue injuries is warranted.

Strength and power training loads were significantly associated with strength and power injuries. In addition, while no significant relationship was observed between field training loads and strength and power injuries, a significant relationship was detected between strength and power training loads and both contact \((r = 0.75)\) and non-contact \((r = 0.82)\) field injuries. While a significant correlation does not imply cause and effect, these results suggest that high field training loads may lead to high rates of contact and non-contact field training injury, but have minimal impact on strength and power injuries. Conversely, high strength and power training loads are associated with high rates of strength and power injuries, but also appear to contribute indirectly to field injuries. It is possible that residual fatigue and muscle soreness arising from strength and power training could contribute to subsequent non-contact field training injuries, or that the high rate of joint sprains \((22.2\%)\) sustained in the gymnasium contributes to similar natured contact injury risk in field training sessions. Of interest was the significant relationship between overall training loads, field training loads, and strength and power training loads; increases in training loads were achieved through both increases in field training loads and strength and power training loads, and when field training loads were high, strength and power training loads were also high. It is likely that this model of periodization would result in increased training strain and monotony, which have been previously shown to be predictive of overtraining.\textsuperscript{11} It is ironic that strength and power training contributes to injury risk, given that the muscular qualities developed through this training is likely to protect against both contact and non-contact injuries. Given that improvements in physical performance are greater with higher training loads, clearly, a challenge for rugby league strength and conditioning coaches is to develop training programs that provide an adequate training stimulus to enhance physical fitness, without unduly increasing the incidence of injury.\textsuperscript{3} Careful scheduling of field and gymnasium sessions to avoid residual fatigue carrying over to subsequent training sessions may minimize the possibility of strength and power training loads contributing to field training injury risk.

Identification of the site and type of non-contact, contact, and strength and power training injuries provides insight into potential problems with the strength and conditioning program. Over half of non-contact training injuries were thigh and calf muscular strains. Conversely, thorax, abdomen, and shoulder strains and sprains were most commonly sustained in strength and power activities. Contact injuries were evenly distributed between the upper body \((e.g.\) head and neck, shoulder, arm and hand, and thorax and abdomen) and lower body \((anterior\) thigh, posterior thigh, and ankle and foot), with muscular strains, joint sprains, and haematomas the most common type of injury. The diverse site and type of contact injuries recorded in the present study may reflect the wide range of tackles \((e.g.\) 1-on-1, 2-on-1, and 3-on-1) performed in rugby league,\textsuperscript{15} or the possibility of injuries sustained in a different training activity \((e.g.\) strength and power activities) contributing to contact injury risk. Future studies investigating risk factors for contact injury risk in professional rugby league players are warranted.

5. Conclusion

In conclusion, the results of this study demonstrate a significant relationship between training load and injury incidence in professional rugby league players. Field training loads were significantly associated with both contact and
non-contact field training injuries, while strength and power loads were significantly associated with injuries sustained in strength and power activities. In addition, while no significant relationship was observed between field training loads and strength and power injuries, a significant relationship was detected between strength and power training loads and both contact and non-contact field injuries, suggesting that high strength and power training loads may contribute indirectly to field injuries. Monitoring of training loads and recovery status and careful scheduling of field and gymnasium sessions to avoid residual fatigue is warranted to minimize the effect of training-related injuries on professional rugby league players.

Practical implications

- This study found significant relationships between training load and injury in professional rugby league players.
- While field training loads were not related to strength and power injuries, strength and power training loads were correlated with field training injuries.
- These findings suggest that the harder rugby league players train, the more injuries they will sustain, and that high strength and power training loads may contribute indirectly to field injuries.

Conflict of interest

No sources of funding were used to conduct this study. The authors have no conflict of interests that are directly relevant to the content of this study.

Appendix A. Supplementary data


References