Training and match volume and injury in adolescents playing multiple contact team sports : A prospective cohort study

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Training and match volume and injury in adolescents playing multiple contact team sports: a prospective cohort study

ABSTRACT

Training and competition loads have emerged as valuable injury risk factors but very few studies have explored injury outcomes in adolescent athletes. The aims of this study were to describe injuries and to explore the relationship between training and match load volumes and injury in adolescent athletes participating in multiple contact team sports. One hundred and three male youth rugby athletes aged 14 to 16 years from 8 rugby union teams were prospectively monitored during a season for weekly training and match volumes and injuries. The relationship between volume and injury was explored by comparing the weekly volume in the week prior to an injury *vs.* weeks without injury. There were 83 time-loss injuries in 58 athletes (62%). Overall injury incidence was 18.5 per 1000 player-hours. Mean weekly injury prevalence was 27% (95% CI 25-30). Average weekly volume was 5.4 (2.2) hours comprising 1.4 (1) match hours and 4 (2.6) training hours. Compared with weeks without injury, weeks prior to an injury had higher match volumes (110 [57] min vs 83 [59] min, p <0.001). Poisson regression demonstrated that match volume was a predictor of injury with an odds ratio of 1.41 (p=0.001). The contribution of match volumes to injury risk and the relatively high injury burden in these athletes may be profound. Very high match volumes are unlikely to be in the best interests of young athletes and could be avoided with a systematic approach to load management and athlete development.

KEYWORDS

Athletic injury, youth, contact sports, volume, load, rugby

1 INTRODUCTION

Sport is associated with a number of benefits for young people and some young athletes aspire to progress to elite levels of participation. Injuries contribute to dropout,[1,2] diminish participation in physical activity,[3] and are among the strongest predictors of future injuries that undermine performance and elite athletic successs.[4] Therefore, minimizing injuries in young athletes is paramount. Yet current youth training approaches and sporting pathways have a strong focus on attaining peak performance and identifying and developing talent.[5,6] These approaches are inherently demanding with rapid ramping of training and match demands. Participation with intensive demands, including early specialization, a high competition to training ratio, excessive training and match volumes, and inadequate recovery have long been recognized as precipitating injuries among young athletes.[3,7] While many of these uniquely youth sport characteristics are frequently cited as concerning as they relate to injury risk, [1,5,8,9] very few empirical studies specifically explore injury outcomes.

The etiology of injuries is multifactorial. A combination of extrinsic and intrinsic risk factors along with an exposure and an inciting event interact to result in injury.[10,11] Training and competition loads are necessary exposures in sport but have recently been explored as independent injury risk factors.[12] Total load and the way in which load is applied (incrementally over time, or abruptly) have emerged as valuable modifiable injury risk factors.[13] Thus, the importance of managing load to reduce injury risk is now well established in professional sport.[14] Relationships between high volumes (the sum of training and competition exposures) and injury have been demonstrated in some studies of youth athletes.[8,15] However, only a paucity of studies describe training and competition demands and their relationship with injury among youth team-sport athletes.[16]

Rugby union and rugby league are popular contact team sports in a number of countries. Whether these sports are especially injurious for young athletes has recently been robustly debated.[17-19] Injury incidence and severity are likely higher in contact sports compared with non-contact sports among both youth and adult participants, [20,21] in part due to frequent exposure to contact and collision events that carry an inherent risk of injury.[22] In team sports additional risk factors may exist that are unique to adolescent athletes. Many adolescents concurrently participate in a variety of contact team sports, and often for more than one team which can result in excessive weekly training and competition demands.[23-25] In these athletes, training and match volumes and injury risks accumulate across sports and teams and may not be fully captured by prospective injury surveillance in a single sport. To the best of our knowledge, no previous injury study has attempted to account for these characteristics of adolescent sports participation. Consequently, a clear understanding of injury risks and burden among adolescent rugby athletes has proven difficult due to comparatively few studies and confounding of athletes participating in multiple teams and multiple sports. Further, the magnitude and nature of training and competition demands among adolescent rugby athletes that may result in elevated injury risk are unclear. Therefore, the aims of this study were to describe injuries and to explore the relationship between training and match volumes and injury in a cohort of adolescent athletes participating in multiple contact team sports.

2 METHODS

2.1 Study design and participants

A prospective cohort study was conducted in the 2016 and 2017 rugby union seasons of school and youth representative teams in Sydney, Australia. Schools participating in an inter-school rugby union competition and representative squads who recruit top rugby athletes from schools and clubs to participate in an interstate youth competition were invited to participate in this study. Once schools and representative team management accepted the invitation and agreed to the proposed study, athletes and parents were invited to participate and provided written consent. Experimental procedures were approved by the Human Research Ethics Committee, Australian Catholic University. One hundred and three male youth rugby union athletes aged 14 to 16 years (15.2 [1.5] years, 178 [7.4] cm, 83.4 [9.8] kg) were recruited from a total of 8 rugby union teams (6 school teams, 2 youth representative teams). Although athletes were recruited from school and representative teams participating in rugby union seasons, many athletes in this cohort concurrently participated in other rugby union teams and also played rugby league (a contact sport similar in nature to rugby union but played with 13, rather than 15 players on each team). Therefore, athletes in this study represent a cohort of adolescent contact team-sport athletes, rather than rugby athletes participating in a traditional rugby union season. Each week of the rugby season, athletes reported training and match load volumes and injuries. School teams played 12-week seasons and youth representative teams played 10-week seasons.

2.2 Training and match volume

Training and match volumes were recorded in minutes for all sports that athletes participated in using a paper-based training diary. To optimize compliance, coaching staff agreed to allow athletes time to complete their diaries before the first training session of each week. Two researchers supervised diary entries to ensure diaries were completed correctly. To assist in recall, athletes were instructed to record all sport training and matches undertaken in the previous week however, only training and matches associated with the contact team sports of rugby union and rugby league were used to explore the relationship between volumes and risk of injury. Therefore, volumes in this study were determined by prospective monitoring of all rugby union and rugby league related training and match activities including resistance training and rugby skill-specific training sessions. Many athletes reported participating in a variety of different sports and activities including, basketball, cricket, tennis, golf, swimming, endurance running, physical education, water polo and surfing. Time spent training and competing in these sports and activities might also contribute to youth injury risk via increases in weekly volume. However, given the comparatively high volume and low intensity of many of these sports and activities they were excluded from weekly volume estimates to avoid 'masking' the effect of time spent in the higher intensity and higher risk contact sports of rugby union and rugby league.

2.3 Injuries

All injuries were recorded using a paper-based modified version of the Sports Medicine Australia injury recording form. The lack of consistent and centralized medical support at the youth participation level necessitated that injuries be self-reported. Each week, athletes responded yes or no to the question 'did you sustain any injury or experience any pain in the past week?'. If yes, athletes completed an injury form in which they reported injury details including injury location, injury type, injury mechanism and the number of training sessions and matches missed as a result of the injury. Injuries not associated with participating in either rugby union or rugby league were excluded. Researchers were present to assist athletes complete the injury form. Occasionally, there was a lag in the reporting of an injury and a diagnosis of that injury. When this occurred, researchers were able to obtain injury details from athletes or coaches the following week after diagnosis by a medically trained practitioner. Injuries were then categorized based on a time-loss definition in agreement with the international consensus statement of rugby union injuries.[26] Injuries that resulted in 24-hours of missed training or matches were included in analyses. Injuries were classified as acute if the injury onset was linked to an identifiable event. Injuries with no clear inciting event were classified as overuse. Injuries to the same previously injured body part were classified as first-time, unique injuries if they were felt to represent a new injury based on return to normal play between injuries.

2.4 Statistical analyses

Data were checked for normal distribution and outliers using Shapiro-Wilk tests and boxplots, respectively. Data are presented as means with standard deviations (SD) or 95% confidence intervals (95% CI) when normally distributed, or as medians with 25% to 75% interquartile ranges [IQR] where appropriate. Injury incidence per 1000 player-hours of exposure was calculated by dividing the number of new injuries during the prospective follow-up period by the total exposure (sum of individuals' training and matches), multiplied by 1000.[27] Mean weekly injury prevalence for the season was calculated by dividing the sum of weekly prevalence by the total number of weeks of follow-up. Weekly prevalence was calculated by dividing the number of athletes reporting being injured by the total number of athletes who completed a training and injury diary that week.[28]

One-way analyses of variance (ANOVA) was used to compare player and volume characteristics between player age groups. The relationship between volume and injury was explored by examining the aggregated weekly volume in the week (7 days) prior to an injury occurrence and the average weekly volume of weeks without injury. Week 1 injuries were excluded from these analyses since volumes for the week prior were not available (n = 22 excluded injuries). Weekly training volume, weekly match volume, and weekly total volume were compared between weeks prior to an injury and weeks without injury using a Mann Whitney *U* test with Holm adjustment for multiple comparisons. Cohen's *d* effect sizes were used for pairwise data defined as small (0.2), medium (0.5), large (0.8), and very large (>1.0). Weekly volume variables were then converted to z-scores and used in injury regression models. The models explored the combined and separate effects of training and match volumes on injury. To avoid biasing volume estimates with low volumes reported as a consequence of an injury, training and match volumes were not included for weeks affected by time-loss injuries.[12] Univariable Poisson regression models for binary outcome data[29] were used to estimate in-season injury likelihood with weekly volume variables as predictors and injury outcome (injury/no injury) as the dependent variable according to recent methodological approaches for injury prediction.[30] Player characteristics were included in the models with positional group (forwards *vs.* backs) as a factor and age, height and body mass as covariates. Significance was set at $p<0.05$ and analyses were performed using IBM SPSS Statistics V.24 (IBM, New York, USA for Windows) and Microsoft Office Excel (2013, Microsoft, Redmond, Washington, USA).

3 RESULTS

3.1 Participants and compliance

One player moved schools at the start of the season and was excluded from the study. Three athletes sustained season ending injuries in the first week of their season and could not be monitored prospectively. These athletes' injuries were included in injury prevalence and incidence calculations but were excluded in analyses exploring the relationship between volume and injury. Nine athletes provided incomplete data for a total of less than 5 weeks of the season. These athletes transitioned in and out of teams, infrequently attended training and did not report any injuries and were thus excluded from analyses. The remaining 90 athletes reported training and match volumes and injuries with a weekly compliance of 85.5%. Athletes reported data for a median of 11 weeks [IQR 10-11].

3.2 Training and match volume characteristics

Player participation characteristics are summarized in Table 1. The average weekly volume across the season for all ages combined corresponded to 5.4 (2.2) hours comprising 1.4 (1) hours of competitive matches and 4 (2.6) hours of training. Nineteen athletes (21%) reported concurrently participating in rugby league. Seventy-two athletes (80%) regularly played rugby union for more than one team each week. In total, athletes reported spending 4491 hours participating in rugby league and rugby union matches and associated training activities in the follow-up period. Differences occurred between player age groups for weekly match volume. However, the Poisson regression model did not find any relationship among injuries and position, age, height or body mass. This is supported by a recent study in a similar player population[31] and all athletes were consequently grouped together for the remaining analyses.

3.3 Injury characteristics, incidence and prevalence

There were 83 time-loss injuries in 58 athletes (62%). The overall injury incidence was 18.5 per 1000 player-hours of total exposure. There were 60 match injuries (72%) and 23 training injuries (28%) with a match injury incidence of 54.3 per 1000 player-hours and a training injury incidence of 6.8 per 1000 player-hours. All injuries were classified as acute. Injury location and type are presented in Table 2. Forty-one athletes (71%) reported one injury, 12 athletes (21%) reported 2, and 5 athletes (8%) reported 3 or more injuries. Mean weekly injury prevalence was 27% (95% CI 25-30).

3.4 Relationship between volume and injuries

Compared with weeks without injury, weeks prior to an injury were found to have a significantly higher match volume (Table 3). No significant differences were found for training volume and total weekly volume in the week prior to an injury compared with weeks without injury. Poisson regression supported the finding of greater match volume in weeks prior to an injury (Table 4). Weekly match volume was a significant predictor of injury in the regression model with an OR = 1.41 (95% CI 1.14-1.74; p=0.001).

4 DISCUSSION

This study explored injuries and injury risk factors among adolescent athletes using a novel approach that accounts for the multi-team, multi-sport participation of youth contact team-sport athletes. The main findings from this study were a high injury incidence and weekly injury prevalence and that weekly match volume was associated with injury. Regression models found that a one z-score (approximately 1 hour) increase in weekly match volume resulted in a 41% increase in injury risk. Many individual athletes in this study frequently reported weeks with match volumes several z-scores above the average. The contribution of match volumes to injury risk and the relatively high injury burden in these athletes may therefore be profound.

Compared with previous studies of injury incidence in youth rugby union and rugby league, the combined training and match injury incidence in this study was high.[17,32] However, it is important that the injury incidence observed in the present study not be compared directly with previous studies of single sports. Rather than determine the injury incidence in specific sports, the aim of this study was to better understand injuries in multi-team, multi-sport adolescent athletes. This is arguably a better approach to understanding injuries in some young athletes. To further explore the burden of injuries in this group of athletes we measured weekly injury prevalence. The results of this showed that, each week on average, 1 in 4 (27%) athletes were unable to participate in normal training or matches due to an injury. This finding is consistent with a recent study exploring injury burden among elite adolescent athletes. Using a time-loss injury definition and a 52-week prospective design, von Rosen *et al*[33] found a high weekly injury prevalence of 30.8% among adolescent athletes in team and individual sports. The relatively high injury incidence and injury prevalence in the adolescent contact team-sport athletes in the present study is concerning, particularly in light of advances in load monitoring methods.

Excessive or inappropriate training and competition loads have recently emerged as important injury risk factors.[12-14] This study is one of few demonstrating a relationship between training and match volumes and injury among youth team-sport athletes. A recent systematic review identified only three studies that specifically explored training and competition loads and injury among male youth football based athletes.[16] Positive relationships were reported between physical stress (encompassing training duration, load, monotony, and strain) and traumatic injuries (odds ratio 1.01-2.59) in youth soccer athletes,[34] while increased workloads in adolescent rugby league athletes lead to increased injury rates.[35] Bone marrow edema at the pubic symphysis was assessed in 19 asymptomatic elite soccer athletes, aged 15 to 17 years, using magnetic resonance imaging.[36] The risk of groin pain was greatly reduced with more training prior to entering the soccer program, and increased with larger increases in workloads after entering the soccer program. We are aware of only a relatively small number of other studies investigating training and competition loads and injury relationships among youth team-sport athletes. One of these studies included older adolescent athletes in English Premier League academies.[37] The training and competition demands of older youth athletes contracted to academies are not comparable to those described in this study's cohort since these athletes are unlikely to participate in multiple sports for multiple teams. Nevertheless, high accumulated and acute workloads significantly increased injury risk. Recently, in a prospective season-long study of youth female soccer athletes, higher acute training loads were associated with an increased risk of injury, while higher chronic training loads increased the risk of illness.[30] By tracking injury and load characteristics of youth athletes from various team and individual sports, Malisoux *et al* found that intensity was greater in the week prior to an injury than the average intensity of the preceding 4 weeks.[38]

Total weekly volume and training volume were not associated with injury in this study. Some youth rugby training may be insufficiently intense to contribute substantially to injury risk. The training demands of youth rugby athletes have previously been compared with match demands using time-motion analyses and were described as having a significantly lower intensity than youth rugby matches.[39] One could further speculate that low training intensities, relative to match exposures, or training with poor specificity might fail to adequately prepare players for competition. Game-specific training approaches that provide the kinds of physically demanding experiences observed in matches are challenging to achieve in contact team sports but might nevertheless prove valuable for reducing injury risk. Contact team sport matches on the other hand are both inherently risky due to frequent collision situations and are performed at intensities that are likely to impact intrinsic risk factors such as fatigue, neuromuscular control and tissue resilience - especially during adolescent growth. High match volumes might therefore contribute to greater injury risk via both exposure and fatigue.[11] Separating the independent contributions of exposure and fatigue to injury risk is desirable but this is especially challenging in a youth sport context.[9] The implications of this are nevertheless clear, high match volumes are an import injury risk factor in adolescent contact team-sport athletes.

Our results raise the question of whether match volume is a modifiable injury risk factor. Participating in competitive matches is an essential part of playing team sports. Athletes in this study played an average of 1.4 hours of matches per week. For youth athletes this equates to approximately 1.6

matches per week (Australian youth rugby matches are 50 minutes in duration). However, weeks above the 90th percentile for match volume had an average of four matches per player with the highest recorded number of weekly matches being six, recorded on five occasions by five separate athletes. There is no simple explanation for factors contributing to the very high match volumes observed in some individuals in some weeks. Adolescent athletes are presented with many opportunities to compete for various rugby teams at school, club and representative levels and many of these same athletes also enjoy competing in other sports. It is also possible that some athletes feel pressured or obligated to play for multiple teams and multiple sports and this may be especially true among more talented athletes. Notwithstanding these complexities of youth sport, very high match volumes are unlikely to be in the best interests of young athletes and could be avoided with a systematic approach to load management and athlete development.[40] Implementing such an approach in real-world youth sport settings is challenging. Decisions around reducing the volume of competitive matches in which athletes participate are not easy. Yet, the independent effect match volume has on youth injuries is difficult to ignore. Quarrie *et al*[18] recently described this dilemma as a question of acceptable risk. Some risk is acceptable because of the many benefits sports confer. However, the benefits of being active during adolescence and participating in competitive sport can be negated by injuries that could be prevented by a more restrained approach to match volumes.

This study has some limitations that warrant discussion. Training and match volumes and injuries were self-reported. While this is likely the most appropriate method in a youth sport context some under-, or over-reporting may have occurred. Additionally, while there was a high compliance (>85%) to weekly data entry there were some missing data. Injuries that occurred in the first week of the season were also excluded from the analyses of the relationship between training and match volume and injury since volumes for the week prior were not available. This reduced the number of injuries included in these analyses. In this study, volume variables from participation in contact team sports were selected a priori as the independent injury risk factors of interest. The contribution to injury risk of volume exposures arising from other sports and activities were therefore not considered and are a limitation in the current study. Injury risk identified in this study could also be attributed to a number of additional factors not measured. Additional research with larger cohorts may be required before recommendations can be made for specific ranges of match volumes in which injury risk is lowest.

5 PERSPECTIVE

In contact team sports, multi-sport and multi-team participation with very high weekly match demands is a uniquely youth sport phenomena. Previous studies among elite adult athletic populations and single sport analyses of injuries and injury risk factors may have limited ability to inform holistic perspectives on injury prevention strategies for adolescent athletes. Monitoring and managing all accumulated loads is important for adolescent athletes and adolescent match volume should be viewed as a modifiable injury risk factor. This has the potential to meaningfully mitigate injury risk in youth contact team sports. The outcomes of this study provide a framework for understanding the relationship between load and injury in a youth sport context, provide evidence of the impact of high training and match volumes on injury, and could help organizations, coaches, parents and athletes begin to determine acceptable risk relating to match volume. Risks of accumulated load from other sports and risks of playing in highly fatigued or under recovered states remain unknown and should be explored in future studies.

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TABLE 1 Adolescent contact sport participation characteristics. Data are mean (SD).

	All (n = 93)	14s (n = 30)	15s (n = 31)	16s (n = 32)
Training volume, min/wk	242 (154)	240 (124)	225 (116)	261 (146)
Match volume, min/wk[a]	83 (59)	98 (63)	83 (59)	69 (51)
Weekly volume, min/wk	325 (130)	338 (137)	308 (153)	330 (168)

[a]Differences were found between age groups for weekly match volume, ANOVA p = 0.008.

TABLE 2 Adolescent contact sport injury characteristics. Data presented as n (%)

Total injuries	83
Injury Location	
Foot	3 (4)
Ankle	11 (13)
Knee	5 (6)
Lower leg	5 (6)
Upper leg	15 (18)
Back	6 (7)
Chest	7 (9)
Wrist	4 (5)
Arm	2 (2)
Shoulder	14 (17)
Neck	1 (1)
Head	10 (12)
Injury Type	
Sprain	28 (34)
Strain	20 (24)
Contusion	20 (24)
Concussion	9 (11)
Fracture	6 (7)

TABLE 3 Differences in load volume variables between weeks prior to an injury and weeks with no injury. Data are mean (SD) minutes per week.

	No injury	Injury	p Value	Cohen's *d*
Training volume, min/wk	243 (127)	246 (161)	0.842	0.02
Match volume, min/wk	83 (59)	110 (57)	0.001	0.47
Weekly volume, min/wk	325 (151)	356 (180)	0.387	0.19

Table 4 Poisson regression analysis to identify predictors of injury

	Univariable	
	OR (CI)	**p Value**
Training volume	1.03 (0.78 to 1.33)	0.84
Match volume	1.41 (1.14 to 1.74)	0.001
Weekly volume	1.19 (0.93 to 1.51)	0.17

Odds ratio and 95% confidence intervals