*Original articles*

# The New Zealand rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football

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**Abstract**

***Objectives*—Although the nature of rugby injury has been well documented, little is known about key risk factors. A prospective cohort study was undertaken to examine the association between potential risk factors and injury risk, measured both as an injury incidence rate and as a proportion of the playing season missed. The latter measure incorporates a measure of injury severity.**

***Methods*—A cohort of 258 male players (mean (SD) age 20.6 (3.7) years) were followed through a full competitive season. At a preseason assessment, basic characteristics, health and lifestyle patterns, playing experience, injury experience, training patterns, and anthropometric characteristics were recorded, and then a battery of fitness tests were carried out.**

***Results*—A multiple regression model identified grade and previous injury experience as risk factors for in season injury, measured as an injury incidence rate. A second model identified previous injury experience, hours of strenuous physical activity a week, playing position, cigarette smoking status, body mass index, years of rugby participation, stress, aerobic and anaerobic performance, and number of push ups as risk factors for in season injury, measured as proportion of season missed.**

***Conclusions*—The findings emphasise the importance of previous injury as a predictor of injury incidence and of missing play. They also show the importance of considering both the incidence rate and severity of injury when identifying risk factors for injury in sport.**

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Participation in physical activity and sport is often recommended as a means by which the risk of contracting many of the "diseases of the sedentary", such as coronary heart disease and cancer, can be reduced.[1 2] Recognition of this protective effect has led to programmes designed to promote the benefits of participation in sport and physical exercise and increase participation rates.[3] Little is known, however, about the risks and costs of participation in sport and other physical activity, partly because of a lack of epidemiological research.[4–7] Calls have been made for the application of epidemiological methods to the investigation of risk factors for injury resulting from sport and physical activity.[6] The undertaking of such studies has been hampered to some extent by methodological issues such as difficulties in setting up injury surveillance systems, defining sports injury, and the complexity of data analysis in cases in which participants sustain multiple injuries during a season of play.[8 9]

The multiplicity of factors that may contribute to injury from sporting activity, and the complexity of the relations among them, mean that identifying causal mechanisms poses a challenge to epidemiologists.[5 6] Potential risk factors have been classified into those intrinsic and those extrinsic to the sportsperson.[10] Intrinsic factors are specific to the individual, and include age, sex, anthropometric characteristics, fitness, psychological characteristics, health status, and injury history. Extrinsic factors are those external to the individual and include the nature of the sport, environmental conditions, and equipment.[10]

Most previous research attempting to investigate risk factors associated with sports injury has used the incidence rate as the outcome variable.[11–13] Studies that identify risk factors for sports injuries and recommend interventions based only on injury incidence rates may be missing an important part of the impact of injury on players—that is, the severity of the injury. Measuring the proportion of the season missed as the result of injury is one method of generating a proxy measure of injury severity.[9] The identification of risk factors associated with the effect of the injury on subsequent participation may be as important in understanding how to reduce the burden of injuries on sports participants as identifying factors associated with the injury incidence rate.

A recent prospective study into intrinsic risk factors for injuries resulting from physical activity identified previous injury and exposure

*Table 1 Potential risk factors for rugby injury, measured before the season*

| *Rugby specific risk factors* | *Basic, psychological, and lifestyle factors* | *Anthropometric, physical performance, and training factors* |
|---|---|---|
| Grade (level of play) | Age | Anthropometric characteristics |
| Years of rugby participation | Ethnic origin | Height |
| Representative experience | Strenuous physical activity (hours/week) | Body mass |
| Playing position | Psychological wellbeing | Body mass index (BMI) |
| Injury experience: | Competition anxiety | Sum of six skinfolds |
| No injury in previous 12 months | Alcohol use | Physical fitness |
| Previous season | Cigarette smoking: | Aerobic endurance (20 m multistage shuttle run test) |
| | Non-smoker | Anaerobic endurance (repeated high intensity shuttle run test) |
| | Ex-smoker | 30 m sprint time (5 m running start) |
| | Current smoker | Vertical jump |
| | | Push ups |
| | | Weekly endurance training load |

time as being more important predictors of injury incidence rate than psychological, psychosocial, physiological, and anthropometric measures.[11] A study of army trainees found that greater age, higher cigarette consumption, previous low physical activity levels, high or low flexibility, and low levels of aerobic fitness were associated with a higher risk of injury.[12 13]

Rugby union football (rugby) is a vigorous contact sport, which enjoys particular popularity in Australia, Britain, France, New Zealand, and South Africa. The nature and incidence of rugby injuries have been well documented, with cervical spine injuries receiving particular attention.[14–22] In New Zealand, the combination of a large player base (about 120 000 in a population of 3.8 million people) and a high incidence of injury[23] result in rugby being the largest contributor to sports injury costs borne by New Zealand's mandatory injury compensation scheme administered by the Accident Compensation Corporation (ACC).[24]

From what is known about rugby injury, it appears that there is a higher incidence at higher grades, although the incidence rate of particular injuries—for example, spinal cord injuries—does not always follow this pattern.[14–16 21] The types of injury a player is likely to sustain are also related to playing position—for example, those in the front row positions are more at risk of cervical spine injury during scrums than those in other positions.[20 21] The tackle appears to be the phase of play associated with the greatest risk of injury overall.[17]

Given the limited information available on risk factors for sports injury in general and the lack of analytical studies on rugby injuries, the New Zealand Rugby Injury and Performance Project (RIPP)[25] was undertaken to examine a wide range of extrinsic and intrinsic factors postulated to be associated with rugby injury. The purpose of this paper is to explore the associations between potential risk factors for rugby injury, as assessed before the season, and both injury incidence during the season and the proportion of the season missed because of injury, using information obtained from the RIPP.

## Methods

### SUBJECTS AND STUDY DESIGN

The RIPP was a prospective cohort study in which rugby players were recruited at the beginning of a rugby playing season and then followed on a weekly basis until the end of the same season. At the beginning of the 1993 rugby season, 356 rugby players (258 men and 92 women) were enrolled in the RIPP. Players were recruited into the study through five rugby clubs and four secondary schools. The study design, basic characteristics, anthropometric and physical performance attributes, alcohol use, and patterns of previous injury of the RIPP cohort members have been reported elsewhere.[18 25–29] This paper examines risk factors for the male players only; the sample of female players was too small to allow reliable estimates of the various risk factors to be calculated independently.

### PRESEASON ASSESSMENT

Players completed a preseason assessment that involved completing a single self administered questionnaire and undergoing a series of anthropometric and physical fitness assessments. The assessment lasted approximately 2.5 hours.[25] Table 1 gives the factors measured at the preseason assessment. The previous injury experience of players was classified as follows: players who had not sustained an injury in the previous season (no injury in previous 12 months), those who had been injured during the previous season but were not currently injured at the preseason assessment (previous season), and those who reported that they were injured at the time of the preseason assessment (preseason injury). Players were asked to estimate how many hours a week, in the previous four weeks, they had spent in "strenuous physical activity" (not further defined). Alcohol use was assessed using the Alcohol Use Disorders Identification Test (AUDIT).[30] The AUDIT is a 10 item questionnaire used to screen people for hazardous or harmful alcohol consumption. A score of 8 or more is taken to indicate an alcohol use disorder. Competition anxiety was measured by the Sport Competition Anxiety Test (SCAT).[31] The SCAT is a 15 item measure of competitive trait anxiety. Scores range from 10 to 30, with a higher score indicating a higher level of anxiety. Psychological wellbeing was measured using the General Health Questionnaire (GHQ).[32] The GHQ is a self administered screening questionnaire which measures general psychological distress. The 12 item version of the GHQ was used.

The anthropometric and physical fitness measurements were taken upon completion of the questionnaire. The methods used are described in detail elsewhere.[28] Anthropometric measurements taken from the players

included height (m), body mass (kg), and skinfolds from six sites (triceps, subscapular, suprailiac, abdomen, mid thigh, and medial calf). The sum of skinfolds from these six sites was used as a measure of body fatness, as was body mass index (BMI) (kg/m$^2$). The physical fitness measures examined were a 20 m multistage shuttle run for aerobic endurance,[33] number of push ups performed at a constant cadence until this could no longer be maintained, vertical jump height (best of three), sprinting 30 m from a 5 m running start, and a set of repeated high intensity shuttles.[28 29 33 34] Weekly endurance training load was calculated from the players' reported intensity, duration, and frequency of aerobic training. Time and resource constraints precluded the measurement of strength and flexibility.

### IN SEASON FOLLOW UP

The in season follow up consisted of a weekly telephone interview conducted with each player. Nine trained interviewers collected information about rugby exposure (number of games and practices attended, warm ups, grade, playing position, involvement in foul play, use of protective equipment) and any injuries sustained (site, type, description of how the injury occurred, medical attention received, treatment, whether the injury caused the player to miss any games or practices, whether the injury was the result of foul play). An injury event was defined as one that caused the player to either miss at least one game or scheduled team practice, or to seek medical attention.[25] During most of the 23 weeks of the club season, interviews were completed with 90–95% of players. Overall, 90% of attempted interviews were completed.[25]

### OUTCOME MEASURES

Two outcome measures were chosen to examine the influence of the preseason factors on injury experience during the season. These were the injury incidence rate (IR) and the proportion of the season a player missed because of injury (PM). IR (per 1000 player hours) was calculated as follows: IR = 1000 × (number of injury events that occurred during games/(1.33 × number of games played)). Each game of rugby lasts 80 minutes, hence the multiplication by 1.33 to convert games played to hours of play.

To calculate the proportion of the season missed, players who did not miss any games were considered to have completed the season with no missed time (PM = 0). For the purposes of calculating PM, any practices they missed because of injury in a particular week were ignored. PM was calculated as follows: PM = number of weeks in which game(s) were missed because of injury in games/number of weeks in which one or more games was played. For weeks in which there was no follow up interview, the entire week was ignored. Although this would have the effect of inflating PM, given that 90% of attempted interviews were completed, this effect was not expected to be large or to introduce any systematic bias.

These two outcome measures were chosen to provide complementary information. The two measures are not independent, but both were used to examine whether specific risk factors were related to different measures of injury. IR provides a measure of the number of injuries sustained per unit of exposure to rugby games, whereas PM provides a proxy measure of injury severity.[9]

### ANALYSES

A total of 258 male rugby players completed the questionnaire and at least part of the physical assessment. The univariate associations between potential risk factors and the two outcome measures (IR and PM) were examined first. Categorical variables were created from continuous variables by assigning players to quintiles (for instance, on the basis of their performance on each of the fitness tests). The relative risk (RR) of sustaining a greater incidence of injuries or of missing a greater proportion of the season because of injury was calculated for each level of the variable compared with one of the levels chosen as the reference level. Ninety five percent confidence intervals (95% CI) for the relative risk ratios were calculated. Differences between groups were regarded as significant if the 95% CI did not include 1.00—that is the level of significance, $p<0.05$.

Associations between risk factors and the two outcome measures were assessed using multiple logistic regression. Overdispersion was controlled for in both outcomes, using variance inflation factors based on the deviance $\chi^2$ values. The regression analyses were performed using the SAS[35] GENMOD procedure.

## Results

### UNIVARIATE ANALYSES

*Rugby specific factors*

Table 2 shows the univariate associations between rugby specific factors and both IR and PM. Players from higher grades sustained a higher rate of injuries than players in the reference group (under 19/18 grades). Players at senior A level reported the highest rate of injuries. Players who reported a preseason injury (an injury that was affecting their ability to train or play at the time of the preseason assessment) had a higher IR than those who had no injuries during the previous season (RR = 2.41; 95% CI = 1.34 to 4.32).

There were no significant differences in PM by grade. In terms of positional groups, midfield backs missed a greater proportion of their season than the reference group (RR = 2.55; 95% CI = 1.29 to 5.04). Players who had played rugby for zero to three years before the 1993 season missed the greatest proportion of their season (16%), and were selected as the reference group for comparisons of risk associated with rugby experience. Those who had participated for four to five years missed less play because of injury (7%) compared with the reference group (RR = 0.42; 95% CI = 0.21 to 0.87). Those who had a preseason injury missed a greater proportion of their season (17%) than players with no injuries in the previous 12 months (8%) (RR = 2.25; 95% CI = 0.99 to 5.11).

*Table 2 Rugby specific risk factors for injury incidence rate and proportion of playing season missed*

| Factor | N | Injury incidence rate (per 1000 hours) | | | Proportion of season missed | | |
|---|---|---|---|---|---|---|---|
| | | Rate | RR (95% CI) | p Value | Proportion | RR (95% CI) | p Value |
| Grade | | | | | | | |
| Under 19/18 (Reference) | 53 | 47 | 1.00 | | 0.10 | 1.00 | |
| Under 21 | 64 | 80 | 1.84 (1.17 to 2.89) | <0.01 | 0.11 | 1.04 (0.56 to 1.93) | 0.91 |
| Senior B | 37 | 81 | 1.85 (1.11 to 3.07) | 0.02 | 0.12 | 1.09 (0.54 to 2.19) | 0.79 |
| Senior A | 90 | 106 | 2.50 (1.67 to 3.74) | <0.01 | 0.12 | 1.11 (0.63 to 1.95) | 0.71 |
| Playing position* | | | | | | | |
| Front Row (Reference) | 38 | 89 | 1.00 | | 0.09 | 1.00 | |
| Locks | 34 | 98 | 1.10 (0.69 to 1.76) | 0.66 | 0.09 | 0.91 (0.40 to 2.08) | 0.82 |
| Loose forwards | 58 | 77 | 0.85 (0.54 to 1.33) | 0.48 | 0.11 | 1.21 (0.60 to 2.44) | 0.59 |
| Inside backs | 38 | 69 | 0.75 (0.45 to 1.22) | 0.23 | 0.07 | 0.76 (0.33 to 1.76) | 0.52 |
| Midfield backs | 40 | 77 | 0.85 (0.52 to 1.41) | 0.52 | 0.21 | 2.55 (1.29 to 5.04) | <0.01 |
| Outside backs | 40 | 83 | 0.92 (0.57 to 1.49) | 0.73 | 0.12 | 1.33 (0.63 to 2.80) | 0.44 |
| Years of rugby participation | | | | | | | |
| 0 to 3 years (Reference) | 52 | 97 | 1.00 | | 0.16 | 1.00 | |
| 4 to 5 years | 42 | 79 | 0.80 (0.51 to 1.24) | 0.31 | 0.07 | 0.42 (0.21 to 0.87) | 0.02 |
| 6 to 7 years | 55 | 75 | 0.75 (0.49 to 1.14) | 0.16 | 0.10 | 0.56 (0.31 to 1.03) | 0.06 |
| 8 years | 47 | 69 | 0.69 (0.43 to 1.09) | 0.11 | 0.10 | 0.58 (0.30 to 1.09) | 0.08 |
| >8 years | 52 | 89 | 0.91 (0.61 to 1.38) | 0.66 | 0.13 | 0.76 (0.43 to 1.33) | 0.32 |
| Representative experience (previous 12 months) | | | | | | | |
| No (Reference) | 138 | 78 | 1.00 | | 0.12 | 1.00 | |
| Yes | 103 | 89 | 1.16 (0.88 to 1.54) | 0.27 | 0.10 | 0.80 (0.52 to 1.22) | 0.28 |
| Injury experience | | | | | | | |
| No injuries in previous 12 months (Reference) | 22 | 50 | 1.00 | | 0.08 | 1.00 | |
| Previous season | 139 | 75 | 1.57 (0.88 to 2.80) | 0.11 | 0.10 | 1.21 (0.54 to 2.72) | 0.64 |
| Preseason | 83 | 109 | 2.41 (1.34 to 4.32) | <0.01 | 0.17 | 2.25 (0.99 to 5.11) | 0.05 |

*Positional groups (position names as specified by International Rugby Board Regulation 14.1): front row (loose head prop, hooker, tight head prop); locks (left lock, right lock); loose forwards (left flanker, right flanker, number eight); inside backs (scrum half, fly half); midfield backs (left centre, right centre); outside backs (left wing, right wing, full back).

### *Basic, psychological, and lifestyle factors*

Table 3 gives the associations between basic, psychological, and lifestyle factors and both IR and PM. The relative risk of injury incidence increased with age when compared with those in the reference group (17 years and under). IR also tended to increase with higher levels of strenuous physical activity, but the increases were not significant when compared with the reference group. Ex-smokers sustained a higher

*Table 3 Basic, psychological, and lifestyle risk factors for injury incidence and proportion of playing season missed*

| Factor | N | Injury incidence rate (per 1000 hours) | | | Proportion of season missed | | |
|---|---|---|---|---|---|---|---|
| | | Rate | RR (95% CI) | p Value | Proportion | RR (95% CI) | p Value |
| Age group | | | | | | | |
| 17 and under (Reference) | 41 | 50 | 1.00 | | 0.10 | 1.00 | |
| 18 to 19 | 75 | 76 | 1.60 (0.99 to 2.57) | 0.05 | 0.11 | 1.06 (0.54 to 2.10) | 0.86 |
| 20 to 22 | 79 | 94 | 2.03 (1.28 to 3.19) | <0.01 | 0.11 | 1.07 (0.55 to 2.10) | 0.83 |
| 23 and over | 53 | 101 | 2.19 (1.36 to 3.53) | <0.01 | 0.16 | 1.69 (0.86 to 3.29) | 0.12 |
| Ethnic origin | | | | | | | |
| NZ Maori/Pacific Islander (Reference) | 44 | 74 | 1.00 | | 0.13 | 1.00 | |
| European | 203 | 83 | 1.13 (0.77 to 1.67) | 0.50 | 0.12 | 0.90 (0.53 to 1.55) | 0.70 |
| Strenuous physical activity (hours/week) | | | | | | | |
| <5 (Reference) | 38 | 68 | 1.00 | | 0.13 | 1.00 | |
| 5 to 9 | 97 | 76 | 1.12 (0.71 to 1.77) | 0.61 | 0.10 | 0.78 (0.41 to 1.46) | 0.44 |
| 10 to 19 | 54 | 83 | 1.25 (0.76 to 2.04) | 0.36 | 0.10 | 0.76 (0.38 to 1.52) | 0.43 |
| 20 to 39 | 22 | 83 | 1.25 (0.69 to 2.27) | 0.44 | 0.10 | 0.77 (0.32 to 1.89) | 0.57 |
| >39 | 29 | 105 | 1.63 (0.96 to 2.77) | 0.06 | 0.21 | 1.86 (0.95 to 3.68) | 0.07 |
| Cigarette smoking | | | | | | | |
| Non-smoker (Reference) | 168 | 77 | 1.00 | | 0.10 | 1.00 | |
| Ex-smoker | 36 | 110 | 1.49 (1.04 to 2.14) | 0.02 | 0.15 | 1.65 (0.96 to 2.84) | 0.06 |
| Current Smoker | 42 | 79 | 1.02 (0.68 to 1.54) | 0.91 | 0.18 | 2.11 (1.28 to 3.47) | <0.01 |
| Alcohol use (AUDIT score) | | | | | | | |
| <8 (Reference) | 54 | 77 | 1.00 | | 0.16 | 1.00 | |
| 8 to 10 | 53 | 77 | 1.00 (0.65 to 1.54) | 0.99 | 0.09 | 0.55 (0.29 to 1.01) | 0.05 |
| 11 to 12 | 40 | 92 | 1.23 (0.79 to 1.92) | 0.36 | 0.12 | 0.74 (0.39 to 1.39) | 0.34 |
| 13 to 16 | 50 | 80 | 1.05 (0.68 to 1.64) | 0.81 | 0.12 | 0.73 (0.40 to 1.31) | 0.28 |
| 17 to 30 | 51 | 86 | 1.14 (0.74 to 1.77) | 0.54 | 0.09 | 0.55 (0.29 to 1.05) | 0.06 |
| Self rated health status | | | | | | | |
| Very good (Reference) | 103 | 80 | 1.00 | | 0.12 | 1.00 | |
| Good | 130 | 84 | 1.06 (0.80 to 1.42) | 0.67 | 0.12 | 0.94 (0.62 to 1.44) | 0.78 |
| Not too good | 12 | 62 | 0.76 (0.38 to 1.53) | 0.44 | 0.06 | 0.42 (0.12 to 1.56) | 0.19 |
| General Health Questionnaire (score) | | | | | | | |
| 0 (Reference) | 196 | 77 | 1.00 | | 0.12 | 1.00 | |
| 1 | 54 | 100 | 1.34 (0.96 to 1.85) | 0.08 | 0.11 | 0.95 (0.55 to 1.60) | 0.84 |
| Stress (previous 4 weeks) | | | | | | | |
| None (Reference) | 52 | 73 | 1.00 | | 0.08 | 1.00 | |
| A little | 126 | 87 | 1.22 (0.85 to 1.77) | 0.26 | 0.14 | 1.70 (0.96 to 3.02) | 0.06 |
| Somewhat | 61 | 74 | 1.02 (0.67 to 1.56) | 0.91 | 0.10 | 1.15 (0.58 to 2.26) | 0.69 |
| A lot | 9 | 128 | 1.92 (0.97 to 3.84) | 0.06 | 0.11 | 1.30 (0.38 to 4.42) | 0.67 |
| SCAT (score) | | | | | | | |
| <18 (Reference) | 43 | 77 | 1.00 | | 0.12 | 1.00 | |
| 18 to 20 | 68 | 80 | 1.03 (0.66 to 1.60) | 0.88 | 0.13 | 1.10 (0.59 to 2.04) | 0.76 |
| 21 to 22 | 41 | 82 | 1.07 (0.66 to 1.74) | 0.79 | 0.11 | 0.90 (0.44 to 1.81) | 0.76 |
| 23 to 25 | 47 | 83 | 1.08 (0.67 to 1.74) | 0.74 | 0.13 | 1.09 (0.56 to 2.13) | 0.79 |
| 26 to 30 | 47 | 89 | 1.18 (0.75 to 1.88) | 0.47 | 0.09 | 0.73 (0.36 to 1.49) | 0.38 |

*Table 4 Anthropometric, physical performance, and training factors for injury incidence and proportion of playing season missed*

| | | *Injury incidence rate (per 1000 hours)* | | | *Proportion of season missed* | | |
|---|---|---|---|---|---|---|---|
| *Factor* | *N* | *Rate* | *RR (95% CI)* | *p Value* | *Proportion* | *RR (95% CI)* | *p Value* |
| Height (cm) | | | | | | | |
| <174 cm (Reference) | 46 | 70 | 1.00 | | 0.08 | 1.00 | |
| 174 to 178 cm | 53 | 67 | 0.96 (0.60 to 1.54) | 0.86 | 0.11 | 1.39 (0.69 to 2.81) | 0.34 |
| 179 to 181 cm | 50 | 95 | 1.40 (0.90 to 2.18) | 0.12 | 0.16 | 2.04 (1.05 to 3.97) | 0.03 |
| 182 to 185 cm | 46 | 84 | 1.24 (0.78 to 1.97) | 0.36 | 0.14 | 1.72 (0.85 to 3.46) | 0.12 |
| >185 cm | 53 | 93 | 1.38 (0.90 to 2.13) | 0.12 | 0.09 | 1.10 (0.53 to 2.29) | 0.78 |
| Body mass (kg) | | | | | | | |
| <74 kg (Reference) | 50 | 56 | 1.00 | | 0.10 | 1.00 | |
| 74 to 80 kg | 52 | 80 | 1.50 (0.93 to 2.41) | 0.08 | 0.11 | 1.16 (0.59 to 2.26) | 0.66 |
| 81 to 87 kg | 46 | 92 | 1.77 (1.09 to 2.86) | 0.02 | 0.17 | 1.85 (0.98 to 3.49) | 0.05 |
| 87 to 94 kg | 51 | 89 | 1.70 (1.08 to 2.68) | 0.02 | 0.11 | 1.09 (0.56 to 2.13) | 0.79 |
| >94 kg | 49 | 95 | 1.81 (1.15 to 2.87) | 0.01 | 0.11 | 1.09 (0.55 to 2.17) | 0.79 |
| Body mass index (BMI) | | | | | | | |
| <23 (Reference) | 40 | 55 | 1.00 | | 0.14 | 1.00 | |
| 23 to 25 | 56 | 72 | 1.34 (0.80 to 2.24) | 0.25 | 0.10 | 0.68 (0.35 to 1.32) | 0.24 |
| 25 to 26.5 | 58 | 83 | 1.58 (0.96 to 2.59) | 0.06 | 0.14 | 1.03 (0.56 to 1.89) | 0.93 |
| 26.5 to 28 | 44 | 103 | 2.02 (1.22 to 3.34) | <0.01 | 0.11 | 0.81 (0.41 to 1.59) | 0.53 |
| >28 | 50 | 94 | 1.82 (1.11 to 2.96) | 0.01 | 0.09 | 0.64 (0.32 to 1.26) | 0.18 |
| Sum of six skinfolds (mm) | | | | | | | |
| <48.2 (Reference) | 48 | 66 | 1.00 | | 0.12 | 1.00 | |
| 48.2 to 57.9 | 49 | 76 | 1.16 (0.73 to 1.88) | 0.51 | 0.13 | 1.08 (0.57 to 2.04) | 0.80 |
| 58.0 to 70.5 | 48 | 97 | 1.54 (0.97 to 2.42) | 0.06 | 0.13 | 1.14 (0.60 to 2.14) | 0.69 |
| 70.6 to 87.7 | 47 | 74 | 1.14 (0.71 to 1.85) | 0.58 | 0.12 | 1.04 (0.54 to 2.00) | 0.91 |
| >87.7 | 50 | 95 | 1.51 (0.97 to 2.35) | 0.06 | 0.08 | 0.67 (0.33 to 1.34) | 0.25 |
| Aerobic endurance (20 m multistage shuttle run test - repeats) | | | | | | | |
| <97 (Reference) | 47 | 75 | 1.00 | | 0.11 | 1.00 | |
| 97 to 105 | 48 | 70 | 0.91 (0.57 to 1.46) | 0.70 | 0.13 | 1.16 (0.60 to 2.23) | 0.65 |
| 106 to 117 | 47 | 80 | 1.06 (0.67 to 1.67) | 0.80 | 0.12 | 1.03 (0.53 to 2.01) | 0.93 |
| 118 to 128 | 48 | 99 | 1.36 (0.89 to 2.08) | 0.15 | 0.10 | 0.88 (0.45 to 1.73) | 0.71 |
| >128 | 52 | 82 | 1.09 (0.70 to 1.70) | 0.69 | 0.12 | 1.00 (0.52 to 1.96) | 0.98 |
| Anaerobic endurance (high intensity shuttle run test) | | | | | | | |
| >83 (Reference) | 47 | 71 | 1.00 | | 0.11 | 1.00 | |
| 65 to 83 | 49 | 70 | 0.97 (0.61 to 1.56) | 0.92 | 0.13 | 1.23 (0.64 to 2.38) | 0.53 |
| 51 to 64 | 47 | 98 | 1.42 (0.91 to 2.26) | 0.11 | 0.15 | 1.49 (0.78 to 2.85) | 0.22 |
| 37 to 50 | 47 | 86 | 1.25 (0.79 to 1.97) | 0.34 | 0.13 | 1.20 (0.61 to 2.37) | 0.58 |
| <37 | 46 | 86 | 1.24 (0.80 to 1.94) | 0.33 | 0.08 | 0.73 (0.35 to 1.56) | 0.41 |
| 30 m sprint time (seconds) | | | | | | | |
| >4.06 (Reference) | 48 | 85 | 1.00 | | 0.11 | 1.00 | |
| 3.96 to 4.06 | 41 | 62 | 0.70 (0.44 to 1.13) | 0.13 | 0.09 | 0.83 (0.40 to 1.70) | 0.60 |
| 3.85 to 3.95 | 49 | 79 | 0.92 (0.60 to 1.40) | 0.70 | 0.11 | 0.99 (0.52 to 1.91) | 0.98 |
| 3.76 to 3.84 | 41 | 67 | 0.76 (0.48 to 1.24) | 0.27 | 0.11 | 1.00 (0.49 to 2.06) | 0.99 |
| <3.76 | 39 | 121 | 1.51 (0.99 to 2.30) | 0.05 | 0.17 | 1.66 (0.87 to 3.19) | 0.11 |
| Vertical jump (cm) | | | | | | | |
| <53.9 (Reference) | 46 | 87 | 1.00 | | 0.13 | 1.00 | |
| 53.9 to 58.2 | 48 | 83 | 0.95 (0.61 to 1.49) | 0.82 | 0.12 | 0.91 (0.48 to 1.72) | 0.76 |
| 58.3 to 61.0 | 46 | 73 | 0.82 (0.52 to 1.30) | 0.39 | 0.07 | 0.51 (0.25 to 1.06) | 0.07 |
| 61.1 to 65.0 | 47 | 79 | 0.90 (0.57 to 1.41) | 0.64 | 0.10 | 0.75 (0.38 to 1.45) | 0.38 |
| >65.0 | 47 | 92 | 1.06 (0.68 to 1.66) | 0.80 | 0.16 | 1.22 (0.66 to 2.24) | 0.52 |
| Push ups (number) | | | | | | | |
| <20 (Reference) | 39 | 74 | 1.00 | | 0.06 | 1.00 | |
| 20 to 23 | 49 | 83 | 1.13 (0.71 to 1.82) | 0.59 | 0.15 | 2.69 (1.24 to 5.84) | 0.01 |
| 24 to 28 | 50 | 83 | 1.13 (0.71 to 1.80) | 0.60 | 0.13 | 2.30 (1.06 to 5.03) | 0.03 |
| 29 to 33 | 51 | 95 | 1.33 (0.84 to 2.11) | 0.22 | 0.12 | 2.19 (0.99 to 4.81) | 0.05 |
| >33 | 40 | 66 | 0.88 (0.52 to 1.48) | 0.61 | 0.09 | 1.49 (0.62 to 3.55) | 0.36 |
| Endurance training load | | | | | | | |
| 0 (Reference) | 60 | 70 | 1.00 | | 0.13 | 1.00 | |
| 1 to 9 | 72 | 80 | 1.17 (0.78 to 1.74) | 0.44 | 0.10 | 0.74 (0.42 to 1.33) | 0.31 |
| 10 to 14 | 54 | 98 | 1.46 (0.97 to 2.21) | 0.06 | 0.10 | 0.74 (0.40 to 1.39) | 0.34 |
| 15 to 20 | 30 | 87 | 1.29 (0.78 to 2.12) | 0.31 | 0.17 | 1.34 (0.70 to 2.57) | 0.37 |
| >20 | 27 | 77 | 1.12 (0.67 to 1.88) | 0.65 | 0.12 | 0.92 (0.44 to 1.90) | 0.81 |

rate of injuries than non-smokers (RR = 1.15; 95% CI = 1.04 to 2.14). There was no significant difference between the IR of non-smokers and current smokers.

Although the difference in PM between the reference group (less than five hours of strenuous physical activity a week) and each of the other groups was not significant, activity for between five and 39 hours a week appeared to have a protective effect, whereas activity for more than 39 hours a week appeared to increase the risk of missing play (RR = 1.86; 95% CI = 0.95 to 3.68).

Current smokers (18%) missed a greater proportion of their season than did non-smokers (10%) (RR = 2.11; 95% CI = 1.28 to 3.47). The difference in PM between non-smokers and ex-smokers (15%) was not significant (RR = 1.65; 95% CI = 0.96 to 2.84).

Players who scored 8–10 points on the AUDIT missed a smaller proportion of their season (9%) than players who scored less than 8 points (16%) (RR = 0.55; 95% CI = 0.29 to 1.01). The other groups (>10 points) also missed a smaller proportion of their season (9–12%), although the differences in these cases were not significant. There appeared to be no consistent dose-response relation between AUDIT scores and either IR or PM.

### *Anthropometric, physical performance, and training factors*

Table 4 gives the results for the anthropometric, physical performance, and training variables. Players with a body mass of greater than 81 kg sustained a higher IR than players whose body mass was less than 74 kg. Players with a

*Table 5 Risk factors for injury incidence rate and proportion of season missed controlling for effects of other risk factors in the models*

| | Injury incidence rate (per 1000 hours) | | Proportion of season missed | |
|---|---|---|---|---|
| *Factor* | *Odds ratio (95% CI)* | *p Value* | *Odds ratio (95% CI)* | *p Value* |
| Injury experience | | | | |
| No injuries in previous 12 months (Reference) | 1.00 | | 1.00 | |
| Previous season | 1.24 (0.70 to 2.18) | 0.45 | 1.46 (0.63 to 3.37) | 0.37 |
| Preseason | 1.81 (1.01 to 3.25) | 0.04 | 2.76 (1.13 to 6.72) | 0.02 |
| Grade | | | | |
| Under 19/18 (Reference) | 1.00 | | | |
| Under 21 | 1.84 (1.18 to 2.87) | <0.01 | | |
| Senior B | 1.69 (1.02 to 2.80) | 0.04 | | |
| Senior A | 2.35 (1.57 to 3.51) | <0.01 | | |
| Playing position | | | | |
| Front row (Reference) | | | 1.00 | |
| Lock | | | 0.67 (0.25 to 1.77) | 0.40 |
| Loose forwards | | | 1.06 (0.44 to 2.56) | 0.89 |
| Inside backs | | | 0.40 (0.14 to 1.20) | 0.10 |
| Midfield backs | | | 1.73 (0.66 to 4.53) | 0.26 |
| Outside backs | | | 1.06 (0.37 to 3.04) | 0.92 |
| Years rugby participation | | | | |
| 0 to 3 years (Reference) | | | 1.00 | |
| 4 to 5 years | | | 0.42 (0.19 to 0.93) | 0.03 |
| 6 to 7 years | | | 1.11 (0.57 to 2.18) | 0.76 |
| 8 years | | | 0.58 (0.29 to 1.16) | 0.12 |
| >8 years | | | 1.44 (0.71 to 2.89) | 0.30 |
| Strenuous physical activity (hours/week) | | | | |
| <5 (Reference) | | | 1.00 | |
| 5 to 9 | | | 1.21 (0.56 to 2.63) | 0.62 |
| 10 to 19 | | | 1.14 (0.49 to 2.63) | 0.76 |
| 20 to 39 | | | 1.19 (0.44 to 3.23) | 0.73 |
| >39 | | | 3.71 (1.58 to 8.72) | <0.01 |
| Cigarette smoking | | | | |
| Non-smoker (Reference) | | | 1.00 | |
| Ex-smoker | | | 1.86 (1.02 to 3.38) | 0.04 |
| Current smoker | | | 1.97 (1.13 to 3.43) | 0.01 |
| Stress (previous 4 weeks) | | | | |
| None (Reference) | | | 1.00 | |
| A little | | | 2.50 (1.34 to 4.66) | <0.01 |
| Somewhat | | | 2.03 (0.97 to 4.22) | 0.05 |
| A lot | | | 1.57 (0.45 to 5.47) | 0.47 |
| Body mass index (BMI) | | | | |
| <23 (Reference) | | | 1.00 | |
| 23 to 24.9 | | | 0.31 (0.14 to 0.67) | <0.01 |
| 25 to 26.4 | | | 0.31 (0.15 to 0.66) | <0.01 |
| 26.5 to 27.9 | | | 0.32 (0.14 to 0.71) | <0.01 |
| >27.9 | | | 0.24 (0.10 to 0.63) | <0.01 |
| Aerobic endurance (20 m multistage shuttle run test - repeats) | | | | |
| ≤96 (Reference) | | | 1.00 | |
| 97 to 105 | | | 1.92 (0.94 to 3.92) | 0.07 |
| 106 to 117 | | | 0.74 (0.34 to 1.62) | 0.44 |
| 118 to 127 | | | 0.58 (0.25 to 1.35) | 0.19 |
| >127 | | | 1.27 (0.52 to 3.07) | 0.59 |
| Anaerobic endurance (high intensity shuttle run test) | | | | |
| >83 (Reference) | | | 1.00 | |
| 65 to 83 | | | 2.78 (1.28 to 6.04) | <0.01 |
| 57 to 64 | | | 2.73 (1.28 to 5.83) | <0.01 |
| 37 to 50 | | | 1.64 (0.73 to 3.67) | 0.22 |
| <37 | | | 1.63 (0.67 to 4.00) | 0.27 |
| Push ups (number) | | | | |
| ≤19 (Reference) | | | 1.00 | |
| 20 to 23 | | | 4.42 (1.85 to 10.53) | <0.01 |
| 24 to 28 | | | 3.88 (1.65 to 9.14) | <0.01 |
| 29 to 33 | | | 3.52 (1.43 to 8.65) | <0.01 |
| >33 | | | 2.68 (1.05 to 6.85) | 0.04 |

BMI of greater than 26.5 sustained more injuries than players with a BMI of less than 23 (the reference group). Among the various physical performance tests, the 30 m sprint from a 5 m running start was the only one for which a significant difference in IR was observed across the groups. Players in the fastest group (<3.76 seconds) reported a higher IR than those in the slowest (reference) group (>4.06 seconds) (RR = 1.51; 95% CI = 0.99 to 2.30).

There were few associations between anthropometric and physical performance variables and PM. Players whose height was in the middle quintile (179–181 cm) missed a greater proportion of their season (16%) than the shortest players (<174 cm), who missed 8% of their season (RR = 2.04; 95% CI 1.05 to 3.97). Likewise, players whose body mass fell in the middle quintile (81–87 kg) missed a greater proportion of their season (17%) than players with the lowest body mass (<74 kg), who missed 10% of their season (RR = 1.85; 95% CI = 0.98 to 3.49). Players who performed between 20 and 33 push ups missed a greater proportion of their playing season than those who completed fewer than 19 push ups.

### MULTIVARIATE ANALYSES

Variables were included in the multivariate modelling on the basis of either significant univariate associations with IR or PM, or, in the case of the physical performance measures, to represent distinct aspects of physical fitness. The

following variables were included in the multivariate analyses: grade, age group, playing position, years of rugby participation, previous or preseason injury, cigarette smoking status, alcohol use, amount of strenuous physical activity in the off season, how stressful the player found the previous four weeks, endurance training load during the off season, aerobic shuttle test, time taken to sprint 30 m from a 5 m running start, anaerobic shuttle test, push ups, vertical jump, and BMI. Table 5 summarises the results of the multivariate analyses.

Grade and having an injury at the beginning of the rugby season were the only variables significantly associated with IR in the multivariate analysis. The risk profiles for these variables remained the same as for the univariate analyses. Players in the under 19/18 grades had a lower IR than players at all higher grades, and players who were injured at the preseason assessment had a higher IR than players who entered the season injury free (RR = 1.81; 95% CI = 1.01 to 3.25). Variables that were significant in the univariate analysis but did not remain in the multivariate model were age group, cigarette smoking status, body mass, BMI, and 30 m sprint time.

The variables that remained in the multivariate model for PM were previous injury experience, position, BMI, amount of strenuous physical activity, cigarette smoking status, stress in the last four weeks, years of rugby participation, both the aerobic and anaerobic shuttle tests, and push ups.

Although there were no significant differences in PM between positions when compared with front row players, locks and inside backs missed less of their playing season and midfield backs more. Players who were injured at the time of the preseason assessment missed a greater proportion of the season than those who reported no previous injury (RR = 2.76; 95% CI = 1.13 to 6.72). With respect to years of rugby participation, those who had played rugby for between four and five years missed a smaller proportion of their season because of injury than those who had played for three years or less (RR= 0.42; 95% CI = 0.19 to 0.93).

Players who engaged in strenuous physical activity for 39 hours or more a week missed a greater proportion of the season than did players who were active for five hours or less a week (RR = 3.71; 95% CI =1.58 to 8.72). Ex-smokers (RR = 1.86; 95% CI =1.02 to 3.38) and current smokers (RR = 1.97; 95% CI =1.13 to 3.43) had higher risks of missing time during their season than non-smokers.

For players whose BMI was less than 23, the risk of missing play was higher than for any of the other groups. There were differences in PM for the various levels on the aerobic shuttle test, but no consistent trend emerged. Players who became fatigued the quickest on the anaerobic shuttle test—that is, the worst performed group—missed a smaller proportion of their season than the players in the next two quintiles (RR = 2.78; 95% CI =1.28 to 6.04 and RR = 2.73; 95% CI = 1.28 to 5.83 respectively). Players at higher levels were not significantly different. Players who completed between 20 and 34 push ups missed a greater proportion of their season than those who completed 19 push ups or less.

## Discussion

The use of two outcome variables enabled risk factors associated with two "dimensions" of rugby injury to be examined: injury rate and time lost because of injury. IR provided information about the incidence of injuries sustained by players given their exposure time. PM measured the proportion of potential playing time lost as the result of injury, providing a proxy measure of injury severity.[9] No previous prospective studies examining rugby injury have reported PM as an outcome. Although there was some overlap, most of the risk factors associated with PM were not associated with IR.

### RUGBY SPECIFIC RISK FACTORS

#### *Grade*

Grade was identified as a significant risk factor for IR but not for PM. Players from higher grades reported higher incidence rates than players from lower grades. This finding is consistent with those of other studies.[14 17] Several explanations of why such a pattern was observed in this study can be proposed. It may be that players at higher grades reported a greater number of less severe injuries than players at lower grades, because of their better access to medical services. That is, they may have been more likely to receive medical attention for a given injury event, which would then qualify the event for inclusion in the study. With poorer access to medical services, players in lower grades may have treated the same injuries themselves or ignored them.

Alternatively, players from higher grades may have had a higher incidence of injury of equivalent severity than players at lower grades, but returned to play sooner after sustaining an injury. Again this may be a result of better access to medical services. Finally, the higher IR apparent among the higher grades may be associated with the greater size of the players[28] and the faster pace at which the game is played. These factors result in greater forces during the contact phases of the game, leading to greater trauma.[14 17] Players at the higher levels are generally highly motivated to return to play and are under pressure to retain their place in the team.

#### *Position*

Previous research findings on the level of risk associated with the various positions are equivocal.[14 15 22] Most previous studies, however, have only examined the proportion of injuries sustained by each positional group, without taking the relative exposure of the players into account. Although position was not found to be a significant risk factor for IR, the midfield backs missed a significantly greater proportion of their season than did the reference group (front row). This finding may reflect the different roles of these players in the

game. Midfield backs are often used as "battering rams" to run the ball directly at the opposing players. The frequency with which they are required to do this and the high speeds they attain when they enter tackles may have contributed to the increased risk observed in this study. The midfield backs missed, on average, 21% of their playing season through injury. In contrast, the inside backs, who are generally involved in fewer high speed impacts, missed only 7% of their season. This finding suggests that, as the injury rates did not differ between positional groups, the injuries sustained by the midfield backs were, on average, more severe and kept them out of play for longer periods.

*Previous injury*

Beginning the season with injury was identified as a significant risk factor for both the incidence of injury and time lost during the season. The first of these findings is consistent with previous research.[11 12] Having been injured the previous season did not significantly elevate the risk of injury during the season if the player entered the next season injury free. These findings emphasise the importance of full rehabilitation from injury before players are permitted to take the field again after sustaining an injury.

BASIC AND LIFESTYLE FACTORS

Although an association was observed between cigarette smoking status and IR in the univariate analysis, neither this nor any of the other basic or lifestyle factors were found to be independently associated with IR in the multivariate analysis. Smoking was found to increase PM, with both ex-smokers and current smokers being at increased risk. It may be that recovery time from injury is longer for smokers and ex-smokers. Alternatively, smoking may be related to players' dedication to the sport, with more highly committed athletes foregoing cigarettes. The more dedicated players are also likely to return to play as quickly as possible.

There was some suggestion of a U shaped relation between hours a week spent in strenuous physical activity and PM, but the association was not significant. Players who were involved in very high levels of strenuous activity (more than 39 hours a week) before the season missed a greater proportion of the season than players who were less active. A similar pattern was observed for IR, although the association was not significant. This finding is in contrast with a previous finding that, for army recruits, lower levels of physical activity before entering the army were associated with a higher risk of injury during basic training.[12] It may be that the large amount of strenuous physical activity reported by the players in the current study contributed to an "over trained" state, in which players' recovery from injury was adversely affected. Over training was one explanation offered for a higher level of recurrent injury observed in professional players during the early part of the season in a recent study of Scottish rugby players.[36] This issue warrants further research to examine whether the same pattern is apparent in other populations of sports people.

ANTHROPOMETRY AND PHYSICAL PERFORMANCE

Players whose BMI was greater than 26.5 sustained a higher rate of injuries than those whose BMI was less than 23 when the IRs between the groups were examined in the univariate analysis. This is consistent with a previous examination of the influence of self reported BMI on rugby injury.[37] That study found that players who reported injuries had an age adjusted mean BMI of 25.4 compared with an age adjusted mean BMI of 24.6 for players who were not injured. In a study of army recruits, a bimodal association between BMI and injury was obtained, with those having high and low BMIs being at greater risk of injury.[13] No such pattern was found in the present study, and the above association did not persist in the multivariate model. Although BMI was not significantly associated with PM in the univariate analysis, a significant association was obtained in the multivariate analysis. It appears that players who are more frail (BMI<23) are at increased risk of losing time during the season because of injury when other risk factors are controlled for. In a previous report on data from the RIPP, BMI, as a measure of relative physical "robustness", was shown to be related to grade.[28] It is not surprising therefore that players with higher BMI reported a higher injury incidence. Overall, it appears that players with a high BMI may sustain a higher IR than players with a low BMI, yet still not miss as much of their season as a result of the injuries they sustain.

Although there were associations between some of the physical performance measures and the outcome variables, there did not appear to be strong linear trends. Of the physical performance measures, the 30 m sprint from a standing start was the only variable that had a significant univariate relation to IR. The only significant univariate result for PM was for push ups. Neither the aerobic shuttle test nor the weekly amount of off season endurance training showed significant univariate relations to IR or PM. Both the aerobic and anaerobic shuttle tests and push ups were associated with PM in the multivariate model. The patterns of association, however, were not linear, which makes interpretation difficult. Research on army recruits has found that those who have lower aerobic fitness have higher risk of injury.[12] No similar pattern was found here. These findings support to some extent previous findings[38] that superior fitness, skill, and experience do not ameliorate the risk of sustaining injuries at higher levels of play.

Although there may be a relation between fitness and certain types of injury—for example, muscle strains and tears[13]—most injuries sustained by players in this cohort were associated with tackles. It is likely that despite physical conditioning, injuries will continue to occur because of the violent impacts of tackles and the minimal amount of protective equipment players are permitted to wear. Reducing the risk of injury in tackles may come through a

variety of measures including changes in technique, refereeing, rules, and protective equipment, but, before this can happen, further research on the risk factors for tackle injuries is needed.[39 40]

A possible explanation for the lack of association between the physical performance measures and injury may be that the physical performance measures used in this study did not adequately assess the fitness requirements of rugby. Rugby is an intermittent high intensity sport, with a unique blend of aerobic, anaerobic, and strength requirements.[41] Although the physical performance measures used are valid indicators of a given aspect of performance, they may not have measured the combination of physical fitness attributes required of players. Furthermore, within the sport, the various playing positions have distinct roles, and players occupying a role generally have a stereotypical set of anthropometric and physical performance characteristics.[28 29] Thus fitness tests specific to the demands of the given positions may need to be developed if the relations between fitness and player injury are to be further studied. One of the limitations of this study was that the flexibility of the players was not assessed preseason, so that associations between flexibility and injury outcomes could not be examined. Another aspect of physical conditioning that has not been examined with respect to injury risk for rugby players is the amount of physical impact drills and training players are exposed to before starting their rugby season. Anecdotally, players and coaches often refer to "match fitness", with the implication that this is an aspect of fitness not achieved through traditional rugby training methods. Part of this match fitness may be physical conditioning to the impacts with other players and the playing surface that players are exposed to during games. Further study is required to determine whether players who are adequately conditioned for physical impacts at the beginning of the season are at less risk of sustaining injuries through the early part of the season, when the injury rate has been shown to be higher.[14]

### INJURY OUTCOME VARIABLES

The primary purpose of this paper was to document risk factors associated with rugby injury, as measured by two outcome variables: injury incidence rate and proportion of season missed. Most previous research has used injury rate as the outcome variable.[11 12 23] IR measures injuries per unit of exposure. It does not, however, take into account the effect of injury on subsequent participation. For example, if the scheduled season consists of 20 games, one player may sustain one serious injury in the fourth game, which excludes him from play for the remainder of the season. He has then sustained one injury (number) and has an injury rate of one injury in four games. Another player may sustain ten minor injuries through the season, none of which have a substantial effect on his ability to participate. Thus he reports ten injuries in 20 games (twice the rate of the previous player). In terms of impact of injury on their seasons, the first player has obviously fared worse, but this is not conveyed by comparison of their injury rates.

One of the strengths of this study was the use of PM as a complementary outcome variable to IR. PM does have its limitations, with injuries that occur early in the season likely to cause a greater proportion of the season to be missed than those that occur towards the end of the season. For instance, players who sustain an injury in the last game of the season will not miss any weeks of play, whereas if they had sustained the same injury at the beginning of the season they may well have. Hence, there is some censoring of the time missed depending on when in the season the injury occurs. In addition, using proportion of season missed does not readily allow modelling of concurrent risk factors through the season, the level of which may vary from week to week. These include factors such as playing out of position and use of protective equipment for a given game.

### SUMMARY AND CONCLUSIONS

This study examined risk factors for injury and playing time lost, as measured by IR and PM. Different sets of risk factors were associated with each of these outcomes. Significant univariate associations with IR were observed for grade, age, and previous injury experience, BMI, and 30 m sprint time from a 5 m running start. After possible confounding factors had been controlled for, grade and previous injury emerged as independent risk factors. Univariate associations with PM were observed for: playing position, strenuous physical activity, cigarette smoking status, alcohol use, previous injury experience, and vertical jump. After possible confounding factors had been controlled for, playing position, BMI, strenuous physical activity, previous injury, and cigarette smoking status emerged as independent risk factors.

The results of the analysis of previous injury indicate that players who entered the season carrying an injury placed themselves at higher risk of both missing play and sustaining a higher injury incidence rate through the following season. Thus returning to play before full recovery from injury may also place players who were otherwise fit at a higher risk of further injury. To reduce their risk of sustaining injuries and missing playing time, players should enter the rugby season injury free. If interventions to reduce the impact of injury are undertaken on the basis of risk factors identified through studies that use IR as the outcome variable, it is important to remain aware that factors associated with the impact of injuries on players' participation through the season may not necessarily be identified, as the risk factors associated with the IR and the PM may differ. Comparison of the results for each of the outcome variables may help to elucidate the nature and severity of injury more effectively than either would be able to separately.

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