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Modelling injury-burden in rugby sevens

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ABSTRACT

Objectives: To develop a time-based model of injury-burden for international rugby sevens teams and to demonstrate its utility.

Design: Descriptive, cohort study.

Methods: Injury data recorded during seven seasons of the Sevens World Series were used to quantify the rate of injury and the rate at which injured players recovered from injury. An equation describing the rate at which injuries were sustained was combined with an equation for the rate at which injured players recovered from injury to produce a time-based equation for the injury-burden of rugby sevens players at any point in time during a season.

Results: The overall rates at which match and training injuries were sustained (incidence of injury) were 108.6 (95% confidence interval: 101.6–116.1) injuries/1000 player-match-hours and 0.91 (95% CI: 0.65–1.27) injuries/1000 player-training-hours, respectively. Injured players recovered from injury according to a first-order rate equation with a rate constant of 0.0257 days⁻¹ calculated from the median severity of injuries sustained (27 days). The time-based injury-burden values predicted from the proposed kinetic model of injury-burden closely matched the values recorded in the Sevens World Series.

Conclusions: For governing bodies in rugby, the proposed model provides a way to examine the consequences of changes in the number and timing of international rugby sevens tournaments. For individual teams, the model provides a means to forecast and manage the team's injury-burden as a function of the team's scheduled match and training loads throughout a season.

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1. Introduction

The popularity of 7-a-side rugby (Rugby-7s) has grown steadily since the first international tournament was played in 1973 as part of the Scottish Rugby Union's centenary. The sport's profile was raised when the Hong Kong Rugby Football Union established the Hong Kong Sevens tournament in 1976 and further enhanced when the International Rugby Board (now World Rugby) introduced the Sevens World Series (SWS) in 1999 and the men's and women's Rugby World Cup Sevens in 2009. Recognition of Rugby-7s as a major international sport was finally achieved when the International Olympic Committee added the sport to the Olympic Games in 2016.¹ World Rugby's annual men's and women's SWS now represent the sport's premier international competitions with the men's Series currently consisting of ten and the women's Series six 2 or 3-day tournaments played over a seven-month period. In addition to the SWS, national teams also compete in other tournaments around the world, such as the Asian, Commonwealth and Pan American

Games.¹ SWS tournaments involve 16 teams apart from the Hong Kong Sevens tournament, which involves 24 teams with each team playing five or six 14-min games per tournament. Other tournaments involve 4–16 teams with teams normally playing 3–6 games per tournament. In addition to the tournament schedule, national teams typically train for between 60 and 120 min per day in the periods between competitions.

Although the incidence and severity of match injuries in elite Rugby-7s are significantly higher than those reported for elite 15-a-side rugby union (Rugby-15s),² there have been few studies examining game activities in Rugby-7s that fully explain the reason for the high incidence and severity of injury. Players' movement patterns in Rugby-7s are generally less position-dependent (backs *v* forwards) than in Rugby-15s, game patterns appear to vary from team-to-team and from game-to-game^{3,4} and game activities are performed at higher intensity with fatigue in the later stages of tournaments suggested as a possible injury risk factor.^{5–7} Although national teams nominate 12 squad players for each tournament, the high injury-burden creates a significant player management issue during Rugby-7s tournaments, as the number of players remaining uninjured and available for play during the latter stages of a tournament decreases.^{5,7} Also in the case of the men's SWS, because

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the ten tournaments are normally grouped into pairs, with paired tournaments played in consecutive weeks, it may not always be possible for the team's management to secure replacement players in time to compete in the second of the paired tournaments. With national teams competing in up to 20 tournaments per year, the leading Rugby-7s countries work with a squad of specialist Rugby-7s players in order to cope with the demanding match and training loads.⁸

A novel kinetic model showing how a team's injury-burden varies from day-to-day and week-to-week, as a function of the incidence of injury, the rate at which players return to play after injury and the team's match and training schedules, has recently been described.⁹ The development of this model was described in detail previously but the basis of the model is that the rate of change in the number of injured players in a team is defined as:⁹

$$d[N_{injured}]/dt = (K_{injury} \times Fn\{[N_{uninjured}], t\}) - (K_{recovery} \times Fn\{[N_{injured}], t\}) \quad (1)$$

where

$[N_{injured}]$ equates to the number of injured players at time t ,

$[N_{uninjured}]$ equates to the number of uninjured players at time t ,

Fn represent functions of the variables shown within the parentheses, and

K_{injury} and $K_{recovery}$ represent the rate constants associated with the rates at which players sustain and recover from injuries, respectively.

In summary, players sustain injuries during relatively short periods of match and training activity, hence:⁹

$$[N_{injured}] = (R \times N_p \times H) \quad (2)$$

where,

$[N_{injured}]$ equates to the number of players injured during a match or training activity,

R is the incidence rate for sustaining injuries during match or training activities (injuries/player-hour),

N_p is the number of players involved in the match or training activity, and

H is the duration (in hours) of the match or training activity.

Injuries, however, resolve over an extended period of time (t) measured in days with the time to recovery being dependent on the nature of the injuries sustained. The rate of recovery from injury has been described as:⁹

$$-d[N_{injured}]/dt = K_{recovery} \times [N_{injured}] \times t \quad (3)$$

Eq. (3) can be integrated and rearranged to provide an equation describing the number of unresolved injuries at any time:

$$[N_{injured}]_t = [N_{injured}]_0 \times \exp(-K_{recovery} \times t) \quad (4)$$

where $[N_{injured}]_0$ is the number of injuries at time $t=0$.

Values for the rate constant $K_{recovery}$ can be determined by taking natural logarithms of Eq. (4) to give:

$$\ln[N_{injured}] = \ln[N_{injured}]_0 - (K_{recovery} \times t) \quad (5)$$

A graph of $\ln[N_{injured}]$ ν time will result in a straight line graph with a negative slope equal to $K_{recovery}$ and an intercept at time $t=0$ equal to $\ln[N_{injured}]_0$. For first-order rate equations, values of $K_{recovery}$ can be obtained more easily, however, as the value $\ln 2/K_{recovery}$ corresponds to the half-life ($t_{1/2}$) of the injury recovery curve defined by Eq. (4). Furthermore, the $t_{1/2}$ value, which is the time required for 50% of injuries to resolve, equates to the median injury severity value.

This time-based model of injury-burden was developed and tested in the context of Rugby-15s match play;⁹ however, it was

claimed that it would be equally applicable to rugby training activities, to Rugby-7s and also to other team sports. The purpose of this study was to develop and assess this model specifically for international Rugby-7s teams.

2. Methods

Ethical approval was obtained from the University of Nottingham and World Rugby institutional review boards for the collection of the Rugby-7s injury data over the period 2008 to 2016; ethical approval was not required for the development of the time-based model of injury-burden. In developing and evaluating the injury-burden model for Rugby-7s, match and training schedules were based on the likely programme of tournaments experienced by a men's international Rugby-7s team, such as England, Scotland or Wales, during the 2017/18 season over the period 1 November 2017 to 31 October 2018. The competition schedule was, therefore, assumed to consist of 17 tournaments comprised: Safari Sevens tournament (November 2017), SWS (10 tournaments from December 2017 to June 2018), Commonwealth Games tournament (April 2018), Rugby Europe Grand Prix Sevens Series (4 tournaments June and July 2018) and Rugby World Cup Sevens 2018 (July 2018). It was assumed that the team would progress to the final stages of each tournament such that the team played 6 games in each tournament. It was also assumed that 20 players would undertake a 1.5-hour training session on each non-tournament day. Other international teams will undergo similar tournament schedules but the number and/or specific tournaments included in their schedules will vary; similarly, the length and frequency of training sessions and the number of players attending training sessions will vary from country to country.

The definitions and procedures employed for the collection of SWS match and training injuries and exposures, which have been reported previously,^{2,10} were consistent with the international consensus statement for epidemiological studies in rugby.¹¹ Injuries were defined as 'Any physical complaint sustained by a player during a SWS match or training session that prevented the player from taking a full part in match play and/or training activities for more than 1 day following the day of injury, irrespective of whether match or training sessions were actually scheduled'. Injury severity was defined as 'The number of days elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection'. Team medical staff (qualified physiotherapists and/or physicians) prospectively recorded match injuries sustained during seven SWS competitions in the period 2008/09 to 2015/16 and training injuries sustained during three SWS competitions in the period 2013/14 to 2015/16. Team match exposures were calculated on the basis of 7 players being exposed for 14 min per team-game (20 min for a SWS Cup Final match); no allowance was made for players temporarily (medical treatment or yellow card) or permanently (red card) missing from a match. Team training exposures were recorded on a daily basis in the week immediately prior to and during each SWS tournament. Incidence of injury is reported separately for match and training activities as the number of injuries/1000 player-hours together with 95% confidence intervals (CI); the mean and median severities of injury are reported as days absence with 95% CIs.¹²

Differences between the mean severities of match and training injuries were assessed using a z-test and between the median severities using a Mann-Whitney U-test.¹² Injury-burden refers to the number of players with an unresolved injury on a specified day. Time-to-recovery curves were produced for players returning from match and training injuries by plotting the percentage of unresolved injuries ν time from injury.¹² These time-to-recovery curves were compared with theoretical time-to-recovery curves predicted

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